Master Thesis

Construction Management & Engineering

By Denis Chiosea

Co-creation process during the development of circular building components for housing renovation

TU Delft

Co-creation process during the development of circular building components for housing renovation

Mapping co-creation process for the case of circular extension and deriving lessons learned for circular building components

By

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to obtain the degree of Master of Science

Construction, Management & Engineering

at the Delft University of Technology

Student Number: 4924681

Project duration: December 2020 – June 2021

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Acknowledgements

With this thesis I finalize my MSc of Construction Management and Engineering. I want to thank everyone who contributed to this project and supported me during it.

First of all, I would like to thank my graduation committee: Dr. John L. Heintz, Ir. Anne van Stijn, Dr.ing. Gerard van Bortel and Dr. Tuuli Jylhä. I am very grateful for your contribution. Thank you, John, for your critical view and the input that helped improve the overall quality of the research. Thank you, Anne, for your greatly detailed feedback, I really appreciate the time you had spent on it, as well as you always being there to patiently hear out my thoughts. Thank you, Gerard, for your on-point recommendations and feedback that helped me imrpove and structure my work. Thank you, Tuuli, for your research suggestions that helped me find the way to structure the process maps, and for your help in sharpening the methodology. Thank you, all, for your guidance. I really enjoyed working with you, and I hope that one day we will meet, and I can tell you this in person.

It would not be possible to carry out this research without the help of the project stakeholders. I would like to thank them for sharing their experience and thoughts. Therefore, I would like to express my gratitude to Nils Vanwesenbeek (ERA Contour), Saskia van der Weerd (ERA Contour), Terry Pater (Door Architecten), Ilse van Andel (Eigen Haard) and Rob van den Oudenrijn (Van den Oudenrijn).

Also, I would like to thank my fellow students Andrei and Stefanos who helped me validate the results of this research. Thank you for your feedback and valuable comments.

Additionally, I would like to thank my friends who listened me talking about my research again and again, helped me proofread my report as well as gain skills with graphic editors.

Last, but not least, I would like to thank my parents and Polina for all your love and support. Without you, this research would not be possible.

Denis Chiosea, June 2021

Abstract

The circular economy transition requires companies to implement innovative supply chains and business models. However, the number of available solutions for the application in the circular built environment is limited. These solutions could be developed through the co-creation between companies aiming for circular transition. However, it is unclear how the co-creation process would look like in the context of the circular build environment. One such case is the REHAB project where stakeholders develop circular building components for housing renovation. Based on the example of one of the components — circular extension — this research develops three process maps of co-creation to help stakeholders organize the co-creation process for the development and implementation of the service loops of the product. This is done by reviewing the academic literature and identifying the requirements and parameters of co-creation for the case for the circular extension, as well as identifying the co-creation designs already available in the literature. Based on this, further process maps were synthesized. The developed process maps consist of six phases: engaging actor, co-conception, co-design, co-production, co-maintenance and co-disposal. Each phase is subdivided into a number of sub-steps for which the best solutions and/or options are mapped. The developed process maps contribute to the circular co-creation literature by showing a clear picture of the co-creation process that practitioners could follow. Additionally, this research evaluates the developed designs with the project stakeholders and derives six lessons learned that could be applicable for circular building components: 1) Cost efficiency is the main aspect influencing implementation of circular building components, 2) Organizing circular co-creation process requires involvement of a human interaction specialist and circular economy consultant, 3) Circularity is largely dependent of the party that initiates the process and becomes the problem owner, 4) Circularity of circular building components in the current reality depends on the formation of secondhand markets, 5) The co-creation process structure is similar for different circular building components, change only network composition and activities/options that could be considered, 6) Sell and buy-back business model and take-back agreements have the most potential for the circular building components, compared to other solution.

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1. Introduction and Research proposal

1.1. Research topic

This section is a short summary of how the knowledge gap was defined. For a more explicit description of the process for arriving at the knowledge gap, see Section 3.

The construction industry is well-known as one of the main producers of waste. It consumes 40% of global natural resources, produces 40% of global waste and 33% of CO2 emissions (Ness & Xing, 2017). The pressure on natural resources and the climate is continuing to increase. Moreover, continuous growth of the world's population and income could also lead to a natural resource shortage (Behrens et al., 2007; Edenhofer et al., 2014). This leads to the risk of many resources becoming scarce and some even disappearing, which leads to rising material prices and material scarcity risk for the industry (Ecorys, 2012). The circular economy is one of the possible solutions to reduce this continuously growing pressure. Contrary to the currently used linear economy of the "take, make and dispose", a circular economy focuses on slowing, narrowing and closing material and energy flows (Bocken, Pauw, Bakker, Grinten, 2016). In the last decade, the concept of the circular economy was widely spread with a large contribution from the Ellen MacArthur Foundation. Europe has already accepted a circular economy as its future strategic vision (EU Circular Economy Action Plan). In the Netherlands, a government-wide program called "A circular economy in the Netherlands by 2050" was launched in September 2016 (The Ministry of Infrastructure et al, 2016).

Slowing, narrowing and closing resource loops requires optimization of the "inner technological cycles" such as maintain, reuse and remanufacture (Stijn & Gruis, 2020). This implies that supply chains should include mechanisms for reclaiming and reusing building parts, components and materials after they reach the end of their lifespan. In literature, these mechanisms are called R-imperatives or value retention processes (VRPs) (see section 3.2). However, it is not yet clear how to realize these mechanisms and guarantee their implementation, because, in many cases, VRPs take place in 10, 20, 50 and 100 years. Therefore, developing these mechanisms requires long-term collaboration among supply chain partners, as well as a suitable business model (e.g. Flink, 2017; Adams, Osmani, Thorpe, Thornback, 2017; Batista, Bourlakis, Smart, & Maull, 2018).

In the last decade, the circular economy, as well as literature in this field, rapidly developed. Nowadays, literature provides examples of circular supply chain configurations (e.g. Nasir, Genovese, Acquaye, Koh, & Yamoah, 2017; Manavalan & Jayakrishna, 2019) and circular business models (e.g. Lewandowski, 2016; Bocken, Pauw, Bakker, & Grinten, 2016). However, most of these studies look at the circular economy from a broader perspective. If we speak about circular economy in the built environment (CBE), the "early" research in this domain mostly focused on downcycling and demolition of waste (Adams, Osmani, Thorpe, & Thornback, 2017). In the recent years the literature in the domain of CBE started to develop more and more rapidly. For example, Hart, Adams, Giesekam, Tingley, & Pomponi (2019) study barriers and drivers in CBE, Leising, Quist, & Bocken (2018) develop a collaboration tool for CBE, Joensuu, Edelman, & Saari (2020) analyze the practices currently applied in CBE, etc. Although it is already possible to draw how the generic

configuration of circular supply chain in construction industry would like (see Section 3.5.4), the literature still provides a very limited number of ready up solutions that could be directly used, and it remains unclear how VRPs should be realized in the construction field. Thus, the knowledge of how the construction industry should transition to a circular economy is not fully developed yet.

Although the are no ready-made solutions, the literature provides some "hints" on how this knowledge gap could be filled. This transition requires cooperation among supply chain partners. Elaborating in more detail, the circular economy encompasses the whole lifecycle of building parts, components and materials, and it requires the development of innovative solutions to accomplish these cycles. Theoretically, a very large corporation could embrace the whole building lifecycle, implement circular economy and accomplish all the necessary loops. However, today we do not see such examples in the construction industry. Traditional construction is very fragmented. Usually different stakeholders (meaning the contributors serving the activity) (McGrath & Whitty, 2017) are responsible for each phase of the building lifecycle. Even when there is one big company responsible for the project, it still usually hires several subcontractors shifting some of its responsibilities. Traditional construction is characterized by a lack of trust and commitment. The responsibilities are clearly divided between the stakeholders and interaction is very limited and remains formal (Vrijhoef, 2011; Behera, Mohanty, & Prakash, 2015). Of course, today we can see much more extensive relationships between the parties than in the past (meaning the projects completed under DBM or DBMF contracts, see Section 3.5), but it is still not enough. In circular economy diverse stakeholders should collaborate to create multiple types of value that exceed the boundaries of individual organizations. Summarizing, transition to a circular economy in the built environment entails collaboration of the extended supply chain (meaning early involvement of the parties, that would not be part of the process in traditional construction, e.g. material suppliers). In literature on the circular economy transition this type of activity is often referred as "co-creation".

The term co-creation has been conceptualized differently by many authors, but if we speak about what co-creation is, in general, one could use the definition provided by Fellows, Liu & Chan (2014, p. 121):

"Co-creation implies dyadic or multi-actor value creation, including identification, formation, leverage and realization of value in products and services as well as value embodied in participation and perceptions. Colloquially, co-creation is value that is more than the sum of the parts that individual organizations can create on their own and in-house".

Early co-creation literature conceptualized this term as a dyadic firm-customer exchange relationship. Later contributions broaden the understanding of the co-creation shifting the focus from co-creation with consumers to co-creation between stakeholders. In the recent literature, the concept of co-creation is usually associated with the business strategy which has the focus on interactive relationships between the number of stakeholders in the supply chain (Smorodinskaya, Russell, Katukov, & Still, 2017).

Although the concept of co-creation was reconceptualized, its application in the circular economy requires an even further shift. Circular economy implies the design of the material loops which in turn requires involvement of the extended (meaning including material suppliers and focused on back-end processes) stakeholder network (Aminoff, Valkokari, & Kettunen, 2016). Thus, when we speak about circular co-creation, we speak about co-creation in stakeholder networks. This change implies increase of complexity. Moreover, the parties need to develop solutions that will function for a long time. Looking on these challenges together from a broader perspective, one quickly realizes that co-creation is no longer only about two firms working together to create additional value. It is a complex topic covering multiple aspects: business models, supply chains, relationships between the parties, the tools they use, and users that will use their products, etc (see Section 3.6 for more details). However, as literature review showed, little research has addressed circular co-creation (DeLosRíos-White, Roebeling, Valente, & Vaittinen, 2020). Moreover, even the co-creation literature (meaning co-creation in general) is fragmented, and authors usually address a specific part or component of co-creation, it requires a systematization in order to draw a picture of the whole co-creation process.

1.2. Context of the research

This section shortly introduces the reference case of this research. For more details about the REHAB project and circular extension see Section 4.

It was already mentioned that a government-wide program called "A circular economy in the Netherlands by 2050" was launched in September 2016 (The Ministry of Infrastructure et al. 2016). The first steps towards this goal are already done. The first projects realized following the principles of the circular economy are already in place (e.g. The making of Circl, 2017; van Vliet, van Grinsven, Teunizen, 2019). However, the number of the new built houses in Europe constitutes only approximately 1% of the total number of the dwellings (Thomsen & Flier, 2009). Therefore, the main challenge of the transition to circularity in the construction sector is making the existing housing stock circular. TU Delft and AMS Institute together with housing associations and industry partners started to look for a solution to achieve this transition. The REHAB project proposes renovating existing housing stock using circular building components, one of which is a circular housing extension. It was considered to be a suitable initial case to study co-creation process, as the extension is a commonly placed renovation component and many housing associations encounter old extensions during energy renovation projects. To date, the project has already been under development for almost two years. Up to this moment the design of the extension, as well as a preliminary design of the supply chain and business models has been developed throughout the co-creation workshops and meetings (see Section 4). However, less attention was given to the development of VRPs, although from the perspective of the circular economy, the development of VRPs is one of the decisive elements, as we need to ensure that even in 10 – 20 years resource loops will still function, and materials and modules will be cycled. Continuing of co-creation process to further develop VRPs would allow finding a "win-win-win" scenario for the stakeholders and ensure their commitment even after such a very long time. Thus,

this research will study what should be included in the co-creation process in the context of the development of VRPs of the circular housing extension.

During the literature review was found that in recent years, several frameworks and models that partly fulfill the gap identified in the previous section were developed and published. These frameworks were developed based on the integration of the available co-creation knowledge using systematic literature reviews. However, they were developed for the application not in CBE, but in other fields. Although they could become puzzle pieces for the development of co-creation process of circular extension, none of them could be used in isolation to do so. Therefore, today it is no longer needed to design the co-creation process from scratch, using the scattered literature, but it is still needed to adapt and specify this knowledge for the case of circular extension.

1.3. Problem statement

Using the knowledge gap found in the literature and the established need of co-creation process for the development of circular extension, the following problem statement was formulated:

> *There is a lack of knowledge in both academia and practice about the co-creation in context of the circular economy and, particularly, in the context of circular building products and circular extension. However, according to the literature review, to successfully realize the shift towards the circular build environment and implement and upkeep the VRPs, we need to establish the co-creation process among the (extended) supply chain.*

1.4. Design goal and research goal

The established problem statement leads to the following research goal. Due to the fact, that this research follows research through design methodology (Aken & Romme, 2009), a design goal and research goal are formulated instead of traditional research question and objectives.

Design goal:

> *Develop a useful and feasible co-creation process map for the development of VRPs of circular extension.*

Research goal:

> *To map how the co-creation process could be organized and what steps need to be included for the development and implementation of VRPs of circular extension and to further identify what lessons learned could be derived for the case of circular building components from the case of the circular extension.*

1.5. Research sub-questions

Five research sub-questions were formulated to help achieve the research goal and objectives. The first two research sub-questions are designed to obtain the necessary knowledge and data to start the design process. The third research sub-question relates to the design process. The fourth research sub-question was developed to evaluate the usefulness and feasibility of the developed

process maps. Finally, the fifth research sub-question is aimed on the identification of the lessons that could be learned.

1. What should be included in the co-creation process model? This question can be further subdivided into the following questions:
    - What are the requirements of the co-creation process?
    - What are the parameters of the co-creation process?
    - What co-creation techniques/tools can we use during the co-creation process?
    - Are there any co-creation models that could be used for the design?
2. What is the current state of the stakeholder network? This question can be further subdivided into the following questions:
    - How are the partners currently collaborating?
    - What barriers/gaps are there in the design, implementation and realization of circular extension?
    - What are the requirements for the co-creation of VRPs from the point of view of partners?
    - What are the resources, boundaries and motives of the partners?
3. How the co-creation maps could look like?
4. Which variants of the developed co-creation process maps are useful and feasible, and can they be used for the other circular building components?
5. Which lessons can be identified on how the co-creation process could be organized for the development and implementation of VRPs of circular building components from the case of the circular extension?

1.6. Scientific relevance

Current co-creation literature lacks examples of co-creation process design developed for the whole process lifecycle. Most co-creation models either stay too abstract or were developed for specific parts of the co-creation process. In recent years, several attempts to integrate this knowledge were done to develop co-creation models that cover the whole process lifecycle (e.g. DeLosRíos-White, Roebeling, Valente, & Vaittinen, 2020; Kruger, Caiado, França, & Quelhas, 2018). This research adapts these models for the case of circular extension. Moreover, in terms of details, this research goes one step further. The models that were developed in the recent years stay on the abstract level. In this research, instead of a model, a process map is developed, mapping the activities and options that could or should take place throughout the co-creation process. By specifying and evaluating a co-creation process for circular extension, the co-creation knowledge domain is enriched.

1.7. Societal relevance

As mentioned in the first lines of the introduction, one of the underlying aims of this research is contribution to the circular economy transition of the construction industry, which is responsible for the major part of resource consumption, global waste and CO2 emissions.

It is believed that with the introduction of the circular economy in the built environment, unsustainable practices could be limited or even ended. Therefore, it can be said that this research supports the Dutch government-wide program which aims to complete the circular transition in the Netherlands by 2050.

2. Methodology

This section defines methodological structure and then looks closer at each step of the developed structure.

2.1. Methodological structure

This research applies research through design approach and followed the design science methodology.

Usually the design science methodology is used in the fields of engineering, medicine and information systems with less examples in education and accounting (Aken & Romme, 2009). The organization and management research traditionally follow the approaches of the natural sciences and the humanities (Romme, 2003). Banathy (1996) distinguishes another approach for the organization and management research which is the design science approach.

The main objective of this research is to contribute to the scientific knowledge of co-creation related to the development and realization of circular building components through design of a co-creation model for development of VRPs of circular extension. The design science approach was considered to be suitable for this research for several reasons.

Aken & Romme (2009) state that design science has the following characteristics:

- Research questions are driven by field problems.
- There is an emphasis on solution-oriented knowledge, linking interventions or systems to outcomes, as the key to solve field problems.
- The justification of research products is largely based on pragmatic validity.

Design science focuses on the development of not yet existing systems or on the improvement of already existing systems through design and application of new practices or changing currently existing practices into the desired ones (Simon, 1996).

Based on the steps of the design science methodology by Aken & Romme (2009) the methodological structure of the research was designed (Figure 1)

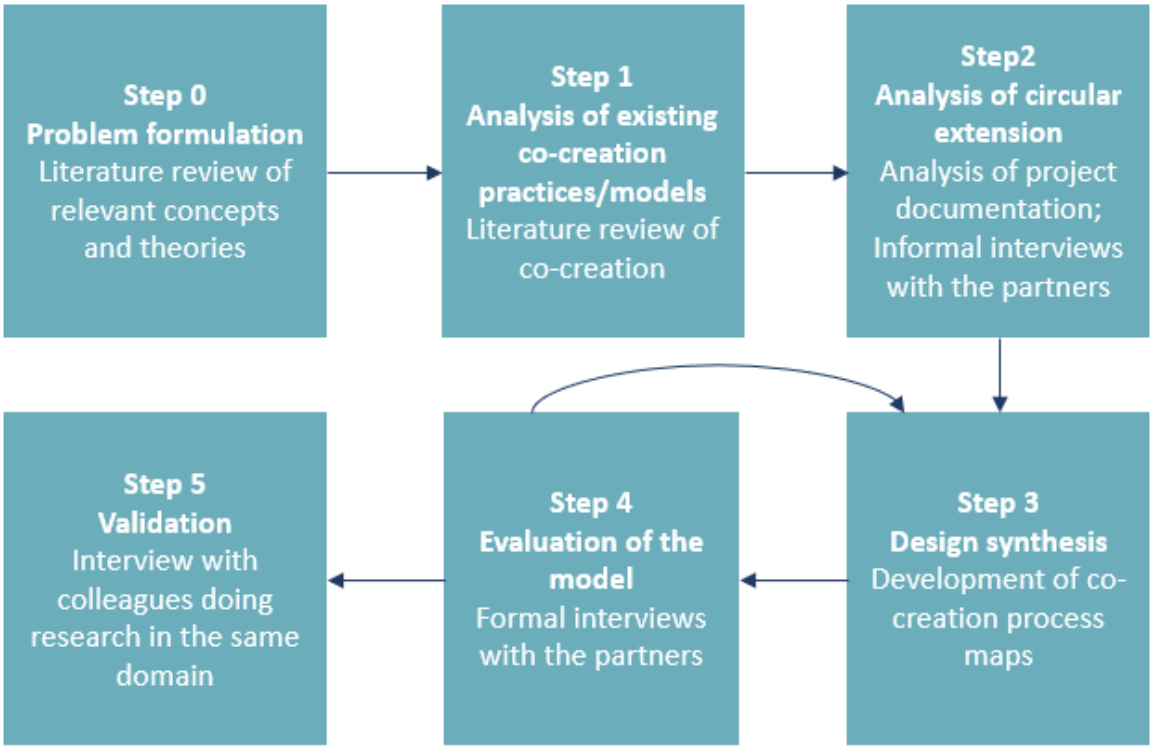

Figure 1. Structure of the research

2.2. Research methodologies

Step 1. Analysis of existing co-creation practises/models

This step includes an overview of the existing knowledge and theories related to the co-creation process through an integrative literature review. This step finalized the theoretical foundation of the research and facilitated the development of the initial design. This step aims to answer sub-questions 1.

The outcomes of the literature review are setting up the basis of the conceptual model. Following the questions that the review aims to answer (see Section 1.5), it is expected to derive the:

- Parameters of the co-creation process.
- Requirements of the circular co-creation process for circular extension.
- Co-creation tools and methods.
- Models that could be used directly or used as a reference example for the design of the co-creation process map of circular extension.

An integrative literature review was considered a suitable approach as its aim is to assess, critique, and synthesize the literature on a research topic in an integrated way such that new frameworks

and perspectives on the topic are generated (Snyder, 2019). The literature review was conducted following the steps described by Snyder (2019).

Step 2. Analysis of REHAB project and circular extension.

This step involves analysis of the REHAB project's documentation, giving special attention to the circular extension. Further, were conducted two informal interviews. First, with the project manager and second, with project manager and concept developer/tender manager. The analysis of the project documentation and informal interviews with the industry partners aim to answer sub-questions 2 by gathering data about the current state of the stakeholder network and to indentify project gaps from the perspective of partners and parameters of co-creation process.

Thus, the goals of this step were to:

- define all the relevant stakeholders
- define the current way of collaborating between the stakeholders
- identify gaps and requirements in developing VRPs from the perspective of partners
- identify parameters and options that could be mapped in the process maps.

Step 3. Design synthesis

The outcomes of the previous steps were combined and juxtaposed to develop a co-creation process map for the development of VRPs of circular extension. This step aimed to answer sub-question 3. Based on the results of the analysis of the existing theories (step 1) and analysis of the REHAB project and circular extension (step 2), it was decided to develop three co-creation process maps based on iterations of the business model and stakeholders' commitment to the process. The identified parameters of co-creation and found co-creation models became basis of the design. Models were developed through several iterations based on feedback provided by project supervisors. The models were developed in layers, first defining the generic structure of the co-creation process, then drawing the co-creation path (steps of the co-creation process) and finally identifying options and/or actions that could or should take place during each step of the process. Moreover, mapping of the options required to address the literature again. New concepts that became part of the process maps are also presented in the design synthesis section.

Step 4. Semi-structured interviews with the partners. Evaluation of the process maps

This step involved presentation of the developed process maps to the partners and their evaluation. Due to the iterative character of the design process it is difficult to spot the origin of the ideas and provide concrete evidence of the impact of the co-creation process in networks (van Dam, Sleeswijk Visser, & Bakker, 2020). Considering the absence of the KPI's/parameters to evaluate the co-creation design, an evaluation procedure was developed by the author of the research. Based on the developed design goal and research goal, the partners were asked to evaluate the process maps, based on three aspects: usefulness, feasibility and transferability of the developed process maps. These aspects, and questions that were developed to evaluate them, are the result of the synthesis of the knowledge acquired during the study of multiple theses throughout the whole research process: during preparation of theoretical background, co-

creation study, search of options that need to be mapped; search of inspirational designs, etc. (e.g. de Blok, 2018; Leising, 2016; Săceanu, 2021; Van der Wijk, 2018; Wei, 2020, etc.). The interviews were conducted online in semi-structured form. Interviewees were asked open question that leave room for discussion and stimulate free expression of opinion and ideas. Two questions were developed to evaluate the usefulness, five to evaluate the feasibility and one to evaluate transferability. The developed questions are presented below:

Evaluation of usefulness:
This aspect represents whether the developed process maps meet the needs of the stakeholders and business in the process of the development of VRPs.

- Do the developed process maps provide the knowledge needed for the organization of co-creation in context of the development of VRPs of circular extension? Why or why not?
- Would you use the developed process maps (and/or which one of them would you use) during the development and implementation of VRPs of circular extension? Why or why not?

Evaluation of feasibility:
This aspect represents whether the developed design could be implemented and identifies their strengths, weaknesses, opportunities and threats.

- Do you consider that the engaging actor (manufacturer/contractor/housing association) would be able to organize the process based on the developed process maps? Why or why not?
- Do you consider that organization of (product as a service/sell and buy-back/user-oriented) co-creation process and implementation of VRPs would be economically feasible? Why or why not?
- Could you highlight any strengths and weaknesses of the developed designs, in your opinion?
- What opportunities and threats, in your opinion, do the developed designs bring to the problem owner?
- The developed designs also include process iteration loops (or feedback loops). How would you rate/evaluate their effect on economic feasibility of the process?

Evaluation of transferability:
This aspect examines whether the developed design could be used in the context of other circular building components.

- Do you consider that the developed process maps could be used for the co-creation in context of other circular building components? Why or why not?

Step 5. Validation of the model

Research through design addresses problems for which a "correct" solution usually does not exist or is almost impossible to define. It is a generative process in which through the mix of methodologies designers try to find a "working" solution. Sometimes it might even be a bad solution, but the final goal is that through multiple design cycles to arrive at a good solution. Reflecting on the developed result, allow insights that broaden the scientific knowledge to appear. Application of the validity criterion of "standard" science would result in a conclusion that research through design is unscientific (Gaver, 2012). Therefore, an independent validation method was developed to validate this research and its results. Two Construction Management and Engineering (CME) graduate students were approached for the validation. Both these students perform(ed) the research on the other aspects of the REHAB project. They were asked to validate the research logic (meaning problem statement and the chosen method) and the research results. The following questions were designed for the validation session:

Problem statement:

- Do you consider the chosen knowledge gap and problem relevant? Why or why not?

Method:

- Do you consider the chosen methods appropriate to fulfill my design goal research goal? Why or why not?

Results:

- Do you consider that the results I got during my research fulfill my design goal and research goal and (partly) fills the identified knowledge gap? Why or why not?
- Does the result of this research match your personal constructions about the topic?
- Do you consider that the developed process maps describe the co-creation process explicitly enough? If not, could you name other parameters that should be included in your opinion?
- How would you improve the developed designs?

3. First literature review and Background of the research

This section first introduces the circular economy, what actions it involves and strategies to transition to it. Next is discussed the current way of collaboration in the built environment and what changes are in place during the circular economy transition. Further, focus shifts particularly to the housing renovation market and what changes circular economy brings to this market. After this is defined the concept of co-creation and the need of co-creation for circular transition is elaborated. Next, is presented the difference between linear and circular co-creation; and between co-creation and collaboration terms. Finally, the problem statement is defined based on the necessity of co-creation application to realize circular transition.

3.1. Circular economy definition and origins

The authorship of the term "circular economy" is ascribed to many authors in the literature, despite using the range of meanings and associations. This term usually entails representation of cyclical closed-loop systems. (Murray, Skene, & Haynes, 2015). The base concepts of the circular economy can be traced back to the 19th century; for example, the idea of using waste as a resource (Simmonds, 1862). Therefore, it is impossible to define the authorship of this term.

In the last decade, the concept of a circular economy was widely spread with a large contribution from the Ellen MacArthur Foundation. This foundation promotes a circular economy as a response to the unsustainable conventional "take-make-dispose" economic model (Ellen MacArthur Foundation, 2013).

As a starting point, this research uses the definition provided by the Ellen MacArthur Foundation (2013, p.14) which is considered to be the most prominent definition (Lehmann, 2018):

> *"The term 'circular economy' denotes an industrial economy that is restorative by intention and design. In a circular economy, products are designed for ease of reuse, disassembly and refurbishment, or recycling, with the understanding that it is the reuse of vast amounts of material reclaimed from end-of-life products, rather than the extraction of resources, that is the foundation of economic growth."*

The Ellen MacArthur Foundation's understanding and definition of circular economy is based on other concepts that considered the reuse and recycling of materials. The following schools of thought had the greatest influence: regenerative design, performance economy, cradle to cradle, biomimicry (Ellen MacArthur Foundation, 2013).

Circular economy is still a developing concept and has been used to denote different mechanisms for resource and organizational coordination (Lehmann, 2018). For example, in China, a circular economy was first focused only on waste recycling and later shifted towards the development of closed resource loops (Su, Heshmati, Geng, & Yu, 2013). In contrast, in Europe, the concept of a circular economy has been framed in broader terms involving systematic changes (system thinking) in the domain of technologies, policies, society, consumer behavior, etc. (European Commission, 2014).

3.2. Strategies and actions to realize a circular economy

Creation of the additional value throughout the whole system, as well as closure of the material loops requires specific actions to be performed in the system. Ellen MacArthur Foundation (2013) provides a schematic representation, a so-called "butterfly diagram", of these actions in their report (Figure #).

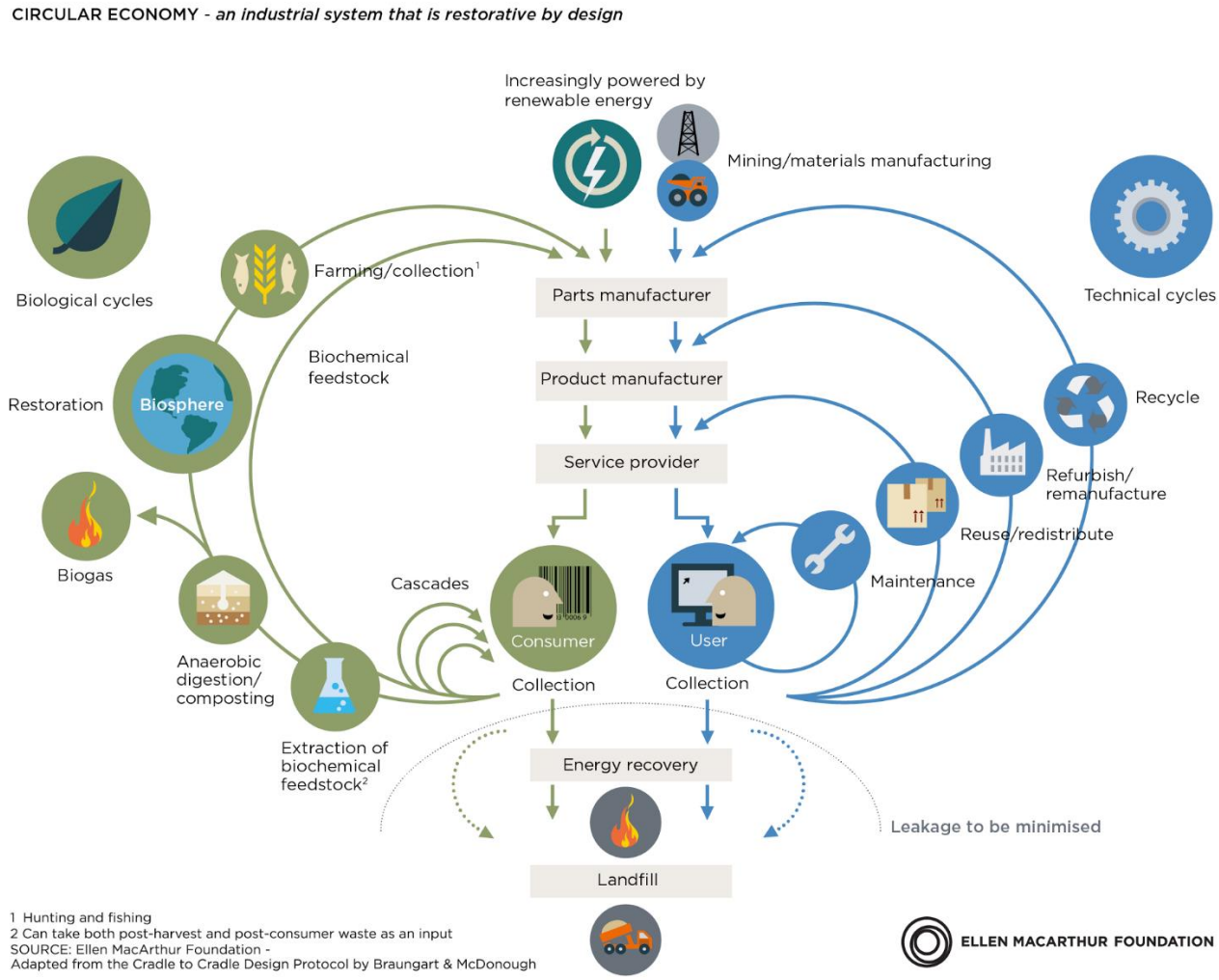

Figure 2. The Butterfly diagram – a representation of the circular economy activities (Ellen MacArthur Foundation, 2013).

The diagram represents two cycles: biological and technical. In the biological cycle, materials are designed to safely return to the biosphere and restore natural capital, they are non-toxic and can be returned to the soil by composting or anaerobic digestion. In the technical cycle, materials are designed to be recovered, refreshed and upgraded — circulate keeping high quality, without entering the biosphere, minimizing the energy input required and maximizing the retention of value. Technical materials are not cascaded to other applications like the biological materials.

However, their value and energy are kept through reuse, maintenance, refurbishment and remanufacturing (Ellen MacArthur Foundation, 2013).

By distinguishing linear resource flows from circular resource flows, researchers originally defined two different types of loops within closed loop systems: slowing resource loops and closing resource loops (e.g. McDonough & Braungart, 2002; Stahel, 2010).

Bocken, Pauw, Bakker, & Grinten (2016) extended this classification and developed a framework that describes circular economy through the three principles of slowing, closing and narrowing resource loops.

The first two fundamental strategies toward the cycling of resources were just mentioned above:

1. Slowing resource loops. The product's utilization period is extended through activities that are aimed at extending its lifespan; e.g., repair, remanufacturing. Product life extension slows the material flow.
2. Closing resource loops implies closing the loop between production and the end of a product's lifecycle through recycling, making the material flow circular.

The third approach is aimed at reducing resource flows and is quite different from the other two, as it does not involve any service loops.

3. Resource efficiency or narrowing resource flows, focuses on using less resources per product.

One of the decisive elements that slow, close and narrow material loops to extend product lifespans for financial feasibility are the actions already mentioned above (e.g., reuse, repair). In literature, these actions are called R-imperatives (Reike, Vermeulen, & Witjes, 2018). Other sources call them Value Retention Processes (VRPs) (e.g. Russell, 2018; Stijn, Gruis, & van Bortel, 2020). Numerous articles review the R-imperatives, proposing from 3 to 10 R-imperatives. However, they vary not only in number of R's, but also in their meaning. In their literature review Reike, Vermeulen, & Witjes (2018) analyzed and synthesized the most common perspective on R-imperatives into a systematic typology of 10 resource value retention options (ROs). Authors present the ROs by distinguishing short, medium long and long loops:

- Short loops. Products remain close to the user and function (refuse, reduce, resell/reuse).
- Medium long loops. Products are upgraded with the involvement of producers (repair, refurbish, remanufacture).
- Long loops. Products lose their original function (repurpose, recycle, recover, re-mine).

Developing design framework for circular building components Jansen, van Stijn, Gruis, & van Bortel (2020) linked R-imperatives to possible stakeholders (for cost allocation), see Table 1, and developed a circular economy life cycle costing model for building components. Considering that this research is focused on the circular building components, the term VRPs is used instead of R-imperatives.

Table 1. Value retention processes (Jansen, Stijn, Gruis, & Bortel, 2020)

	R#	CE concept	Key customer activity	Key market stakeholder activity	Possible stakeholder (for allocation of costs)
Client/user choices	R0	Refuse	Refrain from buying	See 2nd life cycle Redesing	Customer, Manufacturer, Third parties
	R1	Reduce	Use less, use longer; recently: share the use of the products	See 2nd life cycle Redesing	
	R2	Resell/ Reuse	Buy 2nd hand, or find buyer for your non-used produced/possibly some cleaning, minor repairs	Buy, collect, inspect, clean, sell	
Product upgrade	R3	Repair	Making the product work again by repairing or replacing deteriorated parts	Making the product work again by repairing or replacing deteriorated parts	Customer, Third parties
	R4	Refurbish	Return for service under contract or dispose	Collect, replacement of key modules or components if necessary	Manufacturer, Third parties
	R5	Remanufacture	Return for service under contract or dispose	Collect, replacement of key modules or components if necessary, decompose, recompose	Manufacturer, Third parties
Product downcycling	R6	Repurpose (Rethink)	Buy new product with new function	Collect, design, develop, reproduce, sell	Third parties
	R7	Recycle	Dispose separately; buy and use secondary materials	Collect, check, separate, shred, distribute, sell	Manufacturer, Third parties
	R8	Recover energy	Buy and use energy (and/or distilled water)	Collect, energy production as by-product of waste treatment	Third parties
	R9	Re-mine	Buy and use secondary materials	Grubbing, cannibalizing, selling (non-industrialized)/high-tech extracting, reprocessing (industrialized)	Third parties

3.3. Business model concept in circular economy

Design of the VRPs can be considered part of the design of the business model, therefore let's have a closer look on circular business models. There are various perspectives on circular business models (CBM) available in the literature. A business model is a tool that helps to acquire understanding of how a company does the business (Bocken, Short, Rana, & Evans, 2014). The concept of a business model covers a variety of aspects starting from how a company earns its revenue to a definition of the organizational structure (Ranta, Aarikka-Stenroos, & Mäkinen, 2018). Most scholars tend to cover similar elements, but present in different classification (Leising, Quist, & Bocken, 2018). However, most of the literature on circular economy business models can be traced back to the business model framework of Richardson (2008) (e.g. Geissdoerfer, Pieroni, Pigosso, & Soufani, 2020; Leising, Quist, & Bocken, 2018; Ranta, Aarikka-Stenroos, & Mäkinen, 2018). Therefore, in line with other studies, this research also uses the value proposition, value creation and delivery, and value capture as the main components of business models. The updated categorization developed by Bocken, Short, Rana, & Evans (2014) was selected for the sub-components (see table 2).

Table 2. Business model framework. (Bocken, Short, Rana, & Evans, 2014)

Value proposition	Value creation and delivery	Value capture
Product/service, Customer segments and relationships	Key activities, Resources, channels, partners, technology	Cost structure and revenue streams

3.4. Circular economy in the Netherlands

A governmental program called "A circular economy in the Netherlands by 2050" was adopted by the government in September of 2016 (The Ministry of Infrastructure et al, 2016). The program is aimed on development of a sustainable economy that would secure a livable earth for future generations. This involves adoption of methods of efficient use and cycling of materials as well as obtaining them in a sustainable manner. Moreover, it is aimed on limiting the necessity of acquiring raw materials as a result of implementation of more efficient products and services. The program aims for a completely circular Dutch economy by 2050. Five chains and sectors have been given priority in the transition: biomass and food, plastics, manufacturing, construction and consumer goods. The program defines several milestones first of which will come in the year 2030 and involves a 50% reduction in the use of raw materials. This implies that these sectors need to speed up implementation of circular practices and develop new business models and solutions, because they need to find a way to be able to cover these 50% from the currently existing products or from those that they will develop until the milestone.

3.5. Circular economy in the built environment

Complying with the governmental program, construction industry has already started its transition. Before defining what changes a circular economy brings to the construction industry, first, let us look at the core characteristics of traditional (linear) construction.

3.5.1. Current way of collaborating in the construction industry

In contrast to process-based manufacturing, construction is by nature dominated by project-based one-off approaches. A traditional construction supply chain for any project usually includes, architects and engineers, main contractor, subcontractors, and direct and indirect material suppliers that come together once to build a project for a specific owner (client). This complex supply chain is characterized by "adversarial short-term relationships driven by the competitive bidding process, very little information sharing and little motivation for continuous learning" (Behera, Mohanty, & Prakash, 2015, p. 1334). A generic configuration of the traditional supply chain is presented in figure 3.

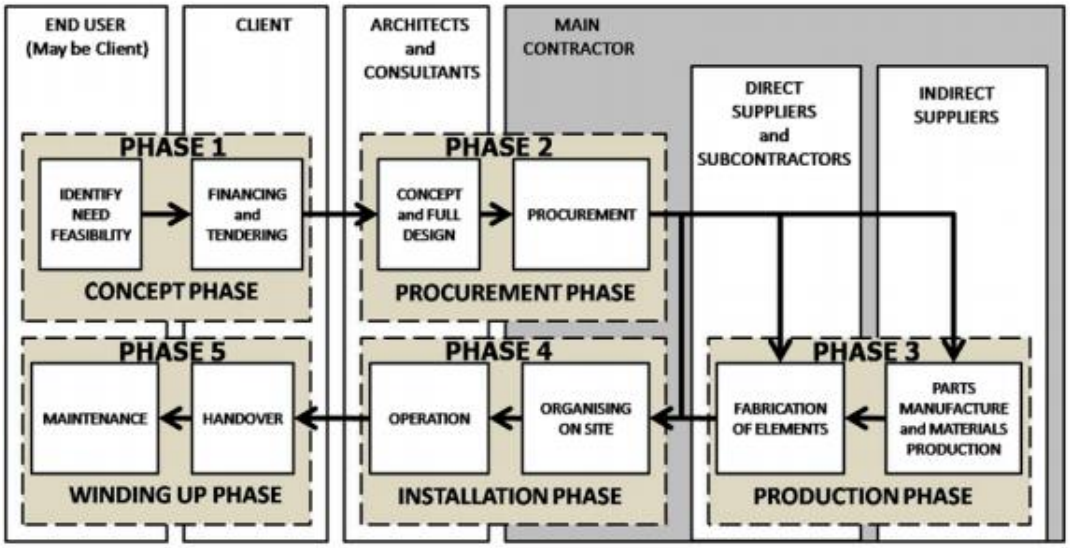

Figure 3. A generic configuration of the traditional supply chain (Behera, Mohanty, & Prakash, 2015).

Vrijhoef and Koskela (2000) characterize the construction supply chain as following:

- It is a converging supply chain. All the materials are gathered on site, where the product is assembled. It is focused on a single product in contrast to manufacturing systems, where multiple products pass through the factory.
- Traditionally it is a temporary supply chain producing a one-off construction project, through the reconfiguration of organizations. This results in the supply chain being fragmented, unstable with a clear separation between design and construction processes.

- It is a typical make-to-order supply chain, with every project creating a new product or prototype. This involves minimum repetition, except for projects of the same type.

Elaborating in more detail on the last two characteristics, the project itself could be defined as a temporary organization aimed at the development of a unique solution through management of the uncertainty and integration of the assigned resources. Since it is temporary, there is a high possibility that the composition of the supply chain will be novel, but not necessary (Turner & Müller, 2003).

3.5.2. Transition to a circular economy in the construction industry

Application of circular economy principles to the construction industry can be considered sustainable innovation in the building sector (van der Wijk, 2018). However, construction is a traditional and conservative industry. Innovation requires new skills and knowledge to successfully implement it and change the current state of the construction sector (Davidson, 2013). The construction sector is project based (Blayse & Manley, 2004; Mlecnik, 2013). The transition to circular construction implies changing the business models in the sector, as such transition is an example of radical change, which requires new ways of thinking and doing business. Bocken, Pauw, Bakker, & Grinten (2016) based on the works of Bocken, Short, Rana, & Evans (2014) and Bakker, den Hollander, & van Hinte (2014) developed business model innovation strategies suitable for the circular economy. One of them is, for example, the access and performance model. This model implies that the responsibility for the design, finance and operation shifts from the commissioning party to the provider (contractor). The contractor shifts from being the supplier of capacity and labor to the supplier of products and services. (Fellows, Liu, & Chan, 2014; Angelis, Howard, & Miemczyk, 2018). To enable this transition, supply chains are considered a critical element. “When closing and slowing material loops, it is essential to include the supply chain as a whole, and to involve all parties from design and raw material suppliers to end users, service providers and recyclers, including the associated information flows” (Leising, Quist, & Bocken, 2018, p.977). However, the feasibility of involving of the whole supply chain of a building could be doubtful. Attempts to include the whole supply chain in one entity could result in the significant rise of complexity of management of such project. That is why further we look on the idea of circular building components which allows to subdivide the building into components and make each component or material a separate “project”. Running them as separate project would be easier than attempting to include the whole chain in every building.

The “early” research of the circular economy in the built environment mostly focused on the downcycling of waste (Adams, Osmani, Thorpe, & Thornback, 2017; Aminoff & Kettunen, 2016). In fact, in the Netherlands, demolition waste has already been downcycled for decades. In 2001, 85% of construction and demolition waste was downcycled for use in road construction. However, the recycling of demolition waste for the use in concrete was only marginal because of the higher costs compared to the raw materials (Hendriks & Janssen, 2001). More recent studies show the current situation is largely the same. If current recycling technologies are not upgraded, the use of waste in concrete manufacturing will continue to be only around 1%. Implementation of cost-

effective and innovative recycling technologies would allow this number to raise between 11% – 16% by 2025 (Zhang et al., 2020). However, although downcycling is better than graving materials, the circular economy promotes avoiding it and developing functional recycling methods, as downcycling limits the usability of materials and therefore maintains the linear dynamic of the material flow system (Ellen MacArthur Foundation, 2013). Although in terms of recycling, there is still a lot to be achieved (moreover recycling can be named the worst option in the hierarchy of VRPs), literature in CBE started to develop in other directions. For example, Hart, Adams, Giesekam, Tingley, & Pomponi (2019) study barriers and drivers in CBE, Leising, Quist, & Bocken (2018) develop a collaboration tool for CBE, Joensuu, Edelman, & Saari (2020) analyze the practices currently applied in CBE, etc.

To date, there are already projects realized in line with circular economy principles trying to achieve maximum potential. For example, The Circl Pavilion in Amsterdam. In this project the building is seen as the future material bank. The building is designed for disassembly and it is expected that the materials will be reclaimed in the future (The making of Circl, 2017). Another example is the temporary courthouse in Amsterdam designed by the CEPEZED. In this project the building is treated as a product and the function can be changed later if needed, and the building itself can even be disassembled and reassembled in another location (van Vliet, van Grinsven, Teunizen, 2019). However, it would take very long time to transition to a circular economy, if applying its principles to only new construction. The number of the new built houses in Europe constitutes only approximately 1% of the total number of dwellings (Thomsen & Flier, 2009). Therefore, the main challenges of the transition to circularity in the construction sector are issues of waste recycling, the transformation of existing housing stock into being circular, and finding ways of using the available materials instead of recycling them. As many scholars' state, solutions and configurations that are fully in line with the principles of the CE are almost absent both in practice and academia (Masi, Day, & Godsell, 2017; Batista, Bourlakis, Smart, & Maull, 2018; Adams, Osmani, Thorpe, Thornback, 2017; Leising, Quist, & Bocken, 2018; Angelis, Howard, & Miemczyk, 2018).

3.5.3. Dutch housing renovation market

An important item in the agenda of many European countries is renovation of the existing housing stock. (Guerra-Santin et al., 2017). As it was just mentioned, the number of new built houses constitutes only approximately 1%. Moreover, this number continues to decline; for example, in the Netherlands social housing organizations built 50% fewer new dwellings in 2014 compared to 2009 (AEDES, 2016). These numbers explicitly demonstrate the necessity of maintenance and refurbishment of an existing dwelling in order to keep the supply and demand balanced.

In most cases, refurbishment (meaning complete renovation, involving substantial functional and technical improvements) is a more challenging process than the new construction. Compared to the regular construction process, the development of the supply chain and continuous production flow is more complicated, as each house has its own specific issues that need to be resolved (Gruis, Roders, & Straub, 2011). Furthermore, another issue that needs to be addressed is the tenants'

consent. According to Dutch legislation, 70% of the residents must agree to the renovation for it to start (Guerra-Santin et al., 2017).

Another influential characteristic of the Dutch housing market is the goal set by the government to improve the energy performance of the properties and achieve average energy label B by 2020. Moreover, this was only a milestone, industry still needs to comply with the EU directive on energy performance (Bleicher, 2008) and achieve a highly energy efficient and decarbonized building stock by 2050. Some housing associations did not stop at only reaching the required energy level and are already looking towards projects with a higher impact (zero-energy renovation projects), as in the long run it should bring more benefits (Boess, Guerra-Santin, Silvester, Budde, & Frederiks, 2016). The fact that housing associations have a limited budget to invest in their project, coupled with the above mentioned challenges of refurbishment, necessity of tenants' consent and the Dutch goal to achieve circularity by 2050 (the first milestone is already in 10 years) brings the need of new business, supply chain and collaboration models to implement and upscale the solutions (Guerra-Santin et al., 2017).

3.5.4. Changes in the supply chain configuration that bring transition to product vision and circular economy

When we transition to a circular economy, the typical linear construction configuration presented above (see Figure 3) becomes more cyclical (see Figure 4).

In a "most traditional" approach to housing renovation (DBB), the client/commissioning party (in our case it is the housing association) has a design drawn up, which is then translated into detailed specifications in drawings. The contractor's only task is to implement this design for a reasonable price. The contractor does not propose any ideas and does not participate in the design phase. Another important aspect is that contractors do not take responsibility for the performance guarantee as they are not responsible for the design. Today it is possible to find various forms of collaboration in the market. Supply chain integration has been embraced to improve client satisfaction (Vrijhoef, 2011). Baldiri Salcedo Rahola & Straub (2013) identify four main types of project delivery methods for housing renovation:

- Iterative minor renovations (IMR)
- Design-bid-build (DBB)
- Design-build (DB)
- Design-build-maintain (DBM).

In case of IMR the renovation it is split into a number of smaller renovation projects; for example, kitchen renovation, roofing, decoration, insulation of the façade, etc. In this case renovation processes are carried out by different companies at different times. The DBB was largely described above. In this case, architects/designers, the construction company and maintenance company become part of the project one after another. In DB, a contractor (or a consortium of companies) takes responsibility for the design and the renovation and is carried out by them without the

involvement of an architect. In DBM, a contractor (or a consortium of companies) takes responsibility for the design, construction works and maintenance under a single contract.

DB and DBM types of collaboration bring more price certainty, reduce the risk of design failure and allows them to implement performance-based specifications. Additionally, DBM also brings certainty about maintenance costs over a fixed period. However, the DBM form of collaboration also brings a change in the role of the parties, and requires extra effort and time to adapt to the situation, as well as a change in the management strategy from housing associations (Chang, Shen, & Ibbs, 2010). IMR and DBB are the most commonly used methods for housing renovation, while DB and DBM are not a common practice. They are mostly used for energy renovation projects, because they are well-suited to utilizing performance-based specifications which, in turn, facilitate implementation of more sustainable practices (Baldiri Salcedo Rahola & Straub, 2013).

Product-service-systems (PSS are business models focused on joint delivery of products and services with the aim of pro-environmental outcomes) are often referred as a potential enabler for the transition to the circular economy and development of innovative business models (e.g. Lewandowski, 2016; P. P. Pieroni, C. McAloone, & C. A. Pigosso, 2019). The value proposition is focused on the delivery of the service (access and performance) rather than ownership. However, it is quite unclear how to implement such a system in the context of housing renovation. For example, the PSS literature suggests that the most “promising” party to keep ownership of the product is manufacturer (Yang, Smart, Kumar, Jolly, & Evans, 2018). However, in the context of circular building products it is doubtful, as it would result in scattered ownership of the parts of a building and would require additional effort to maintain houses. Moreover, manufacturers of building products do not have experience in the long-term management of capital resources, while the housing associations do. Lastly, it is doubtful that manufacturers would even agree to take such a responsibility for existing buildings.

However, the product way of thinking still provides the ground for the transition to circular economy. Current construction practices limit the possibility of the transition to a circular economy for many reasons: design practices that limit the possibility to recover materials; use of unsustainable materials that cannot be effectively recycled; business and supply chain models that would require drastic changes to achieve circularity. Therefore, development of circular building products for housing renovation facilitates the re-looping of materials and components, as in the following case parties act differently from the very beginning. They choose the materials that can be recycled, design the product for disassembly, and try to change their approach and business model to fit into the circular economy. This process requires joint effort and cooperation with upstream partners. To achieve this transition parties should obtain knowledge of the product, housing stock and end user. In short, they should have knowledge about not only the technical characteristics, but also about the needs of the residents, what they would prefer, how to embed circular ambitions, etc. Using as the example the energy renovation projects (TU Delft, 2019), because they also require intensive cooperation between all parties and aim to enhance sustainability (moreover they are closer to the reality of housing renovation market, than

examples that could be found in the PSS literature), it is possible to draw how the generic (possible) configuration of circular construction phases would look like (See Figure 4).

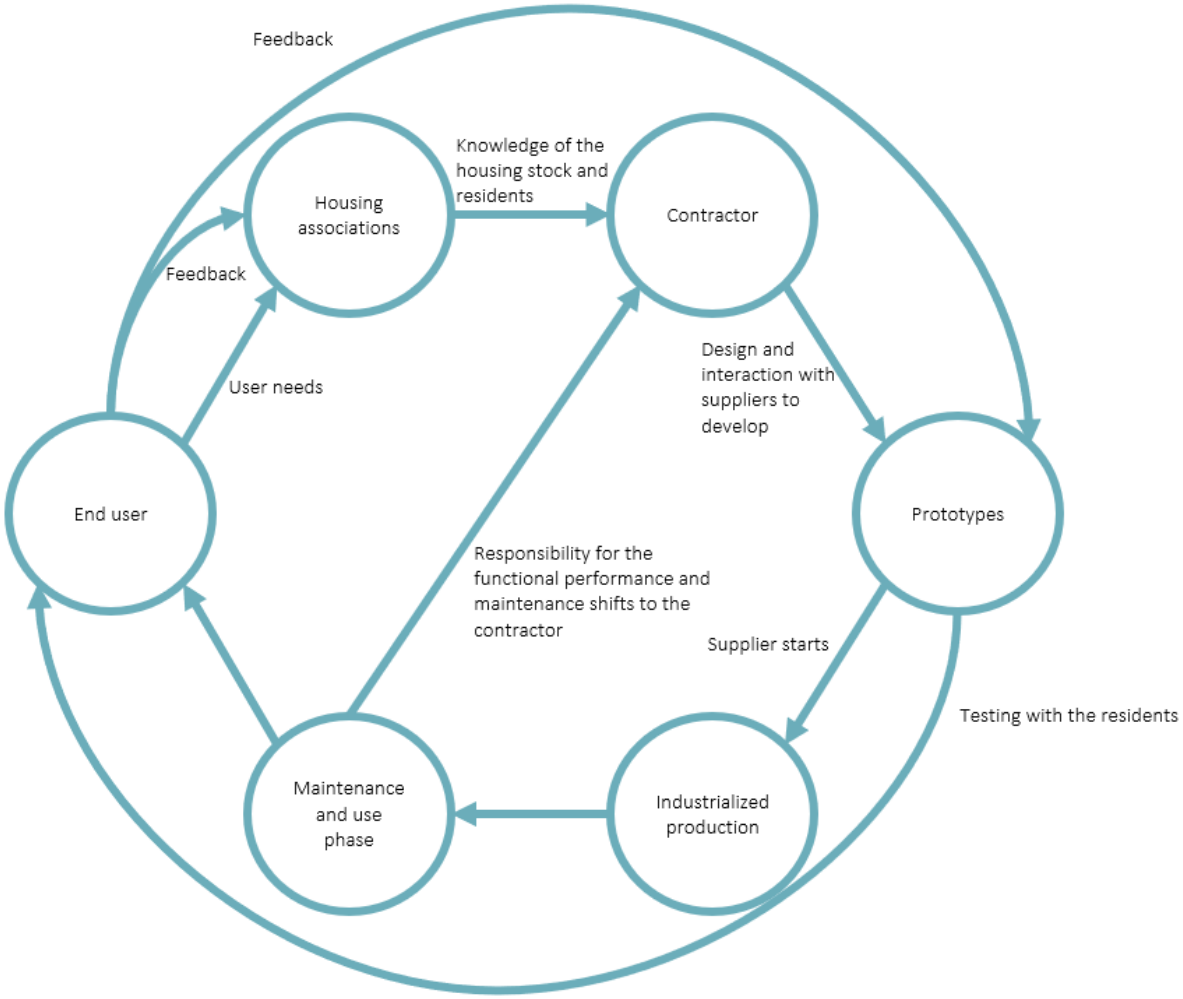

Figure 4. Generic (possible) configuration of circular construction phases (based on energy renovation projects supply chain, TU Delft, 2019).

Similar to energy renovation projects, the DBM project delivery method could be used, so the responsibilities for the design, implementation and maintenance would shift from the client to the contractor. Then in the scenario of circular building components, the contractor role changes. From a supplier of capacity and labor, the contractor becomes a supplier of products and/or services. The product (dwelling) becomes the subject for the continuous development and ongoing evaluation, in terms of technology, as well as the resident's opinions. Moreover, implementation of circular economy in the housing sector brings the necessity to think and plan far ahead, as re-looping should be kept up in the long run. Stakeholders need to divide responsibilities far in advance and prepare backup solutions that will guarantee functional performance. However, on par with complexity and need for adaptation, this transition also brings various benefits. One of them is for example generation of new revenue streams because now the materials and modules could be reused, refurbished and remanufactured. Moreover, with the

transition from project to products it is possible to make the last mass customizable what would allow the generation of new revenue streams through selling different configurations to the users, etc.

3.6. Why is co-creation needed and what is it?

3.6.1. Need of co-creation

As stated above, the application of the circular economy in the built environment (and in housing renovation) brings radical changes to the configuration of the supply chain. Materials should be in fact re-used, repaired, recycled etc. (VRPs). To achieve this, supply chain should include mechanisms of reclaiming and re-using of the materials after they reach the end of their lifespan. Moreover, it is not enough only to design these mechanisms, we need to ensure their implementation. This problem includes many "hidden" tasks, e.g. we need to ensure circular knowledge throughout the levels of the organization; secure information flows and that "the next" maintenance group could repair or dissemble and re-use the parts or materials; secure that even after decades there is still a partner that could provide re-use and dissemble service, etc. To achieve this task diverse stakeholders should collaborate to create multiple types of value that exceed the boundaries of individual organizations (Flink, 2017; Adams, Osmani, Thorpe, Thornback, 2017; Batista, Bourlakis, Smart, & Maull, 2018). In short, transition to the circular economy in the build environment necessarily entails collaboration throughout the extended supply chain (meaning involvement of the parties, that would not be part of the process in traditional construction, e.g. material suppliers). In literature discussing the circular transition this type of collaboration is named *"co-creation"*.

3.6.2. Origins and current advances of co-creation literature

The term "co-creation" has been conceptualized differently by many authors, but if we speak about what co-creation is in general, one could use the definition provided by Fellows, Liu & Chan (2014, p. 121):

"Co-creation implies dyadic or multi-actor value creation, including identification, formation, leverage and realization of value in products and services as well as value embodied in participation and perceptions. Direct creation involves activities spanning organizational boundaries. Colloquially, co-creation is value that is more than the sum of the parts that individual organizations can create on their own and in-house".

The co-creation term originates from the public sector, where it was developed as an attempt to answer the question of how customers could contribute to the development of products and services that they purchase (Lusch & Vargo, 2015). In the co-creation process, customers become part of the service production through definition of their needs. Furthermore, they evaluate the service they purchase and how they can further improve it (Torfing, Sørensen, & Røiseland, 2016). In other words, early co-creation literature conceptualized this term as a dyadic firm-customer exchange relationship. Later contributions broaden the understanding of co-creation by shifting the focus from co-creation with consumers to co-creation between stakeholders. In the recent literature, the concept of co-creation is usually associated with the business strategy which

focuses on interactive relationships between the number of stakeholders in the supply chain (Smorodinskaya, Russell, Katukov, & Still, 2017). Speaking more precisely, the literature defines co-creation as a process "that takes place between economic and social actors within networks interacting and exchanging across and through networks" (Pera, Occhiocupo, & Clarke, 2016, p. 4034). Here, co-creation is seen as the way to guarantee the correct exercise of social responsibility, given that the co-creation is aimed at finding the state in which parties would be able to express their opinion and benefit from the results (Kruger, Caiado, França, & Quelhas, 2018).

3.6.3. Is there a difference between linear and circular co-creation?

This section defines the difference between linear and circular co-creation and draws the final picture of co-creation in this research. After examining the number of sources (Aminoff, Valkokari, & Kettunen, 2016; Arnold, 2017; Dokter, Andersson, Thuvander, & Rahe, 2019; Durugbo & Pawar, 2014; Fellows, Liu, & Chan, 2014; Frow, Nenonen, Payne, & Storbacka, 2015; Payne, Storbacka, & Frow, 2007; Prahalad & Ramaswamy, 2004; Ren, Hu, Ngai, & Zhou, 2015; Romero & Molina, 2011), the following conclusion was drawn:

The main difference between them is the scale. Co-creation in traditional projects usually takes place between a limited number of parties. Co-creation in these projects focuses on customer value-creating processes (co-creation between a company/business and end user) or supplier value-creating processes (co-creation between a limited number of partners/stakeholders to create additional value through the supply chain). In contrast to this, to achieve success in a circular project, co-creation needs to be applied on a larger scale. Aminoff, Valkokari, & Kettunen (2016, p.632) link the co-creation concept to the concept of collaborative networks, defining the concept of circular economy co-creation networks, which is "a dynamic network including both the actors of the core business value network and other relevant stakeholders". Figure 5 shows the circular economy co-creation network presented in their article.

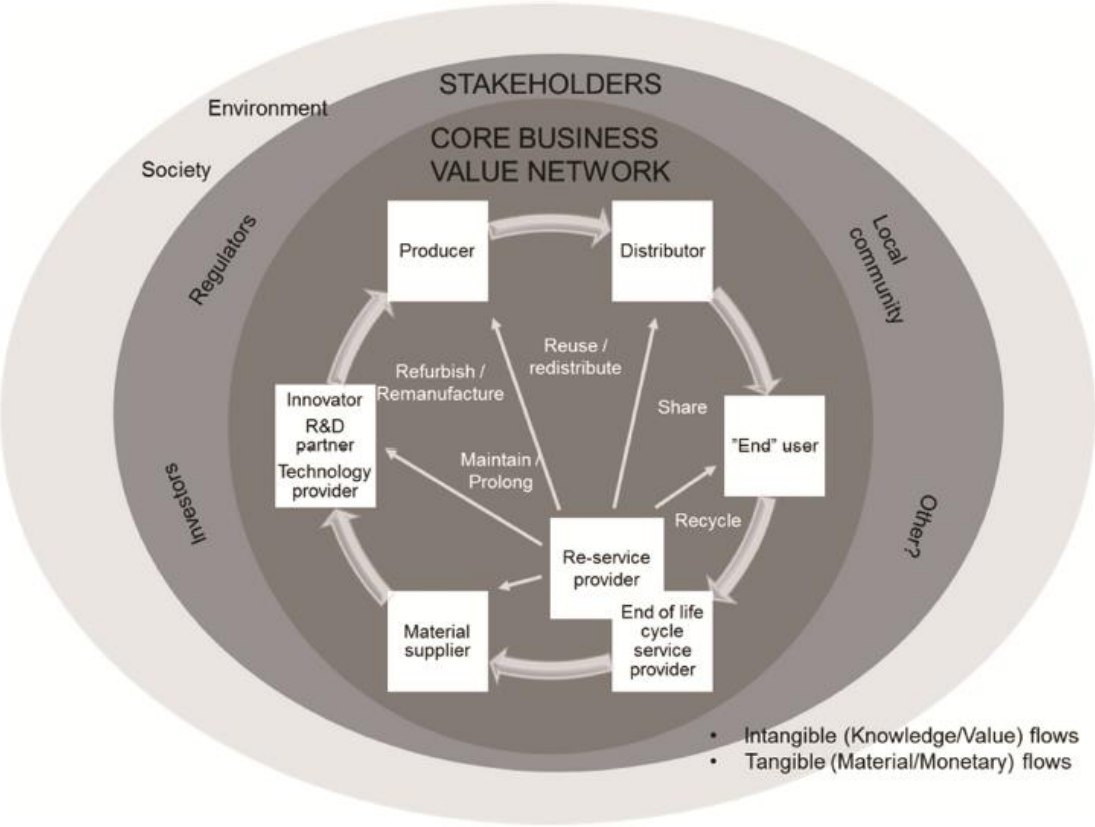

Figure 5. Actors in the circular economy co-creation network (Aminoff, Valkokari, & Kettunen, 2016)

The main challenge of co-creation network in circular economy is to find the "win-win-win" solution that will satisfy all the parties in the stakeholder network. Thus, it is crucial to identify their needs and drivers. This includes identification of both intangible and tangible flows between the actors. The consideration of value for the broad range of networks, actors and stakeholders becomes crucial, as in the circular economy, the value is not created by a firm in isolation, it is created by the network acting together.

The circular economy context and change of the scale also bring higher complexity of the process. The roles of the parties are changing, some parties need to adapt and take additional responsibilities, some might even no longer be part of the process, etc. Adapting to the new situation requires additional effort and changes in the management approach, as the whole process structure becomes different (see Sections 3.4.4, 3.5.1).

Another issue that arises with the circular economy transition is the upkeep of the process in the long run. This creates another difference between linear and circular co-creation. The duration of the relationships between the parties is much longer compared to the linear process model. Not

only should parties keep this in mind during the initial stages of process development, they also need to define the knowledge transfer mechanisms and develop backup solutions that will guarantee the process upkeep and circular economy integrity.

Finally, when all these arising challenges are integrated together, and you look at circular co-creation from a broader perspective, you quickly realize that co-creation is no longer only about stakeholders, tools they use and feedback they get. It is a topic covering multiple aspects: business models, supply chains, relationships between the parties, the tools they use, and users that will use their products, etc.

Summing up, one could say, that speaking about the circular co-creation process, we speak about complex network co-creation process. This implies that when developing the circular co-creation process map we should address the "later" block of co-creation literature that defines co-creation as a process happening in networks, rather than between only business (a company) and customers (although some of the models could be relevant for both types of co-creation). Going ahead, none of the found frameworks would cover all the aspects relevant to the development of the VRPs of circular extension (not even speaking about mapping these aspects). However, their combination allows for drawing the desired process map.

3.6.4. Co-creation and collaboration terms

The terms collaboration and co-creation have often been used to substitute for each other in colloquial speech. Therefore, a line between these two terms should be drawn. Many authors acknowledge that collaboration is a difficult to define term (e.g. Brown, Von Daniels, Bocken, & Balkenende, 2021; Hughes, Williams, & Ren, 2012; Schöttle, Haghsheno, & Gehbauer 2014). In broader terms collaboration "denotes various forms of interactive communication" (Smorodinskaya, Russell, Katukov, & Still, 2017, p.5248). Even in the boundaries of the construction industry, the term collaboration has been used differently and is usually used as an "umbrella term" for alliancing, joint ventures, networking and partnering. Moreover, the definition of collaboration could change depending on the person's role in the project and therefore, for example, the definition from the perspective of client and contractor would differ (Hughes, Williams, & Ren, 2012). The concept of co-creation is also usually associated with the business strategy, which has the focus on interactive relationships between the stakeholders in the supply chain. It is an active, creative and social process initiated by a firm to generate additional value for consumers and producers. It includes not only the frequency of interaction, but also the quality of relationships among the network to determine how knowledge is created, shared and transferred. Co-creation uses joint resource bases, engagement platforms and an ecosystemic approach as a new means for business (Smorodinskaya, Russell, Katukov, & Still, 2017). It was decided to use the term "co-creation" because the research concerning the circular economy implementation in most cases uses this term. Moreover, the initial analysis of the articles studying co-creation and collaboration, showed that the articles studying co-creation are closely linked with the business strategy and supply chain configuration and, thus, provide more insight into the process design (e.g. DeLosRíos-White, Roebeling, Valente, & Vaittinen, 2020; Kruger, Caiado, França, & Quelhas,

2018), compared to the research concerning collaboration, which mainly focuses on what forms collaboration takes (e.g. Brown, Bocken, & Balkenende, 2018; Mishra, Chiwenga, & Ali, 2019).

Summing up, one could probably say, that in fact both terms have multiple interpretations and are used by the authors to address sometimes the same and sometimes different things. Moreover, there is a variety of other terms available to define the same or almost the same process (e.g. participatory design, user centered design, collaborative innovation, etc.). The term co-creation is used, because the literature found under this term was considered to be more relevant for the scope of this research. Moreover, it is more important how the term is defined in the context of the particular research, what was also presented above.

3.7. Conclusion

Summing up, co-creation could be an answer to find the solutions to the problems housing associations are currently facing. However, the research of co-creation in the built environment is limited (Fellows, Liu, & Chan, 2014; Arnold, 2017; Farooque, Zhang, Thürer, Qu, & Huisingh, 2019). Furthermore, if we speak about the management of the co-creation process in stakeholder networks (which is the requirement for circular co-creation) in the context of circular built environment, such knowledge is limited to a couple of articles. The available co-creation knowledge mainly consists of generic models (e.g. Mostafa, 2015; Payne, Storbacka, & Frow, 2007; Aminoff, Valkokari, & Kettunen, 2016; Durugbo, Riedel, & Pawar, 2011) that cannot be directly applied by housing associations; and cases describing the co-creation process in other industries, that also cannot be directly applied due to the substantial discrepancy between industries (the majority of articles are about IT, medicine and education). Additionally, even if we speak about other industries, there is also little knowledge available involving stakeholder networks in the circular economy. However, in the same time, the literature review of co-creation models and frameworks showed that, this opinion is outdated, because in the recent years a number of solutions that could become the basis for designing a co-creation process of VRPs for circular extension were published. The models found will be further presented in Section 5.

4. Introduction to REHAB project and circular extension

This section aims to answer second sub-question of the research: What is the current state of the stakeholder network? First it introduces the REHAB project and circular extension. Then is short description of the background of the project and circular building components. Next is defined that this research focuses only on a part of the project — circular extension. Further, the stakeholders involved in the project are mapped and the design of extension is presented. After is a summary of the preliminary design of the business model and supply chain for the circular extension that was developed during partner workshops.

Stijn & Gruis (2019) propose a strategy of how to integrate circularity into the existing Dutch housing stock (which is basically the bigger part of the built environment within the framework of the REHAB project. The solution was designed keeping in mind the following criteria (Stijn & Gruis, 2019, p. 2). The retrofit solution should:

- *Be able to spread the retrofit investment over multiple retrofit cycles.*
- *Accommodate different retrofit needs and practices from professional landlords and private owners through customization.*
- *Be adaptable to accommodate future changes.*
- *Be able to accommodate the loops of the circular economy.*

4.1. REHAB project

In essence, the REHAB project proposes to create circular housing stock through natural maintenance and component-by-component retrofit using circular building components. In this project the principles of CE are realized through retrofit using products that are modular, mass-customizable and cyclable, see Figure 6. This approach integrates the most strategies to narrow, slow and close the resource loops (Stijn & Gruis, 2019).

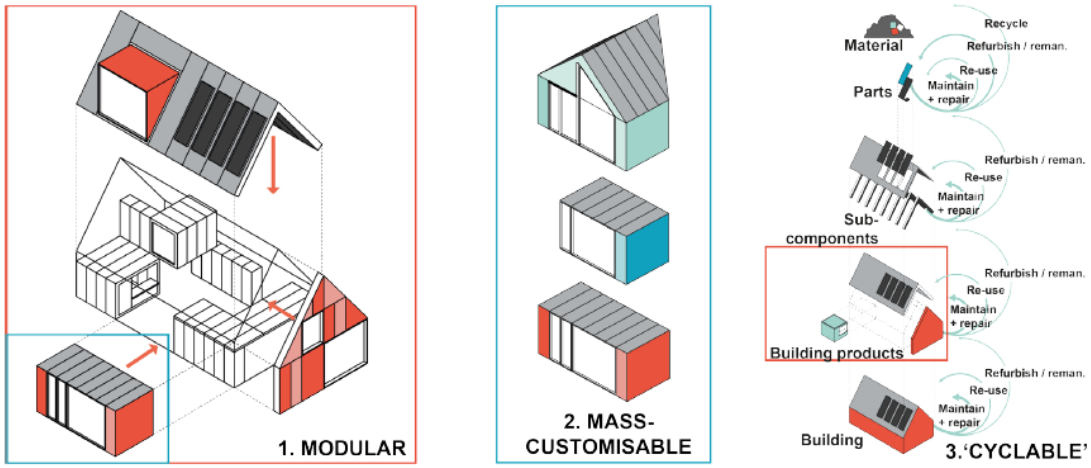

Figure 6. Three principles of the circular retrofit strategy for the Dutch context: (1) Modular, (2) mass-customizable, and (3) 'cyclable' retrofit products (Stijn & Gruis, 2019).

First prototypes of circular building components include the circular skin, circular roof, and circular extension (REHAB), see Figure 7. In addition, work is also underway on another component — a circular kitchen; however, it is being carried out as a separate project.

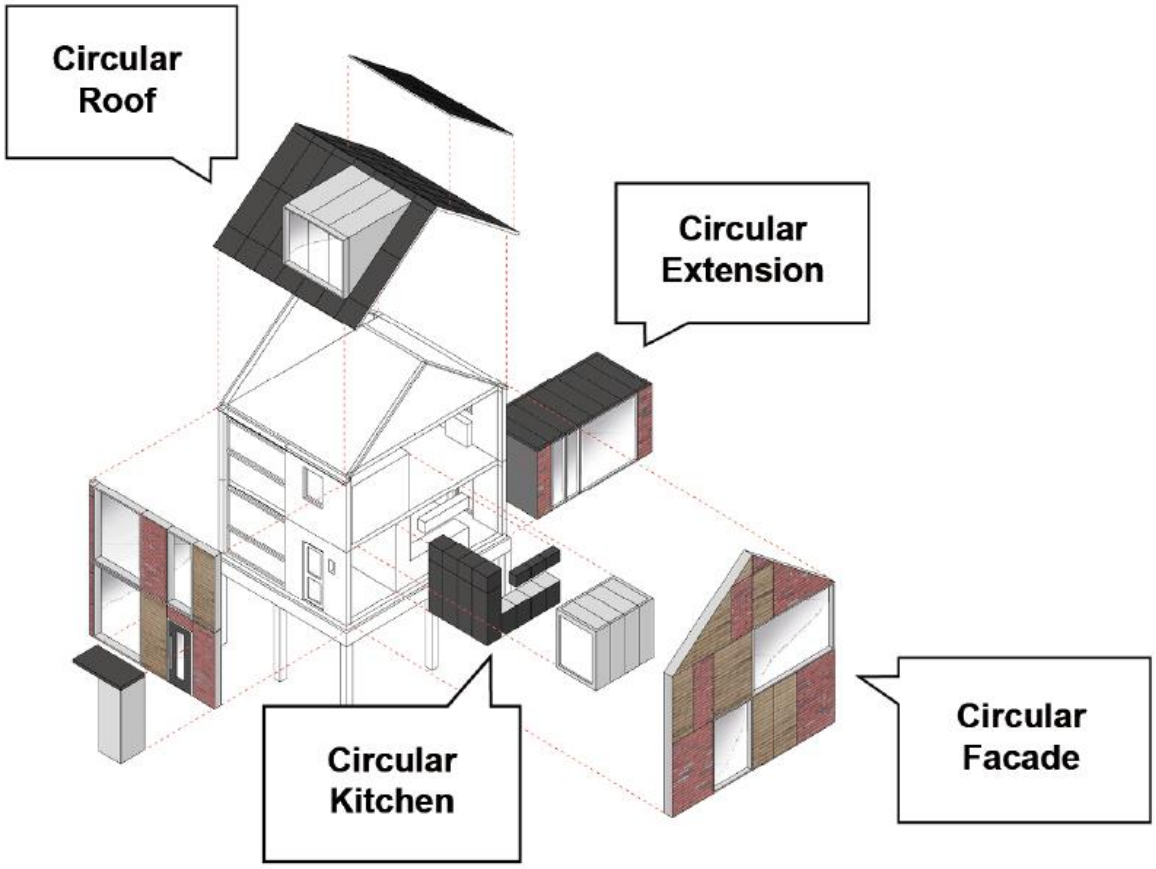

Figure 7. Circular building components (Stijn, 2019a).

4.2. Limiting the scope

It was decided to research the topic on the example of one of the circular building components (namely circular extension) and the development of its VRPs. (Development of VRPs is currently the main gap in the project, the preliminary design of the supply chain and business model were already developed; however, it needs to be further defined and parties need to make decisions regarding what VRP loops they are going to implement.) This decision was taken because each of the circular building components is developed by different stakeholders and, correspondingly, by different networks. Although it is expected the results of the research could be applied on a wider scale for all building components, the initial data, project gaps and starting requirements might differ between the components. Moreover, the research is performed under considerable time

and resource limitations (the research is performed by one student in the scope of the master thesis). Thus, it was considered not feasible to research the co-creation in the "whole" REHAB project. Circular extension was considered to be a suitable initial case, as the extension is a commonly placed renovation component and many housing associations encounter old extensions during energy renovation projects. The circular extension is going to be used in the Kuilsenhofweg project (renovation case at Eigen Haard), which consists of 60 dwellings.

4.3. Stakeholders

Identifying stakeholders provides insight into the system composition and resources of the involved actors. Understanding the influence and interests of the parties is one the first steps towards system restructure to get an understanding on how the system could be restructured to make it circular. The list of stakeholders was developed based on the analysis of project documentation and informal interviews with the representative of the contractor, see Table 3.

Table 3. Stakeholders having influence on the circular extension project.

Stakeholder	Role in the project/Type of organization
Eigen Haard	Housing association, project initiator
ERA Contour	Main contractor
DOOR architecten	Project architects
TU Delft	University – scientific advisor, circular economy advisor
Residents	The end users
Government	Legislative influence
Rob van den Oudenrijn	Timberframe manufacturer
Subcontractors (painter, roofer, carpenter)	Not yet established

4.4. Design of the circular extension

The preliminary design of the circular extension was developed in 2019 through the series of co-creation workshops with the stakeholders. Initially, there were five design prototypes, particularly: RECLAIM, BIO-EXTEND, RECYCLE ME!, B2B, PLUG-AND-PLAY.

The adopted final design combines the characteristics of several preliminary variants (mostly plug-and-play, reclaim and bio-extend). The extension system has been made modular and demountable at various levels. The walls, floors and roofs are made of standard sized modules, which are detachable and remountable. The modules are prefabricated. This allows for replacing only "parts" of the structure during maintenance or any future adjustments, and to reuse modules in other extensions, similar to "LEGO" blocks. Moreover, modular design allows for building

different extensions in varying sizes and purposes from the same base components (e.g. energy module, storage, temporary kitchen/bathroom, etc.). Modules can be further reused to build new extensions. Another important characteristic is that even the modules themselves are designed to be "modular". Parts of the modules are separated by the lifespan, what allows them to be easily customized (e.g. change finishing), and to repair and adjust parts with a short lifespan without "wasting" those with a longer one. Materials in the final design are also reused, low-impact, recyclable and biodegradable as much as possible. For example, windows that are installed in the extension are taken from the existing extension, insulation used in the project is produced from recycled cellulose, covering panels are made from recycled wood, used sheet material is "plywood", etc. Figure 8 shows the design of the wall module.

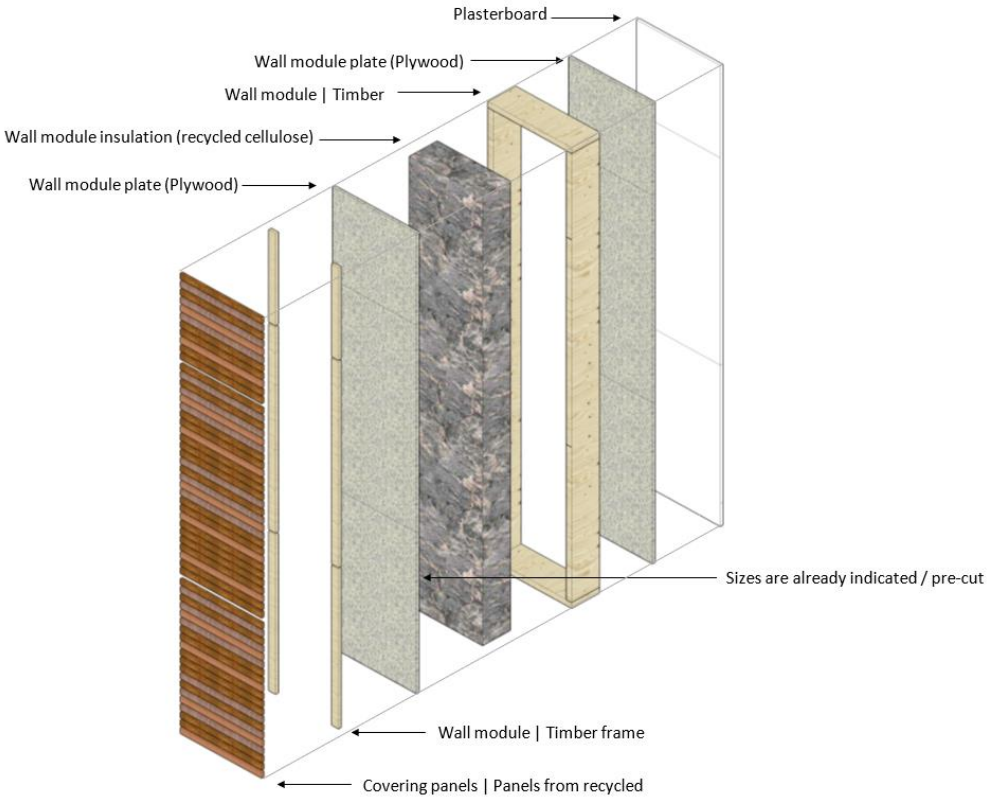

Figure 8. Design of the wall module (Stijn, 2019b)

4.5. Preliminary design of the business and supply chain models

One can say that co-creation activities are already part of this project. The design of the circular extension was developed throughout workshops with the partners. Further, the preliminary design of the business model and supply chain of the circular extension was adopted during the REHAB partner workshop, which took place on 16 October 2019. This section summarizes the results of this workshop. During the first part of this event, five variants for circular business models for circular building components were discussed, namely:

1) Green sale (or user oriented). The product is designed to be circular and sold to the housing owner. Other parties are not involved in what happens after completion of the project.
2) Buy and sell secondhand. In this model, the contractor sells the building components to the housing associations. After use, they can reuse and resell the modules, parts and materials in the secondhand marketplace. The building components need to have a high end value.
3) Sell and take-back. In this model, the contractor also sells the building components to the housing associations. However, here, after use, the contractor takes back and reuses modules parts and materials
4) Sell and buy-back. This model is similar to the previous one. The main difference is that the contractor buys back modules instead of just taking them back.
5) Component-as-a-service. In this model, the contractor leases the building component to the housing associations. The product becomes the service.

It was decided that the most desirable and feasible model is combination of several variants — 2, 3 and 4. This combination results in a "sale-and-and-and model". Model 4 was discussed in more detail, establishing possible types of buy-back agreements. It was concluded there are three options:

1. Buy-back price unknown up front.
2. Buy-back price known up front (e.g., deposit).
3. Buy-back prices known and discounted from the sale price (up-front buy back).

Several challenges of these models are that:

- Today, manufacturers would not agree to a buy-back arrangement.
- Models 2 and 4 might be sensitive to material speculation.
- For all the models its vital to document the components, particularly to make a component/material passport. It is also unclear who should be responsible for this.

The second part of the workshop focused on developing the supply chain variants for circular building components. Two of the three groups worked on the supply chain for circular extension. Correspondingly, they developed two supply chain models. The model of the first group was centered around the building component manufacturer or housing association. The model of the second group was centered around the contractor.

The adopted key findings and solutions are presented in more details as follows:

- Ideally, the component producer should arrange the re-loops as a service.
- It was discussed that it would be more efficient if the housing association bought the extension directly from the manufacturer instead of the contractor. Following this, they discussed whether the contractor should or should not be removed from the supply chain. However, it was concluded that currently housing associations are not ready to work without a contractor.

- The number of activities of the contractor might even increase.
- The role of the architect shifts to becoming part of the contractor or combiner of the building components.
- Another important finding is that to organize the circular loops it is necessary to shift from project thinking to component thinking.

4.6. Conclusion

Summing up, the circular extension case is used as a reference case for the mapping of co-creation process. Up to this moment, the design and preliminary supply chain and business models were already developed during the co-creation workshops and meetings. However, the stakeholders still did not decide which of the variants they will implement and what VRPs will be implemented. Considering that the design of the extension is finalized and the customer segment (housing associations) is identified, one could say that the value proposition in the project is complete. However, how value is created and captured still needs to be defined. Furthermore, stakeholders did not consider what will happen further, after the installation of the extension. They have some ideas, but not a concrete plan. The process maps that are introduced further, represent what steps they could expect and follow after the extension is installed and they need to design and implement the VRPs.

5. Second literature review. Literature review of co-creation models.

This section aims to answer the first sub-question of the research: *What should be included in the co-creation process map? First it defines the procedure of the literature review. Further, it presents the findings of the literature review, first defining the requirements for the co-creation process found in the literature and then the parameters of co-creation.*

5.1. Method

The search of the literature was performed using the Scopus database. The review was conducted in stages by reading abstracts first and making selections and then reading full-text articles before the final selection.

First, the search term was defined based on the goal of the review. Defining the search term required several iterations, as first attempts resulted in irrelevant search results (see the protocol of search term definition in Appendix A). The final search term became the following:

(TITLE ((co-creation OR collaboration) AND (model OR framework OR process* OR manag* OR "circular economy" OR strateg*)) AND KEY ("co-creation" OR "value co-creation")) AND (LIMIT-TO (LANGUAGE , "English"))

The search resulted in 360 articles out of which, after two choice iterations (first based on abstract reading and then on cursory reading), 31 articles that could be useful for the design of the model were selected. Based on the knowledge of co-creation gained during the preparation of the theoretical background of this research, the selection rules, presented below were formulated. Additionally the references of the selected articles were analyzed:

- An article was selected if it addressed co-creation in the built environment or other industries, except articles involving industries had substantial conflict with construction industry, these were:
    - IT, game development industry, “experience” co-creation, crowdfunding and tourism, as these articles address only the co-creation with the user (client). This was considered not relevant as this research studies co-creation in a multi-stakeholder environment.
    - Education and brand co-creation, as these articles look at co-creation from the perspective of a single organization (co-creation between students and staff, co-creation between employees of the firm).

The last step involved the qualitative analysis of the selected articles to arrive to at a list of requirements and parameters for the future model. Elaborating in more details, the aim of the analysis was to identify the:

1. Requirements of the circular co-creation process for circular extension
2. Parameters of co-creation (steps of co-creation, tools, resources, motives, etc.).
3. Options per parameters and partial solutions that can be directly applied in the design.

5.2. Findings

5.2.1. Requirements for the process maps

The requirements were developed based on the literature analyzed during the preparation of theoretical background and during the literature review of co-creation models, and interviews with the industry partners.

The first requirement of the co-creation process map for the development of VRPs of circular extension is drawn from the scope of the research:

> *The process map should support the co-creation process for the development of VRPs of circular extension*

Another "starting" requirement of circular co-creation was defined during the process of becoming familiar with the co-creation topic (see Section 3.6.2). Circular economy implies the design of the material loops which, in turn, requires involvement of the whole stakeholder network (Aminoff, Valkokari, & Kettunen, 2016). CE companies need to shift the focus from seeing themselves as isolated entities responsible only for their performance and their part of the project, to seeing themselves as part of a collaborative network and find possibilities to cooperate with other stakeholders (Aminoff, Valkokari, Antikainen, & Kettunen, 2017). Thus, when we speak about circular co-creation, we basically speak about a later block of co-creation literature that addresses the co-creation in the networks. Following this, the second requirement was formed:

> *Circular economy co-creation implies co-creation in the networks. Thus, the morphological scheme should be designed to deal primarily with the co-creation in networks.*

A circular economy covers the whole lifecycle of the product. Even the butterfly diagram developed by the Ellen MacArthur foundation can be brought back to a lifecycle perspective through the necessary flow of data and information (Stillitano, Spada, Iofrida, Falcone, & De Luca, 2021). This implies, that circular co-creation processes should encompass all stages of the co-creation process, defining all the necessary data (DeLosRíos-White, Roebeling, Valente, & Vaittinen, 2020).

> *The process map of the co-creation process of development of the VRPs of circular extension, should be based on the lifecycle perspective.*

VRPs are one of the key elements of implementation of a circular economy. The aim of co-creation in the development of VRPs is guaranteeing that material cycles will be upkept even after a long time period, because a circular product will not be circular anymore if the process is interrupted during one of the phases (development, realization and upkeep). This would result in the formation of the next requirement *"Stakeholders should be continuously involved in the process".* However, considering, that theory does not always match reality, and nobody can guarantee the involvement of the stakeholders throughout the whole process, so this requirement becomes questionable. We do not know whether parties will display the same responsibility and attitude in 5, 10 and/or 20 years or if the company is sold, whether the new owner will decide not to continue

the collaboration or some of the partners can go bankrupt, etc. The approach that allows for the upkeep of the process, even in the case of elimination of one of the parties, is knowledge transfer. Knowledge sharing and transfer is critical for circular economy transition (Atiku, 2020). Stakeholders should define in advance these mechanisms and prepare backup solutions to guarantee the process continuation.

> *Definition of mechanisms of knowledge transfer should be part of circular co-creation process.*

During the interviews, partners were asked about the parameters of the co-creation process and their view on the development of VRPs. The interview transcripts can be found in Appendices B and C. Based on the insights acquired during the interviews, analysis of the project and the results of the partner workshop (see Section 4.5) and considering the time limitation of the research, the following requirement was formed:

> *Should be developed three process maps, based on product as a service, sell and buy-back and user-oriented business models.*

Considering, that in different business models, changes the problem owner, another requirement was developed:

> *The process maps should be centered around manufacturer (1st variant), contractor (2nd variant) and housing association (3rd variant)*

The requirements for the process map identified in the literature and during the interviews are presented in Table 4.

Table 4. Requirements for the co-creation process model for the development of VRPs

Requirement	Requirement based on:
The process map should support the co-creation process for the development of VRPs of circular extension	Scope of research
The process maps should be based on network co-creation literature	Aminoff, Valkokari, & Kettunen (2016)
The process maps should be based on the lifecycle perspective	DeLosRíos-White, Roebeling, Valente, & Vaittinen (2020); Stillitano, Spada, Iofrida, Falcone, & De Luca (2021)
Definition of mechanisms of knowledge transfer should be part of circular co-creation process.	Atiku (2020)

Should be developed three process maps, based on product as a service, sell and buy-back and user-oriented business models.	Interview, partner workshop summary
The process maps should be centered around manufacturer (1st variant), contractor (2nd variant) and housing association (3rd variant)	Conclusion done based on the previous requirement

5.2.2. Parameters

5.2.2.1. Literature overview

During the literature review was found that co-creation process maps were not previously developed. Moreover, the majority of the available models stay on a very abstract level, describing the co-creation process in several blocks/steps (e.g. Mostafa, 2015; Payne, Storbacka, & Frow, 2007; Aminoff, Valkokari, & Kettunen, 2016; Durugbo, Riedel, & Pawar, 2011; etc.). However, this is the picture that we get addressing older sources. In last years were published several frameworks and models that could become the basis for the design of the co-creation process maps for circular extension. Although neither of them maps the process or can be used in isolation as the design basis, it was considered that their combination would provide the necessary basis for the design. The most used frameworks are presented as follows:

- Frow, Nenonen, Payne, & Storbacka (2015) propose a framework for the design of the co-creation process. However, this framework provides only general guidelines and sets the direction of the design. Moreover, it was designed primarily for the design of business-to-consumer co-creation and not specifically for use in the context of a circular economy. Thus, it cannot be used by itself for network co-creation in the context of the development of VRPs for a circular extension. It requires some restructure and extension.
- Kruger, Caiado, França, & Quelhas (2018) developed a co-creation model towards sustainability (see Figure 9). The model combines the disciplines of co-creation and sustainability involving the relevant factors and methodologies for the success of the co-creative activity for engaging stakeholders and contributing to sustainable development. Considering that circular economy concept is closely related to sustainability, it was considered a good choice to use it as a reference for the design. However, the model was designed for organizations of any nature and, thus, once again, it stays abstract so cannot be directly used as the solution for circular extension.

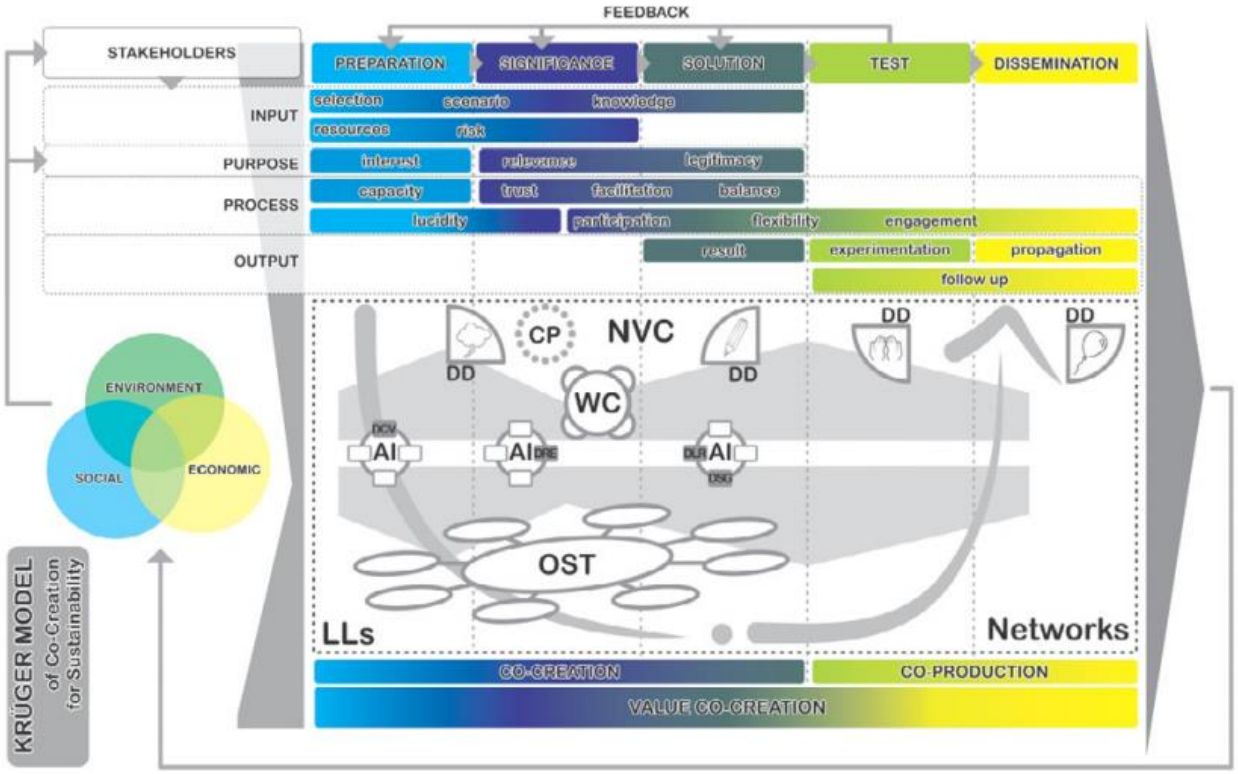

Figure 9. Kruger model of co-creation for sustainability (Kruger, Caiado, França, & Quelhas, 2018)

- DeLosRíos-White, Roebeling, Valente, & Vaittinen (2020) developed a co-creation model for urban climate change adaptation. In contrast to other models, this model shifts from being abstract to focus on co-creation design for a specific problem (See Figure 10). This model was used as the exemplary reference for the design of the co-creation "path", which became the basis of the process maps. Moreover, a valuable input of this article is the overview of methods and tools that can be used for the co-creation process.

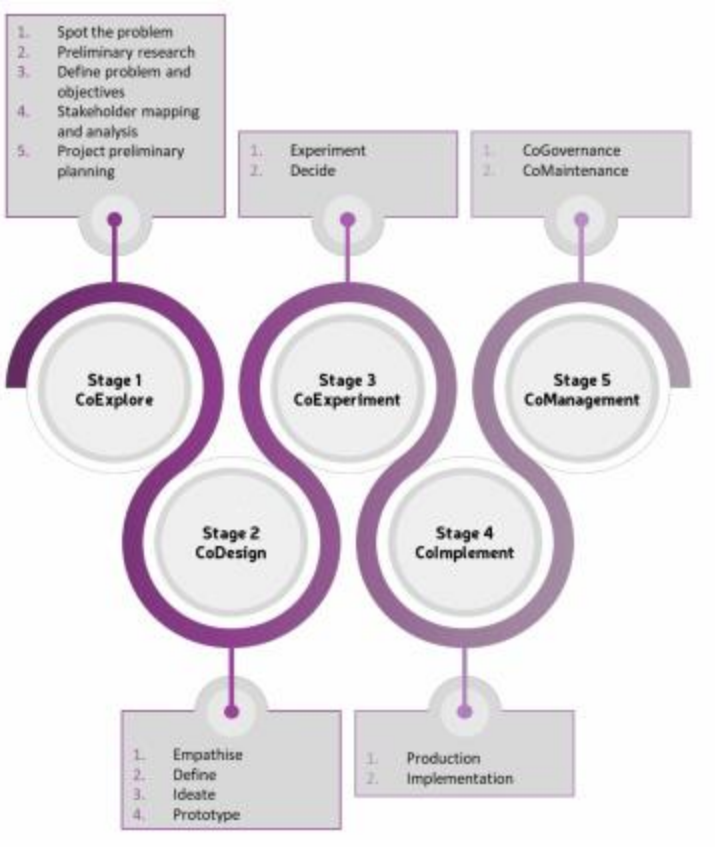

Figure 10. Life Cycle Co-Creation Process develop for urban and peri-urban ecosystem services development (DeLosRíos-White, Roebeling, Valente, & Vaittinen, 2020).

- Further, some other models and frameworks were used during the design of the morphological scheme of the final models. For example, Žlender, Erjavec, & Goličnik Marušić, 2020 developed a model for co-creation in urban planning projects, giving special attention to the information and communication technologies that could be used in the project (see Figure 11). This article provided input for the definition of tools that could be used. Loureiro, Romero, & Bilro (2020) study how to engage stakeholders in the co-creation process. Salvatierra (2020) study management of participation in the process.

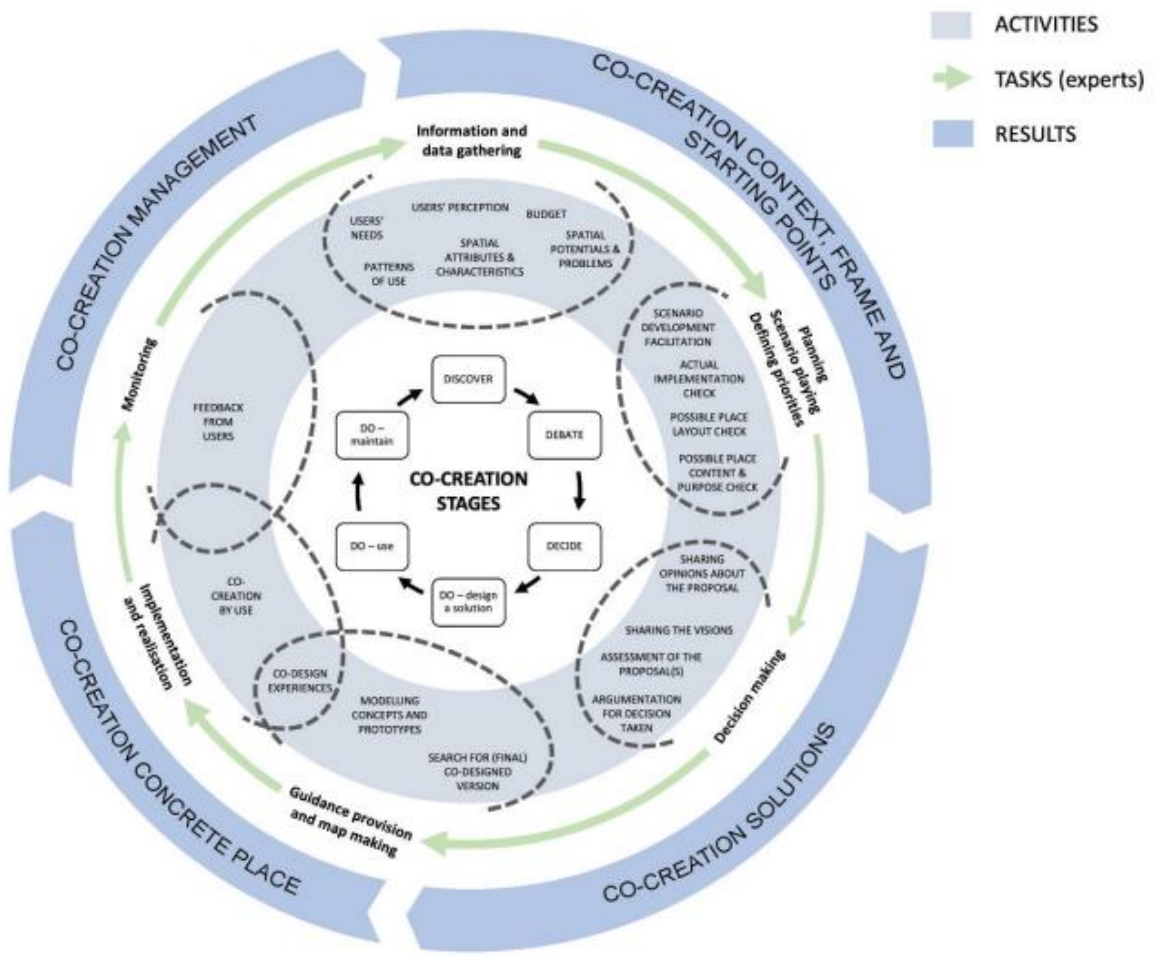

Figure 11. Co-creation stages, activities, tasks of actors and likely results, for co-creation during public open space development (Žlender, Erjavec, & Goličnik Marušić, 2020).

Summing up, it was found that by today, literature already provides the methodologies that could be used for the design of the co-creation process of circular extension. However, none of them can be used in isolation. Therefore, the available knowledge was combined to develop the morphological scheme of the co-creation process, based on which further were developed the co-creation process maps. The next section presents, in more detail, the parameters drawn from the articles and summarizes them in a morphological scheme presented in Table 5.

5.2.2.2. Design of the morphological scheme

Frow, Nenonen, Payne, & Storbacka (2015) developed one of the first frameworks that are based on the combination of available co-creation knowledge. Based on the literature review of co-creation they propose a matrix that helps to develop co-creation design. They identify six dimensions that should be defined during the design of the co-creation process, they are:

(1) co-creation motive,
(2) co-creation form,
(3) engaging actor,
(4) engagement platform,
(5) level of engagement and,
(6) duration of engagement.

These dimensions became the first building blocks of the morphological scheme, they are presented in the columns 1-6 of the morphological scheme. Considering that they constitute around half of the presented parameters, one could say that the developed morphological scheme is an extension of the framework of Frow, Nenonen, Payne, & Storbacka (2015), that includes the advances of the more recent literature and parameters that were considered necessary for circular co-creation as follows:

(1) The starting point of the firm developing the co-creation process is the identification of organizational motive(s) (column 1, table #) for engaging in co-creation activities, as it drives other design aspects.
(2) Following the framework of Frow, Nenonen, Payne, & Storbacka (2015), another parameter that needs to be defined among the first is identification of what forms the co-creation is taking (column 2, table 5) in the process and duration of this process.
(3) Another parameter that should be defined is the "engaging actor" (column 3, table 5). Other literature sources call it, for example, the project facilitator (Lambert & Enz, 2012). However, the meaning stays the same. This is the leading actor, who focuses on a co-creation solution and oversees the process and relevant actors. In many cases it is very clear who it is, as companies organize the co-creation process by themselves and the process itself involves only a limited number of actors (e.g. Ren, Liu, & Liu, 2012; Dollinger & Lodge, 2019).
(4) Engagement platform (column 4, table 5) refers to the technical or physical platforms that enable parties to share their resources and develop solutions.
(5) Level of engagement (column 5, table 5) refers to the identification of the degree of consumer engagement and is subdivided into three types: emotional (when the actor cognitively acknowledges and provides their resources to the lead actor), cognitive (when the actor cognitively acknowledges and provides their resources to the lead actor) and behavioral (when, given a specific frame of reference, the actor changes their behavior because of the lead actor's offering).

(6) Three types of duration of engagement are identified (column 6, table 5): one-off, recurring and continuous

Considering, that the success on the network level does not necessarily mean success for every part of the network, it is important for the stakeholders to have a clear understanding of the types of outcomes that could be achieved. Reypens, Lievens, & Blazevic (2016) identify six types of outcomes of the co-creation implication. The types of outcomes are presented in the column 7 of the morphological scheme, they are: Innovation outcomes, Knowledge outcomes, Relational outcomes, Internal processes development, Knowledge development, Network position.

Loureiro, Romero, & Bilro (2020) argue that identification of the factors that could stimulate stakeholder engagement is crucial for the co-creation process. They divide them into three categories, which are represented in the column 8 of the morphological scheme:

1. Stakeholder-based factors: leadership style, cohesion, empowerment, attitudes, identification, goals, individual traits.
2. Firm-based factors: organizational culture, capabilities, resources, interactive platforms, crowdsourcing, marketing tools.
3. Context-based factors: politics, economics, social, technology, competition.

A large number of co-creation engagement tools and methods have been developed to date. However, as well as with co-creation in general, these tools were developed and described mostly for the specific stages/forms of the co-creation process. Considering that the co-creation tools is an inseparable part of the co-creation process, another parameter was added to the morphological scheme. DeLosRíos-White, Roebeling, Valente, & Vaittinen (2020) introduce available toolkits and provide an example of tools allocation for each step of the process. Additionally, Žlender, Erjavec, & Goličnik Marušić (2020) allocate the available ICT tools per stages/phases of the co-creation process. This parameter is presented in the column 9.

Kruger, Caiado, França, & Quelhas (2018) highlight the importance of the co-creation of communication materials and propagation of the developed knowledge for co-creation in sustainability. Authors call this phase “dissemination”. As it was defined in the theoretical background, implementation of circular economy in construction can be considered sustainable innovation. Therefore, in the case of the co-creation of VRPs of circular extension, we should include the definition of the mechanisms of knowledge transfer. Moreover, a circular product will not be circular anymore if, after 10 – 20 years (for the case of circular building components), no one takes care of it. This implies that the parameter “knowledge transfer” gets two options that need to be developed and they are included in the morphological scheme. These options are: “beyond the project duration knowledge transfer (facilitate learning)” and “knowledge transfer mechanisms to guarantee the upkeep of the process”.

Considering that the next step of the research was design of the co-creation process maps of circular extension, some of the available co-creation models were also included in the morphological scheme under column 11. Some of these models were presented above.

These models were used as the design references. Additionally, table 6 represents each parameter and source from which this parameter was drawn. Table 7 represents the steps of the chosen reference models.

Table 5. Morphological scheme of co-creation process design.

	Parameters										
Options	1	2	3	4	5	6	7	8	9	10	11
	Co-creation motive	Co-creation form	Engaging actor	Engagement platform type	Level of engagement	Duration of engagement	Types of outcomes	Factors influencing stakeholder engagement	Co-creation toolkits	Knowledge transfer	Co-creation models (as references for the design)
	Access to resources	Co-conception of ideas	Focal firm	Digital application	Cognitive	One-off	Innovation outcomes	Stakeholder-based: leaderships style, cohesion, empowerment, attitudes, identification, goals, individual traits	Žlender, Erjavec, & Goličnik Marušić (2020) – ICT tools	Beyond the project duration knowledge transfer (facilitate learning)	Žlender, Erjavec, & Goličnik Marušić (2020)
	Enhance customer experience	Co-design	Customer	Tool or product	Emotional	Recurring	Knowledge outcomes	Firm-based: organizational culture, capabilities, resources, interactive platforms, crowdsourcing, marketing tools	U4IoT. User engagement toolkit	Knowledge transfer mechanisms to guarantee the continuation of the process	Kruger, Caiado, França, & Quelhas (2018)
	Create customer commitment	Co-production	Supplier	Physical resources, spaces/events	Behavioral	Continuous	Relational outcomes	Context based: economics, social, technology, competition	UNaLab. UNaLab Co-Creation Toolkit. 2020		Ehlen, van der Klink, Stoffers, & Boshuizen, (2017)
	Enable self-service	Co-promotion	Partner	Joint processes			Internal processes development		MindTools. Management Training and Leadership Training		Lambert & Enz (2012)
	Create more competitive offerings	Co-pricing	Competitor	Personnel groups			Knowledge development		Tassi, R. Service Design Tools (2009)		Dollinger & Lodge (2019)
	Decrease costs	Co-distribution	Influencer				Network position				Amenta et al. (2019)
	Faster time to market	Co-consumption									DeLosRíos-White, Roebeling, Valente, & Vaittinen (2020)
	Emergent strategy	Co-maintenance									
	Build brand awareness	Co-outsourcing									
		Co-disposal									
		Co-experience									
		Co-meaning creation									

Table 6. Parameters of co-creation and sources from which they are drawn

Parameter	Source
Co-creation motive	Frow, Nenonen, Payne, & Storbacka (2015)
Co-creation form	Frow, Nenonen, Payne, & Storbacka (2015)
Engaging actor	Frow, Nenonen, Payne, & Storbacka (2015)
Engagement platform type	Frow, Nenonen, Payne, & Storbacka (2015)
Level of engagement	Frow, Nenonen, Payne, & Storbacka (2015)
Duration of engagement	Frow, Nenonen, Payne, & Storbacka (2015)
Types of outcomes	Reypens, Lievens, & Blazevic (2016)
Factors influencing stakeholder engagement	Loureiro, Romero, & Bilro (2020)
Co-creation toolkits	DeLosRíos-White, Roebeling, Valente, & Vaittinen (2020)
Knowledge transfer	Kruger, Caiado, França, & Quelhas (2018)
Co-creation models (as references for the design)	See Table 7

Table 7. Reference designs and their steps.

#	Co-creation model/framework	Steps in the model	Relevant for the design parts/pieces
1	Žlender, Erjavec, & Goličnik Marušić (2020)	Six step cyclical model: Discover; Debate; Decide; Do – design a solution; Do-use; Do-maintain;	Structure, steps, activities and tasks identification
2	Kruger, Caiado, França, & Quelhas (2018)	Five step model: Preparation; Significance; Solution; Test; Dissemination	Structure, steps, activities per step identification, co-creation platforms mapping, "dissemination" (knowledge transfer) step

3	Ehlen, van der Klink, Stoffers, & Boshuizen, (2017)	Four dimension cyclical model: Construction; Relation and emotion; Expertise; Action	Steps, co-creation enablers mapping
4	Lambert & Enz (2012)	Six step model: Assess companies drivers; Align expectations; Develop action plan; Develop product and service agreement; Review performance; Periodically reexamine drivers	Structure, steps, activities identification, detailed definition of co-creation meetings process
5	Dollinger & Lodge (2019)	Three step model defining inputs, processes and outcomes	Inputs and outcomes mapping, activities definition (as exemplary design, as the content is not suitable for case of CBE)
6	Amenta et al. (2019)	Five step model: Co-exploring; Co-design; Co-production; Co-decision; Co-governance	Steps, structure
7	DeLosRíos-White, Roebeling, Valente, & Vaittinen (2020)	Five step model: CoExplore, CoDesign, CoExperiment, CoImplement, CoManagement	Structure, steps, mapping of the activities per step, co-creation path, definition of methodologies per step

6. Design synthesis

This section aims to answer the third sub-question of the research: How the co-creation maps could look? It describes the design process and presents the steps of the design process. Iterating design for different business and supply chain models were developed in three process maps: product as a service, sell and buy-back user oriented. Additionally, for the product as a service and sell and buy-back process maps was assumed that current stakeholders are willing to further co-create and for the user-oriented design variant it was assumed that they are not willing to further co-create. First, the co-creation steps were defined (first layer of the process map). The co-creation steps stay the same for all three design variants. Further, based on the co-creation steps, the co-creation path was developed (second layer of the process map). The co-creation path also stays almost the same for all models, with some small iterations. Further, based on the chosen business/supply chain model, options and/or best solutions for each block of the co-creation path were identified and mapped (third layer of the process map). It is recommended to read this section looking at the developed process maps.

6.1. Design of the co-creation phases (First layer of the process map)

Based on the developed morphological scheme and co-creation models design examples, first, the phases of the co-creation process of circular extension were identified.

Considering that the desired process maps should be based on the lifecycle perspective, to define the phases of the co-creation process it was decided to use an approach similar to other scholars that developed their co-creation models based on the lifecycle perspective (e.g. Amenta et al., 2019; DeLosRíos-White, Roebeling, Valente, & Vaittinen, 2020; etc.). Namely, the studied process (development of VRPs of circular extension) was reviewed from the process perspective. Building on the process design approach of Kolfschoten & de Vreede (2009) and analyzing the current system from the process point of view, the development of the VRPs can be subdivided into five main phases:

1. Conceptualization/task diagnosis (identification of the needs).
2. Process design.
3. Implementation,
4. Upkeep and actual re-looping,
5. Rearrangement of the network/transfer of responsibilities (in case if one of the parties cannot be part of the process anymore).

Designing the co-creation process, the author assumed that co-creation will be continued throughout the whole process as it is suggested by the literature discussing circular economy transition. Although during the later phases of the process, co-creation could be more limited, the parties could still keep their relationships and, if needed, solve the problems together. Therefore, to show that co-creation is kept through the whole process, the main phases of the development of the VRPs were merged with the existing co-creation forms (column 2, table 5), and what resulted is the following phases of the process maps:

- Conceptualization
- Process design
- Implementation
- Upkeep and actual re-looping
- Rearrangement of the network/transfer of responsibilities

- Co-conception
- Co-design
- Co-production
- Co-maintenance
- Co-disposal*

*Originally, co-disposal was defined as the joint recycling of products and materials. In contrast, in the case of the development of VRPs for the co-creation process, the meaning changes to the phase in which one of the parties cannot be part of the process anymore. Moreover, further in the design, it helps to show the process iteration loops (or feedback loops) that could take place.

Additionally, considering that in the case of a circular extension, it is unclear which business model will be implemented, so one more phase was included: engaging actor. Engaging actor is one of the parameters included in the morphological scheme (column 3, table 5). The party that should take the role of the engaging actor changes depending on the applied business model.

Combining the defined phases into one structure was developed in the following representation (Figure 12).

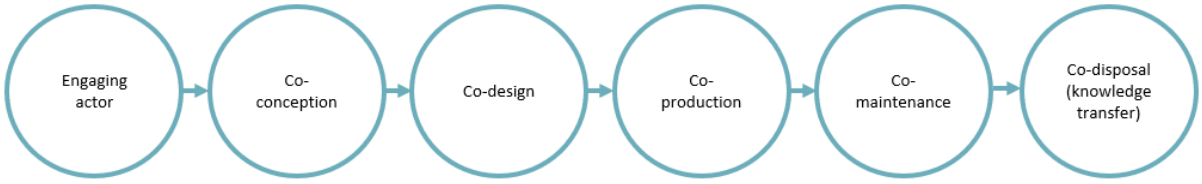

Figure 12. Phases of co-creation process for the development of VRPs of circular extension

Further, the co-creation process is reviewed from the perspective of each phase of the process defining what each phase includes and allocating other parameters, what results in the drawing of a co-creation path and mapping of the options of the co-creation process.

6.2. Mapping the co-creation path and options/activities of the sub-steps (second and third layers of the process map)

The idea of the co-creation path was drawn from the Life Cycle Co-creation Process model of DeLosRíos-White, Roebeling, Valente, & Vaittinen (2020). The co-creation path steps (or the sub-steps of the co-creation phases) are largely inspired by the models of DeLosRíos-White, Roebeling, Valente, & Vaittinen (2020); Kruger, Caiado, França, & Quelhas (2018) and Žlender, Erjavec, & Goličnik Marušić (2020) which, in turn, are based on PDCA (Plan-Do-Check-Act) cycle and Design Thinking methodology.

During the design of the process maps, multiple attempts were made to develop the structure. First variants were very chaotic, for example one of them you can see in Figure 13.

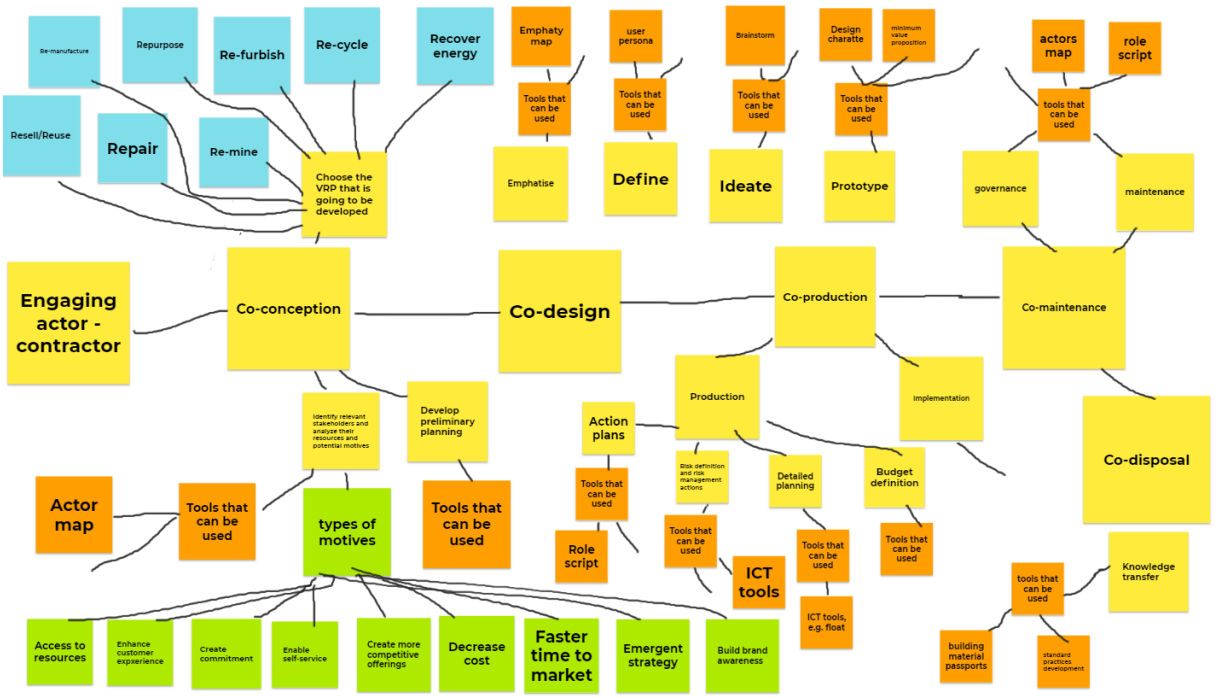

Figure 13. First attempts to structure the available information.

Next, attempts were made to develop a linear structure to show each step of the process; however, it resulted in a very long map, which was not a good representation. During later attempts, a cyclical structure was developed similar to the model of Žlender, Erjavec, & Goličnik Marušić (2020) (see Figure 11). However, mapping the options around this cycle resulted in an unreadable piece, because it was unclear where the start and finish were, also options overlapped each other. Finally, at some point the author's eyes stopped on the word "path". DeLosRíos-White, Roebeling, Valente, & Vaittinen (2020) describe the co-creation path that stakeholders participating in a public space development project could follow. However, in the author's opinion, in fact, they do not develop a "path", they developed a list or a checklist (although all the steps follow each other) of what should be included in the co-creation process. Thinking about how a "path" could look like and spending an indefinite amount of time on Pinterest, a structure was developed and that became the basis for the final design of the process maps. The co-creation phases were integrated into one route, mapping stakeholders, activities and options, and creating a route that cascades the stakeholders through the steps that they could follow to develop the VRPs of circular extension. Figure 14 represents the developed co-creation path. The picture is inserted to provide an understanding of what the co-creation path is. For a higher quality resolution see Appendix H or the final designs of the process map (Appendices I, J, and K)

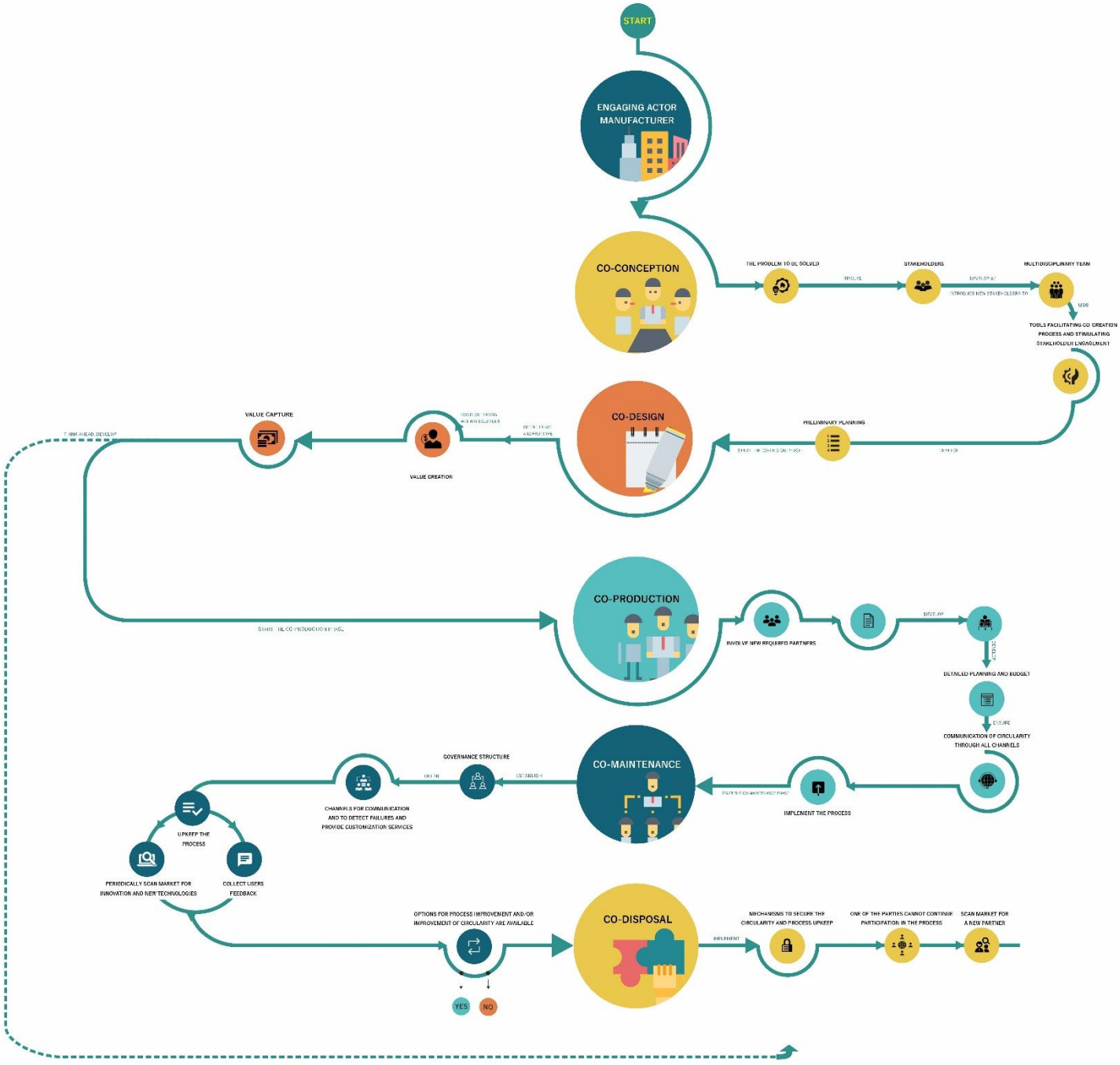

Figure 14. Co-creation path

6.2.1. Engaging actor definition

In line with the identified requirements, three process maps were developed, based on three business models: product as a service; sell and buy-back; user oriented; and assumptions about stakeholders' willingness to continue co-creation.

Product as a service

This design variant is based on a product as a service business model. It is also assumed that current stakeholders are willing to further co-create. Considering that this business model is centered around the manufacturer, they become the problem owner and keep ownership of the product, leasing it directly to housing associations.

Sell and buy-back

This design variant is based on a sell and buy-back business model. As well as with the previous scenario, it is also assumed that current stakeholders are willing to further co-create. In this scenario, the contractor buys the extension from the manufacturer and sells it to the housing association together with services. One could say that the contractor becomes the system enabler, because it functions due to the contractor's actions. Therefore, it was decided that in this case the contractor will be mapped as the engaging actor, because they are the one taking the role of a bridge that connects all value chain partners.

User oriented

This design variant is based on a user-oriented business model. Opposite to previous scenarios, it is assumed that current stakeholders are no longer willing to further co-create. Considering that in this case the housing association becomes the problem owner and needs to find new partners for the installation and maintenance of the circular extension, as well as partners that ready to work on the development of secondhand markets, it was mapped as the engaging actor.

6.2.2. Co-conception

Further, each subsection presents how the elements of the co-creation path were developed and how the options and activities were mapped.

6.2.2.1. Development of co-creation path

This phase is similar to co-explore step of DeLosRíos-White, Roebeling, Valente, & Vaittinen (2020), preparation step of Kruger, Caiado, França, & Quelhas (2018) and discover step of Žlender, Erjavec, & Goličnik Marušić (2020).

After the leading actor is defined, the preparatory phase of the process starts. This phase represents the initial preparation done prior to co-designing the solution. This includes identification of the problem and sub-problems that need to be solved and selection of the relevant stakeholders, as well as assessment of their willingness to co-create. Further, the identified stakeholders should be involved, and a multidisciplinary team developed. Comparing to the "traditional" approach instead of development of a list of requirements and hiring project

executors, in co-creation process is developed a team with a common goal, that works together to achieve it. Additionally, this phase also includes the identification of tools that will be used further throughout the co-creation process to promote the stakeholder engagement and achieve management goals. Finally, parties develop preliminary planning and proceed to the next step. This step helps the engaging actor to integrate the stakeholders' resources, which helps to achieve success in the co-creation process. Summing up, this phase begins with spotting of the problem and ends with a developed team ready to design a solution. Based on the process outline of this phase, it was subdivided into the following sub-steps:

(1) Problem definition
(2) Stakeholder identification
(3) Development of multidisciplinary team
(4) Identification of tools for co-creation
(5) Preliminary planning development.

The option and activities of each sub-step are presented in the following section.

All the reference models also include a sub-step dedicated to the preliminary research of the problem; however, it is not included for the case of circular extension, as the problem has been largely identified and, during the development of the design of the circular extension, parties already acquired knowledge about the topic.

6.2.2.2. Mapping options/activities of the sub-steps

(1) Problem definition.

The problem has been largely identified as:

- Development of VRPs of the circular extension.

This problem could be subdivided into a number of objectives, for example:

- Decide what VRPs will be implemented for circular extension.
- Focus on finding win-win solutions for all the parties involved.
- Develop guidelines for the involved parties.

(2) Stakeholder identification

Identification of the stakeholders provides the engaging actor understanding of who should be involved in the co-creation process. This helps to more effectively integrate the partners resources. In the case of circular extension, there is already the existing network; however, from the perspective of development and implementation of VRPs several new parties could be involved. Further are listed the stakeholders for each design variant.

Product as a service and sell and buy-back design variants

Current stakeholders were identified during the study of the project (see Section 4), they are:

- Housing association

- Manufacturer
- Architect
- Contractor
- Scientific advisor
- Residents.

During the interviews it was found that the contractor considers that it would be reasonable to also involve a recycling advisor/consultant to identify how the materials used in the extension could be recycled; and subcontractors could use their knowledge about the maintenance of the buildings. Additionally, co-creation literature suggests involving a human interaction specialist (e.g. DeLosRíos-White, Roebeling, Valente, & Vaittinen, 2020) as it would stimulate stakeholders' engagement in the process; and CBM literature suggests involving raw material suppliers (Lüdeke-Freund, Gold, & Bocken, 2018) because their knowledge about the material could provide new insights and help develop new circular opportunities. Summing up, other potential stakeholders include the following:

- Recycling advisor/consultant
- Subcontractors
- Human interaction specialist
- Raw material suppliers.

User oriented design variant

In this scenario current stakeholders do not take part in the process of VRP development. Therefore, the housing association needs to find a new contractor(s) for the installation and maintenance (VRPs implementation) of the circular extension. Moreover, the user-oriented business model also includes development of secondhand market(s). The housing association needs to find partner(s) that will be able to take this role. Based on the existing design examples of CE systems it is assumed this role could be taken on by material suppliers or waste management operators (based on Ranta, Aarikka-Stenroos, & Mäkinen, 2018). Additionally, similar to the other design variants, a human interaction specialist could be involved in this case. However, considering the much lower number of co-creating parties it is not necessarily needed.

(3) Development of multidisciplinary team

This sub-step does not include/require a list of options.

(4) Identification of tools for co-creation

Co-creation tools facilitate the co-creation process and stimulate stakeholder engagement. These tools help to structure the process and rise efficiency of communication. Therefore, it was decided to include this sub-step in the process maps. If a human interaction specialist is involved, they oversee the co-creation process and defines what tools and when they should be used. It is suggested to use the available toolkits during the co-conception and co-design phases (U4IoT. User

engagement toolkit; UNaLab Co-Creation Toolkit; MindTools. Management Training and Leadership Training; Tassi, R. Service Design Tools, 2009).

For example, to list a few possible options, digital tools stakeholders could use include cloud storage; planning support systems; tools for online discussions; interactive sites for customer involvement; electronic mail; newsgroups; etc.

Listing the physical tools, could include workshops; brainstorming; actors' map; walls of ideas; task analysis grid; role scripts.

(5) Preliminary planning development

The last sub-step is similar to what would be done in any traditional project. During the first co-creation sessions parties develop preliminary planning that supports the whole process. It provides a concrete plan that the parties could follow, so they know what to expect during their meetings.

Summing up, the co-conception phase designs are very similar for all three process maps. The only difference between them lies in stakeholder composition. Figure 15 shows the design of this phase for product as a service and sell and buy-back variants. Figure 16 shows the design of this phase for the user-oriented variant. The result of this phase is a team ready to start the development of a solution, having a plan of their meetings and activities, and knowing what tools they could use to accelerate the process.

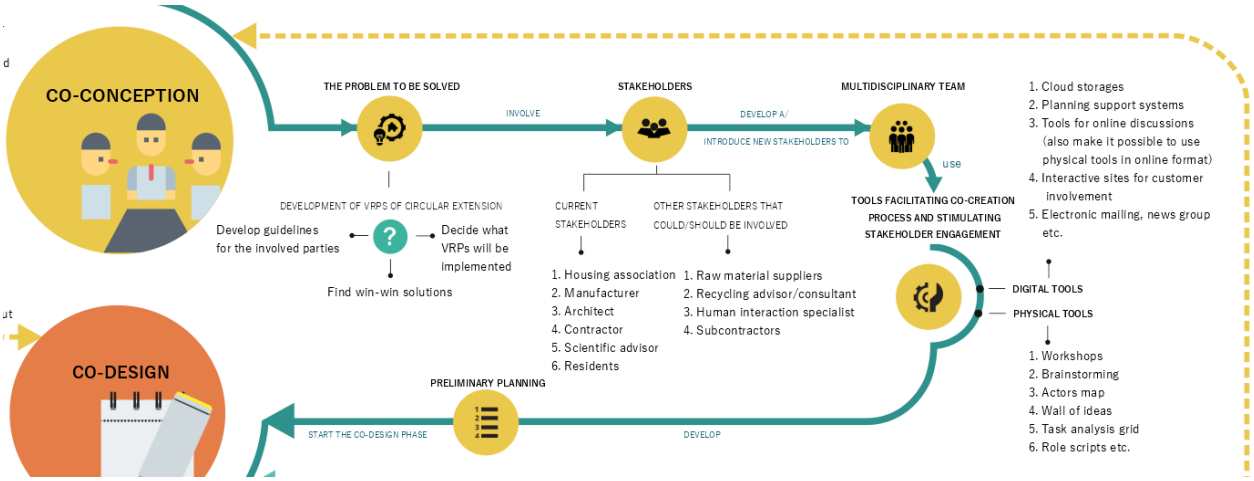

Figure 15. Co-conception phase in product as a service and sell and buy-back design variants

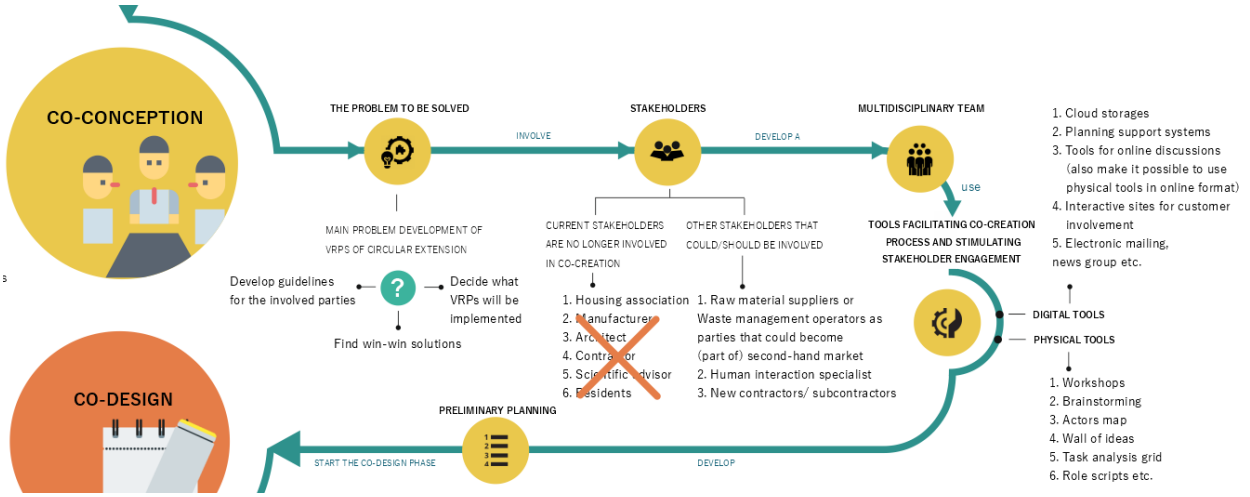

Figure 16. Co-conception phase in user oriented design variant

6.2.3. Co-design

6.2.3.1. Development of co-creation path

This phase encompasses co-designing a solution. This phase is similar to the co-design step of DeLosRíos-White, Roebeling, Valente, & Vaittinen (2020), solution step of Kruger, Caiado, França, & Quelhas (2018) and debate, decide, do-design a solution steps of Žlender, Erjavec, & Goličnik Marušić (2020). In the reference models this phase is designed referring to the Design Thinking methodology. It is proposed to use the same method but comparing them to reference models that stay on the abstract level. The process maps show what solution could be developed and how it would look.

In the co-design phase the team developed during the co-conception phase starts developing solution and tries to find win-win-win scenarios. This process significantly differs from the traditional approach, in which solution would be developed in isolation by the architect (in DBB) or contractor (in DB), based on the requirements of the client. Team members should share their knowledge and experience to develop a solution that goes beyond that they would be able to create by themselves. To draw the design of this phase, first we need to answer the question: what do we develop? The current main project gap is the development of VRPs, and the process maps of co-creation were drawn primarily to resolve this issue. VRPs are part of the business model and, if we speak more precisely, it is part of the value capture and delivery component of the business model (based on Lüdeke-Freund, Gold, & Bocken, 2018). However, for the full development and implementation of the VRPs, not only the definition of sub-components of value creation and delivery is required, but the finalization of the design of the whole business model. Therefore, it was decided that co-design phase should aim primarily on the finalization of the business model of circular extension. One could say that by today, the dimension of value proposition has been already developed by the stakeholders during previous workshops and product design. The proposed product is a circular, modular and mass-customizable extension that could embed services of customization and upgrade (see Section 4). Target customers are housing associations

that need to renovate their properties. Therefore, the co-design phase should include the definition, ideation and prototyping* of sub-components (see Section 3.3) of (1) value creation and delivery mechanisms, and (2) value capture. This phase ends with a fully developed business model, accepted by the stakeholders. Further is presented what options were identified for mapping of the sub-components.

**The Design Thinking methodology also includes steps to understand the problem (empathizing) and testing of the developed solution. However, in the case of circular extension, the parties already acquired understanding of the problem; therefore, this sub-step (empathizing) is not included in the final design. The short-term testing of the developed solution is impossible as the implementation requires heavy financial expense and the actual implementation of VRPs takes place after a long time. Therefore, the testing is not included in the co-design phase; however, considering that the solution will be tested in place, the necessity to adapt the solution is shown through the feedback loops/process iteration loops that happen during the later co-creation steps.*

6.2.3.2. Mapping options/activities of the sub-steps

(1) Value creation

For value creation, the key activities and channels for the product and services were mapped. The additional value is created through the circular design of the product (which also enables the implementation of services [VRPs]). Here, the key activity that stakeholders could do is further research the possibility of using recycled materials for the manufacturing of the circular extension because it further contributes to the goal of reducing the use of raw materials. The content of this block is similar for all the designs and is presented in Figure 17.

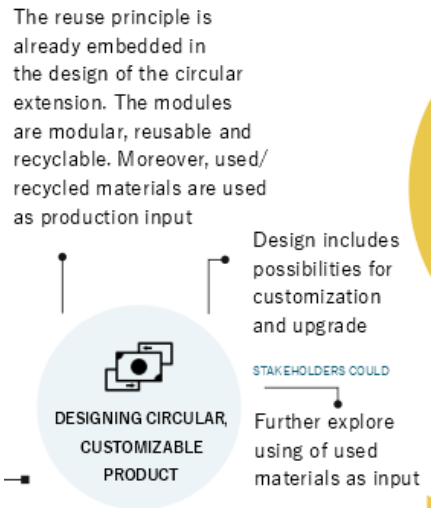

Figure 17. Value created through the product

To map the key activities and channels for the services, was decided to develop VRPs blocks for each design variant, which would show the links between actors and VRPs. The content of these blocks is based on the dissertation about VRPs by Russell (2018), mainly using the descriptive summaries of arranging reuse, repair, refurbishment and remanufacturing processes as the input

(see Figures 18, 19, 20, 21); and supply chain models developed by (Săceanu, 2021). Additionally, the ideas and concepts drawn during the study of circular business models' implementation are mapped.

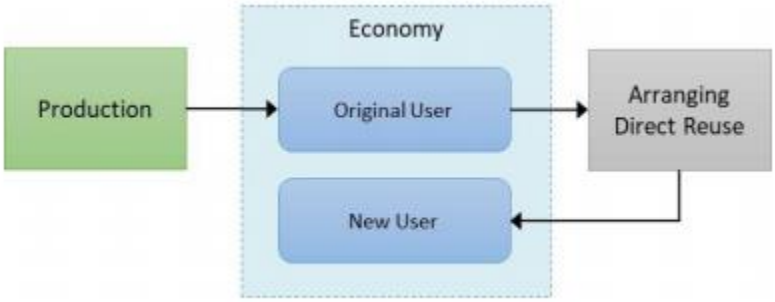

Figure 18. Descriptive summary of reuse process (Russell, 2018)

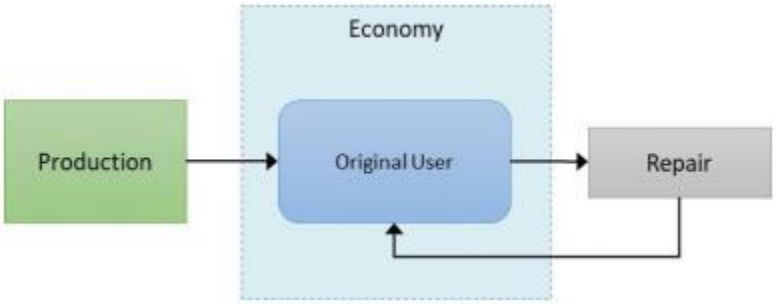

Figure 19. Descriptive summary of repair process (Russell, 2018)

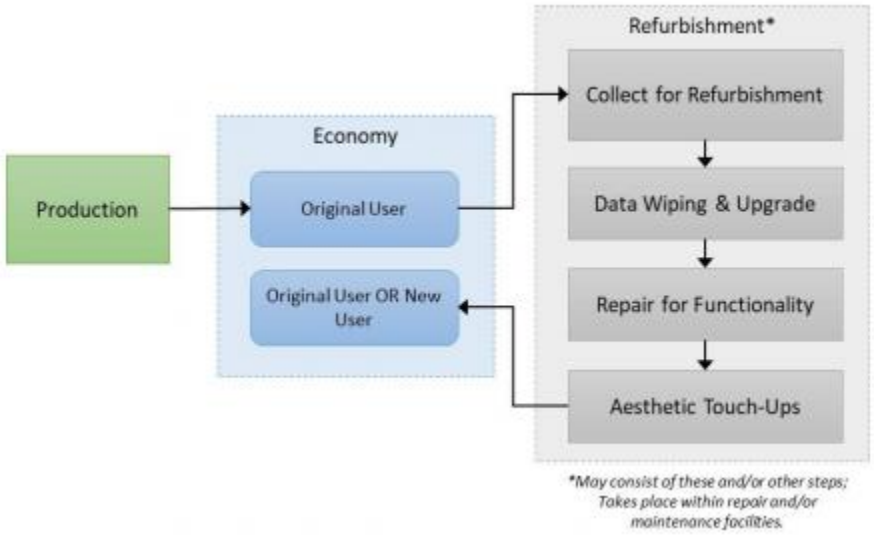

Figure 20. Descriptive summary of refurbishment process (Russell, 2018)

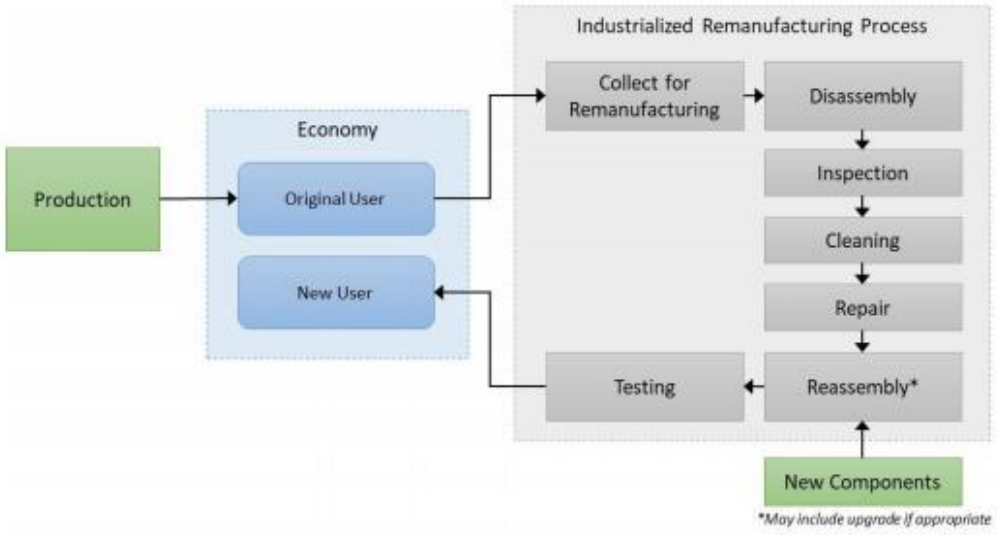

Figure 21. Descriptive summary of remanufacturing process (Russell, 2018)

Product as a service design variant

For the product as a service design variant the reuse, repair, refurbish, remanufacture and recycling processes were mapped.

- Reuse involves the direct reuse of the circular extension and is not further elaborated.
- For repair, based on the origins of the co-creation literature (meaning co-creation with the end user), it is proposed to involve customers in the repair. This would require development of incentive schemes as well as the development of customer education schemes and/or repair guidelines. Another option is to outsource the repair of the extension to the current contractor.
- The refurbishment process requires development of refurbishment scenarios (this should be done using a bill of materials breakdown, data on the lifetime of the materials and experience of the parties and industry). Further, depending on the developed scenarios, refurbishment could be also outsourced to the current contractor (if the refurbishment could be done on site) or kept in-house (if the refurbishment will require the collection of the extension).
- For the remanufacture process, remanufacturing scenarios need to be developed based on identifying what infrastructure is required to implement this process.
- The recycling process requires further research about the possibility of recycling the used materials and identification of the partners that would buy/accept the materials (another option is vertical integration and the development of in-house recycling facilities. However, considering the complexity of this task and expenditure linked to this task, it was considered not feasible and was not included in the process map). As was mentioned before, this is recommended to be done in collaboration with a recycling consultant. Figure 22 represents the developed VRPs block.

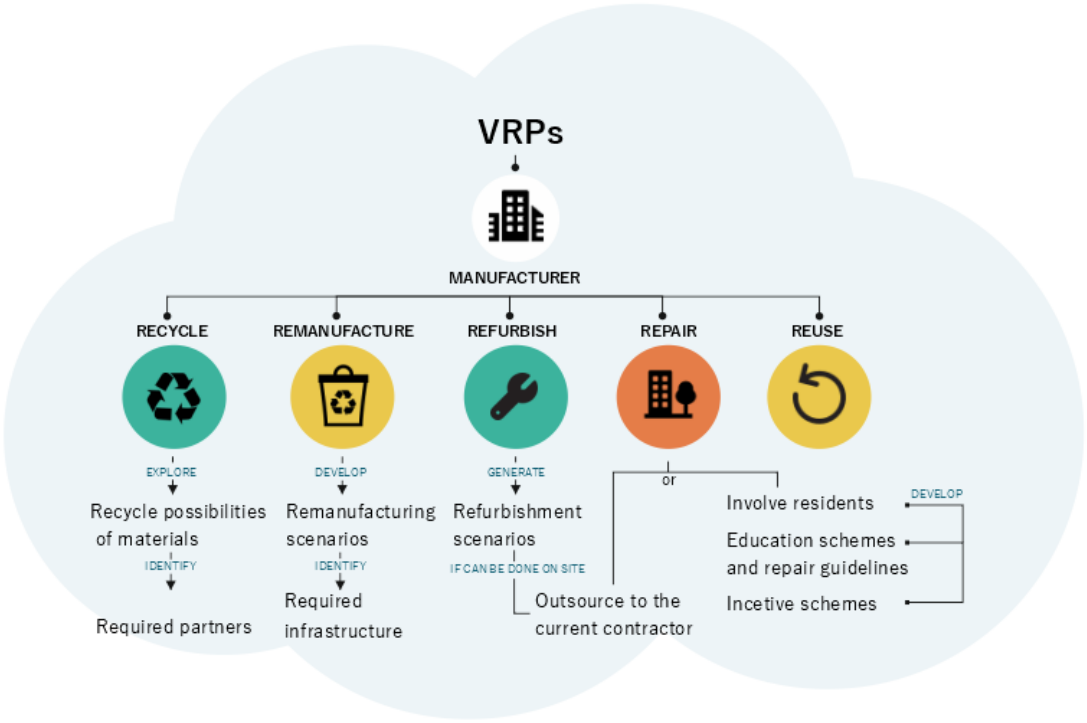

Figure 22. VRPs block in product as a service design variant.

Using the experience of other industries and considering that in this scenario, the manufacturer oversees the whole process and keeps ownership of the product, it is also recommended to develop a "value realization cascade" to maximize the value captured during the cascading of materials through the loops (based on Hopkinson, De Angelis, & Zils, 2020). A generic structure of the value realization cascade (Figure 23) was developed and is represented above the VRPs block (based on Hopkinson, De Angelis, & Zils, 2020 and Russell, 2018).

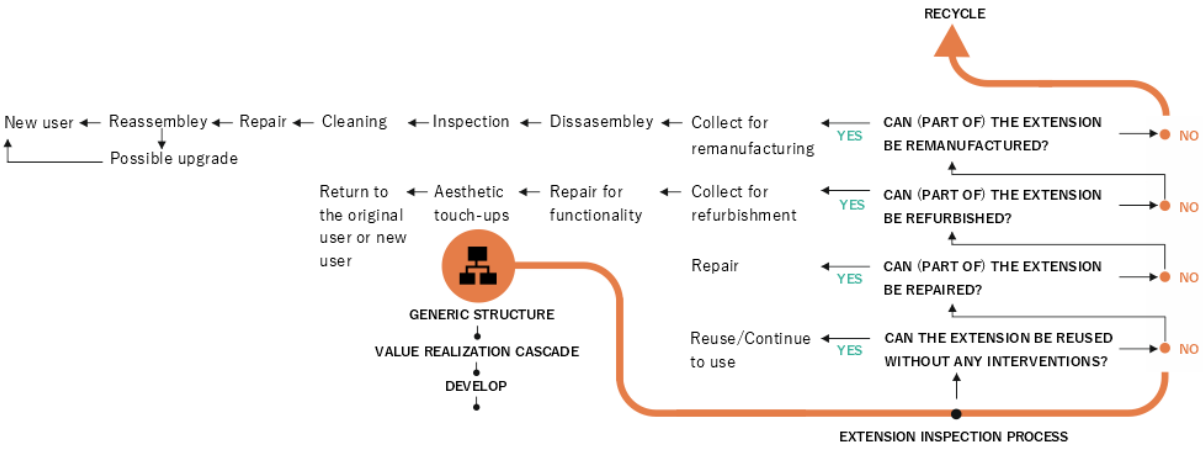

Figure 23. Generic structure of Value realization cascade.

Sell and buy-back design variant

Compared to the previous scenario, the sell and buy-back variant has no single party that oversees the whole process. Therefore, in this case, the VRPs block represents the processes and relationships between the parties involved (Figure 24). The contractor's role switches to being the system enabler, linking the value chain partners. Parties (manufacturer, contractor and housing association) form a trilateral take-back agreement to securing the product's value. The contractor takes responsibility for the repair and refurbishment process and, when the extension reaches the end of use, delivers it to the manufacturer for reuse and remanufacturing (for modules that can be remanufactured/reused) and recycling (delivering the recovered materials to recycling partners as identified during the process design).

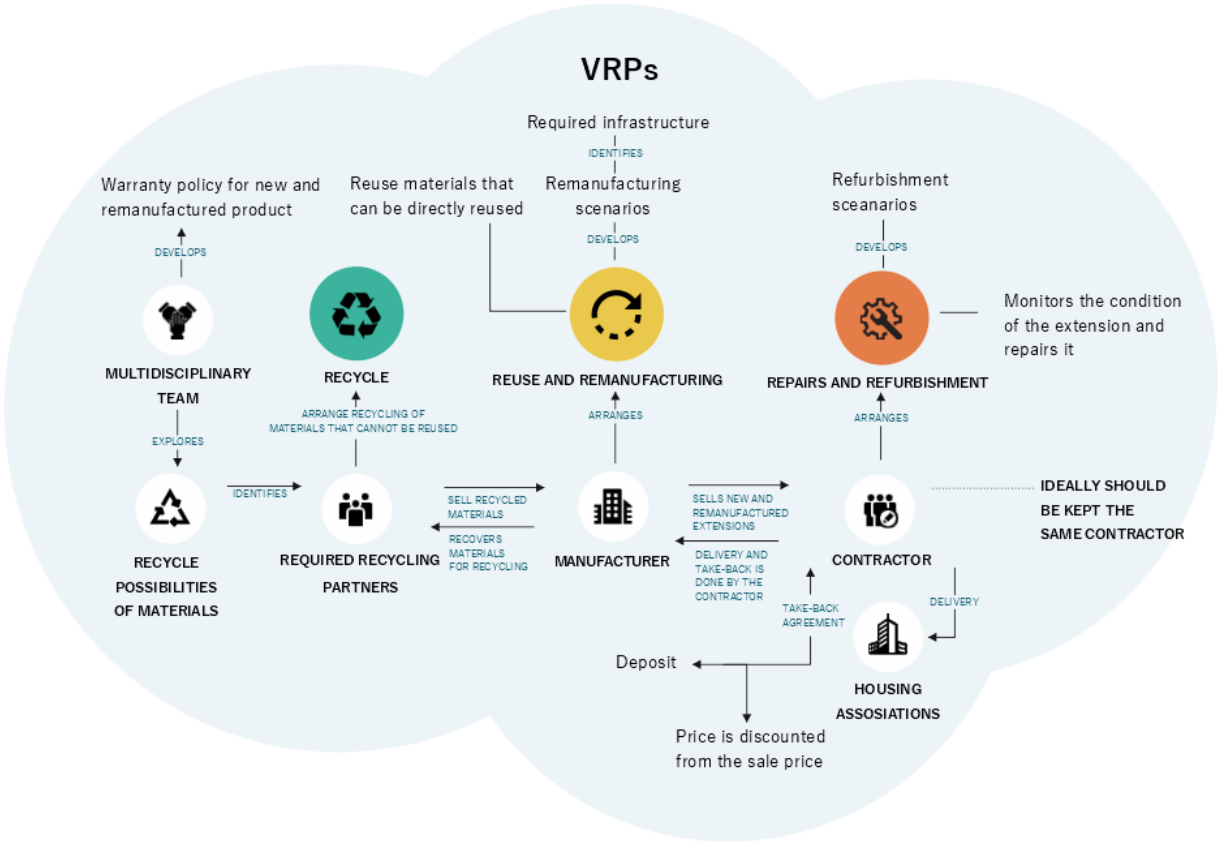

Figure 24. VRPs block in sell and buy-back design variant.

User oriented design variant

The user oriented design variant is much more uncertain than the previous two because it heavily relies on the formation of secondhand markets. In the current network there are no partners that could take on this role without incurring additional time and resource expenditure. Opportunities that could be created through co-creation are much more limited as the housing association is basically developing a new stakeholder network from scratch. New contractors, that are not familiar with circular economy, are hired to do the repair and refurbishment of the extension. When the extension reaches the end of use, it is sold to the secondhand companies. It is assumed that implementation of the remanufacturing of the extension becomes questionable, as looking at the current experience, the parties recovering the materials usually only recycle them (based on Ranta, Aarikka-Stenroos, & Mäkinen, 2018). Moreover, there is no guarantee the secondhand market will even be established and, therefore, circularity is not secured. In terms of co-creation, in this step the housing association co-creates together with secondhand materials companies primarily to identify the end of use value of the extension. However, considering that we do not know yet who could take on this role, it is unclear what steps would be part of this process. Such network composition is the closest to the traditional configuration. Figure 25 represents the design of VRPs block in user oriented design variant.

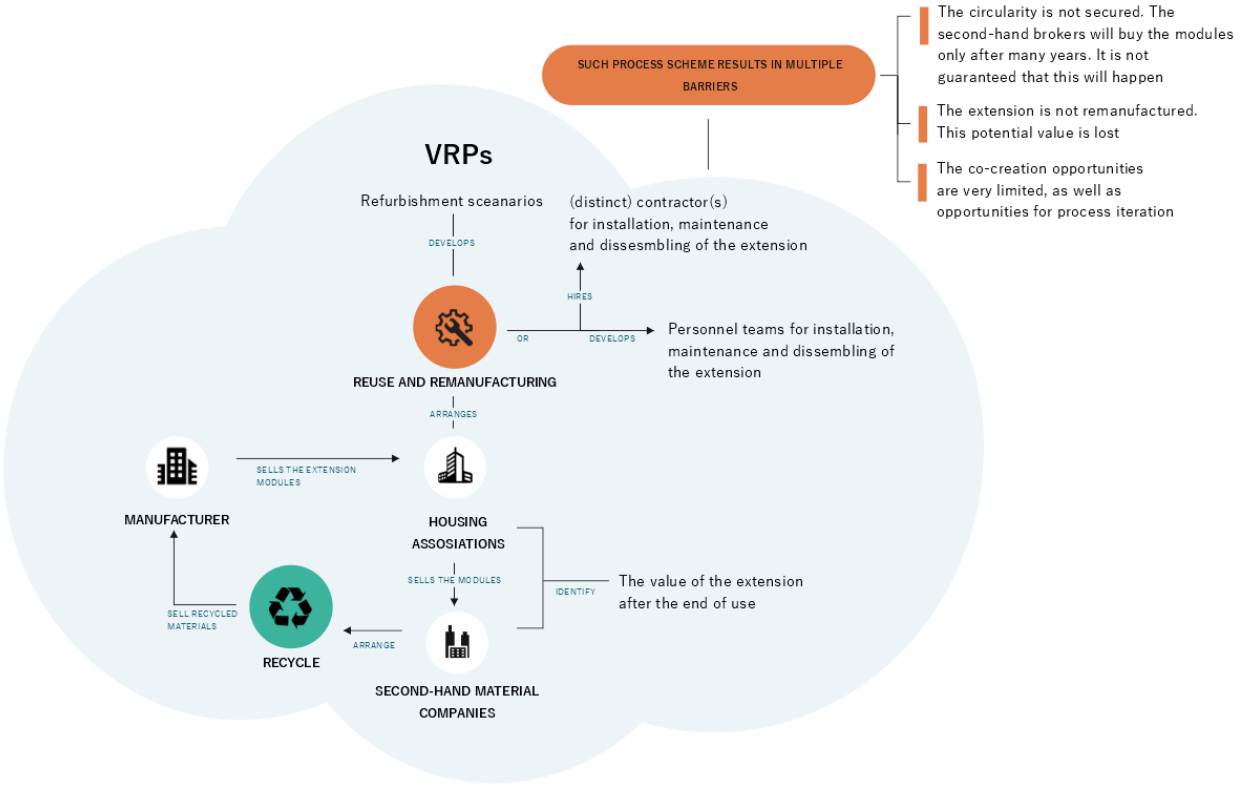

Figure 25. VRPs block in user oriented design variant

(2) Value capture

The value capture component of the business model consists of two sub-components: cost structure and revenue streams. Considering that mapping the costs and revenue streams for each party involved would create a mess and cause confusion when reading the map, it was decided to show the costs and revenue streams for the key stakeholders (depending on the business model). In the product as a service scenario, the costs and revenue streams shown are incurred by the manufacturer (Figure 26); in the sell and buy back scenario they are for the manufacturer and contractor (Figure 27); and in the user oriented they are for the housing association and parties that will form a secondhand market (Figure 28).

Based on the CBM review by Lüdeke-Freund, Gold, & Bocken (2018), the following types of costs were mapped: manufacturing, logistics, installation, repair, refurbishment, remanufacturing; additionally, two more types of costs were added based on the acquired understanding of the process: required infrastructure and facilities development, and other indirect costs. To map the costs' sub-components (e.g. sub-components of manufacturing, logistics, etc.) was decided to use the accounting point of view on costs (Averkamp, 2013; MOSIMTEC, 2020). The final results of this step are a fully developed business model ready for implementation.

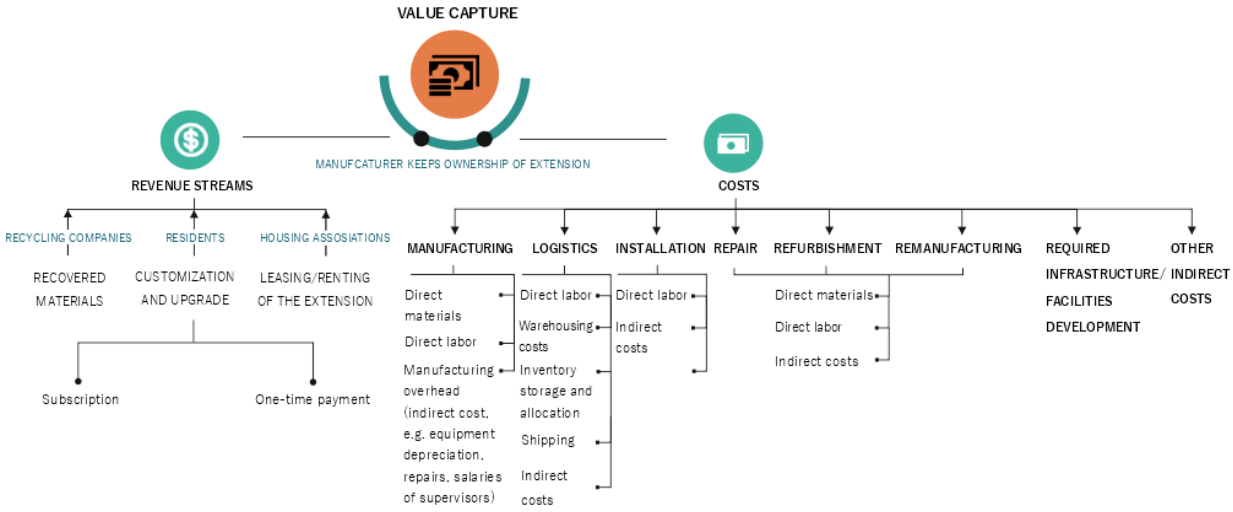

Figure 26. Revenue streams and costs structure in product as a service design variant

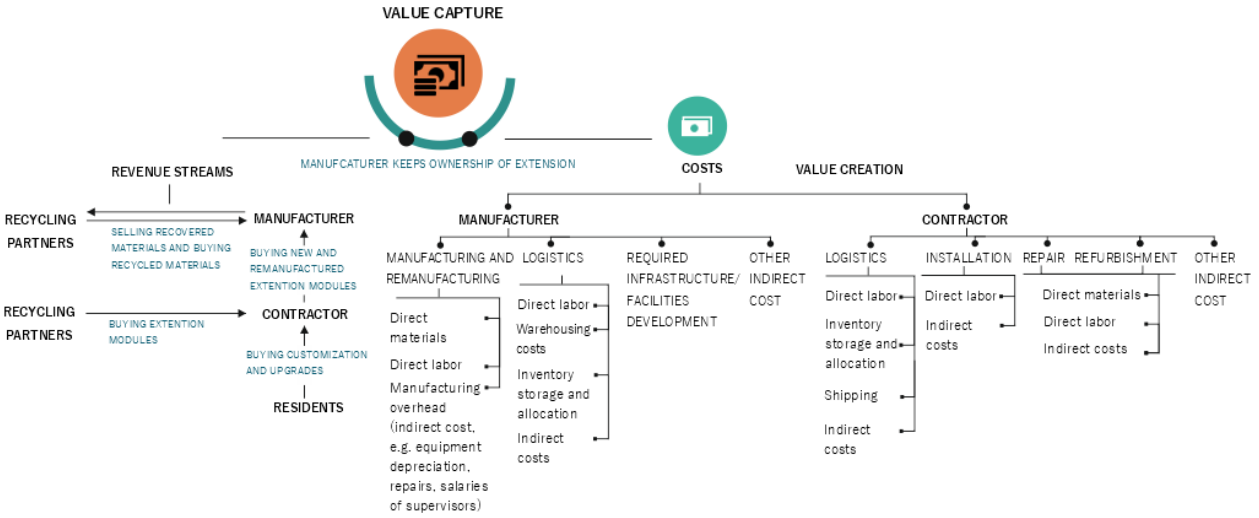

Figure 27. Revenue streams and costs structure in sell and buy-back design variant.

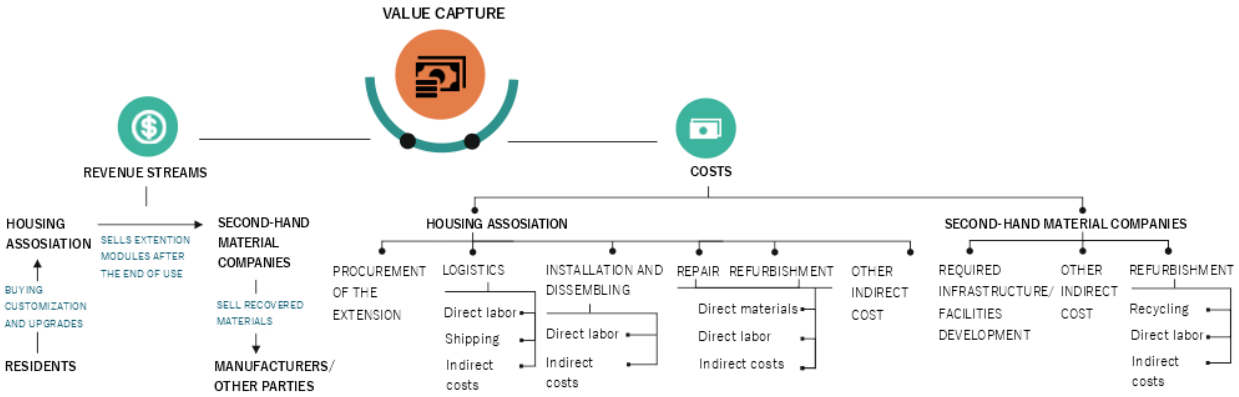

Figure 28. Revenue streams and costs structure in user oriented design variant.

6.2.4. Co-production

6.2.4.1. Development of co-creation path

The sub-steps of the co-production and co-maintenance steps were developed based on the co-implement step of DeLosRíos-White, Roebeling, Valente, & Vaittinen (2020) and insights gained during the study of cases of circular business model implementation (Hopkinson, De Angelis, & Zils, 2020; Pieroni, McAloone, & Pigosso, 2020; Ünal, Urbinati, & Chiaroni, 2019).

The sub-steps of the co-production phase represent what actions take place after the solution is developed. The steps of this phase are dependent on which process design will be developed during the previous step, but building on the assumption about the business model used and the mapped processes it is possible to draw this phase. First, considering that the developed solution might involve new actors, the new actors should be introduced to the network and all the contractual relations should be established (it is important to mention, that prior steps do not include any contractual arrangements because the current network already has contracts for the

development of a circular extension). Following this, stakeholders develop detailed guidelines and planning and budget for each party involved. Further, parties should ensure communication of circularity through all channels as it creates additional value for customers and helps to outweigh the tendency towards profit maximization. Finally, parties implement the process and proceed to the next co-creation step. Summing up, the steps of the co-creation path for the co-production phase are the following:

(1) Involve new required partners
(2) Contracting
(3) Develop guidelines for each party involved
(4) Develop detailed planning and the budget
(5) Ensure communication of circularity through all channels
(6) Implement the process.

Next section presents each of the steps in more details and provides the reasoning for adding them.

6.2.4.2. Mapping options/activities of the sub-steps

(1) Involve new required partners

Depending on the parties' willingness to participate in the co-creation process and their opinion on the need to redesign the process, the first feedback loop could take place here*. Therefore, if parties consider that the developed process requires changes after the involvement of new partners, the process returns to the co-design step. This loop moves the system closer to a closed-loop supply chain through the integration of external partners. This significantly differs with the traditional approach, because using the knowledge of new partners the system could be redesigned, while in traditional projects could be done only minor changes. If the new partners are not willing to participate in the co-creation process (or they do not need to), KPIs and a feedback system for communication with external partners needs to be developed to ensure the circularity of the system.

**It can be said that the co-creation process for the user-oriented design variant ends during the previous step after the housing association together with the secondhand material companies identify the end value of the extension; therefore, it is not applicable for this design variant and the feedback loop is not shown. Taking this into account, could be said that such process stays closer to the traditional way of working.*

(2) Contracting

Based on the insights gained during the study of the types of project delivery methods in housing renovation projects (see Section 3.4.4) it is suggested to use non-traditional contracts*, which allows the use of performance-based specifications that focus on outcomes and ambitions because it contributes to the implementation of sustainable solutions.

**Considering that the user-oriented design variant stays closer to the traditional way of working, it is suggested to use IMR contracts as, in this case, the housing association is the only party that hires subcontractors that do not have circular knowledge, so the housing association will need to oversee the process.*

(3) Develop detailed guidelines for each party involved

(4) Develop detailed planning and budget

Next, parties should focus on development of detailed guidelines, and planning and budget for each of the parties. This would allow each party to fully understand their functions, deadlines and costs incurred. Depending on the design of the system developed during the co-design phase, this could be done individually or jointly.

(5) Ensure communication of circularity through all channels

None of the reference designs include this step. It was decided to add it, because the experience of existing circular business shows that promotion of circularity and creation of circular culture is one of the key factors to achieve success implementing circular solutions (Centobelli, Cerchione, Chiaroni, Del Vecchio, & Urbinati, 2020; Ünal, Urbinati, & Chiaroni, 2019). Among the channels circularity should be promoted through include the following:

- Sales personnel
- Company website
- Advertising
- Circular economy related fairs, talks, seminars
- Develop a CE culture inside the company.

(6) Implement the process

This sub-step represents the building of required infrastructure and development of personnel teams, which together with the previous actions turns into implementation of the developed process design. Another feedback loop takes place at this point. If during the process implementation faced unsolvable problems/challenges, parties should reconsider the process design* (go to the co-design step of the process map).

**Similar to the previous feedback loop for the user-oriented design variant, this one also does not take place. The challenges could be faced due to the implementation of more complex remanufacturing processes and the recycling of modules and materials. In the user-oriented variant, these loops are not implemented by the problem owner.*

Summing up, this phase is the same for the product as a service and sell and buy-back design variants. The difference between them and the user-oriented variant lies in the presence of feedback loops. Another difference lies in the types of contracts that are recommended to use. The developed designs are presented in Figures 29 and 30. The final results of this phase is a solution that is implemented.

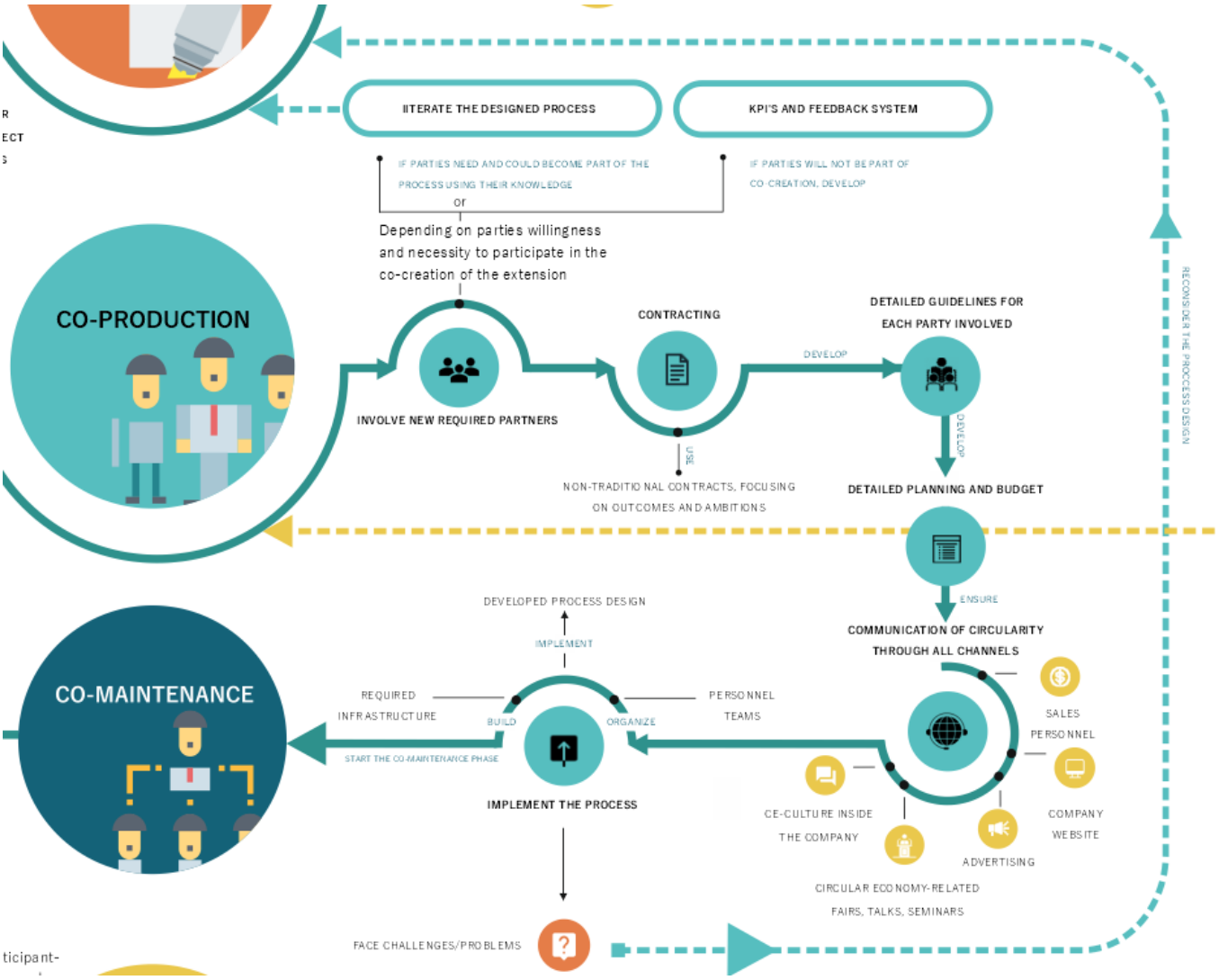

Figure 29. Co-production phase in product as a service and sell and buy-back design variants

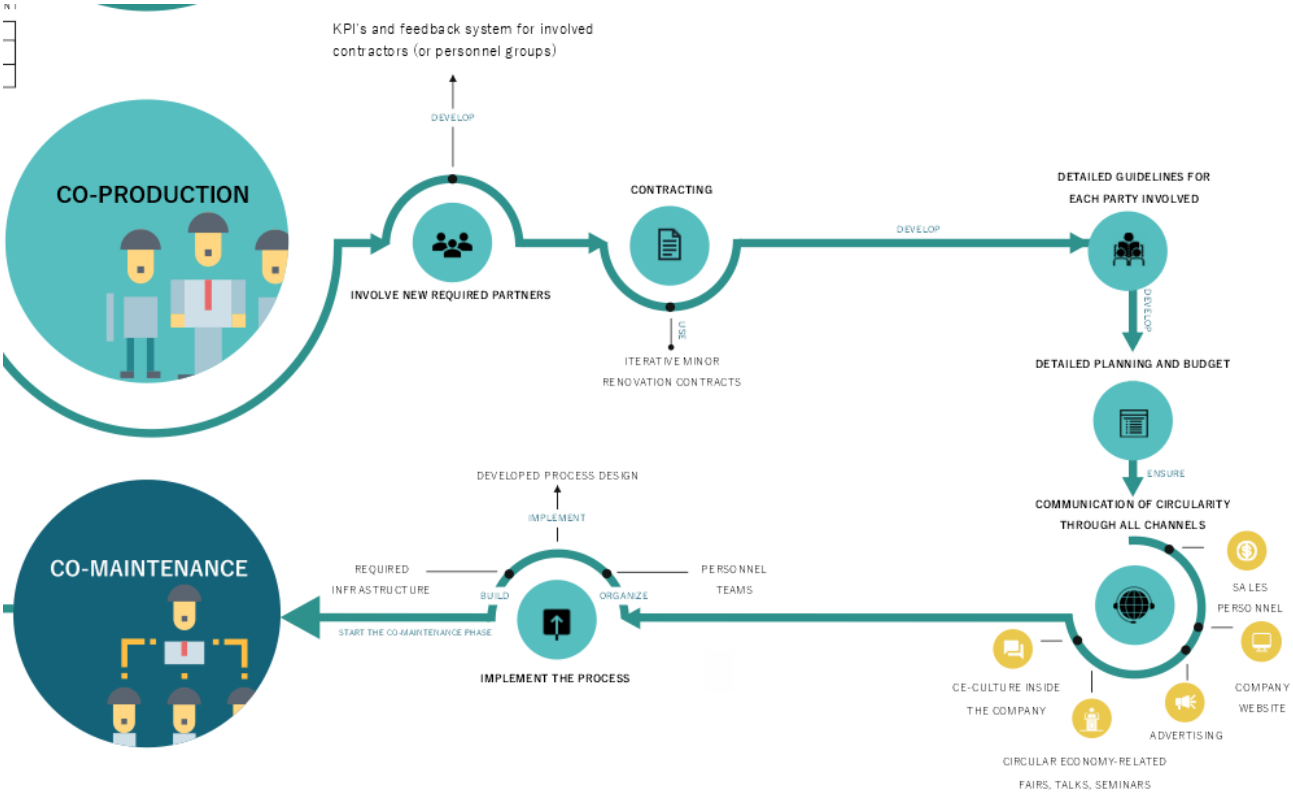

Figure 30. Co-production phase in user-oriented design variant

6.2.5. Co-maintenance

6.2.5.1. Development of co-creation path

The co-maintenance sub-steps represent what actions need to take place for successful upkeep of the process. Here biggest difference with the traditional approach lies in the fact that parties that participated in co-creation of the solution could be further involved in the maintenance phase (while in traditional approach, client hires a distinct contractor for the maintenance). First, after the process is implemented, to prevent any debates regarding management of the product, a clear governance structure should be defined. The choice of the governance structure is largely based on what business model was implemented and what process structure was developed. The ownership of the product is also largely dependent on the implemented business model. Further, the upkeep of VRPs requires the establishment of communication channels with users to detect failures and provide customized services. At this point one could say that co-creation stops because parties have defined their functions and the only thing left is upkeeping the process (or as in the example of user-oriented variant, the co-creation stopped even earlier). However, on the other hand, comparing to traditional approach, parties keep their relationships, because the roles in the project change (comparing to the traditional approach), e.g. in sell and buy-back design variant, contractor becomes responsible for the repair and refurbishment of the extension. Further, considering that circular economy topic is rapidly developing and is a subject for continuous improvement, depending on users' feedback and the new technologies available in

the market, the multidisciplinary team could be gathered again to restart the co-creation process, going through another feedback loop to improve the product or the process. Summing up, the steps of the co-creation path for the co-maintenance step are the following:

(1) Establish a clear governance structure
(2) Define communication channels
(3) Upkeep the process
(4) Based on available new technologies and users' feedback, improve the process.

6.2.5.2. Mapping options/activities of the sub-steps

(1) Establish a clear governance structure

The established network requires a clear governance structure in order to function stably. Provan & Kenis (2007) identify three types of network governance structures:

- Participant-governed networks. Participant governed networks is the simplest and most common type of governance. In this case, the network is governed by its members without developing a distinguished governance entity. It is controlled either formally through meetings of the organization's representatives or, more informally, through the ongoing effort of the participants. Network participants manage relationships and operations individually, both on an internal and external level. Power in the network is more or less equal and the network relies on equal participation of all members

- Lead organization — governed networks. This type of governance is opposite to the previous one. In this case all the important decisions are taken/coordinated by the lead organization. This type of governance structure is highly centralized and brokered.

- Network administrative organization. The idea of this governance structure lies in the establishment of a separate administrative entity that governs the network. This model is also centralized and the network broker (the established organization) coordinates the resources and activities. However, unlike the lead organization structure, it is not governed by one of the participants of the network. The separate administrative entity is established only with the goal to control the network. This entity, in turn, is controlled by the participants through mandates.

Product as a service design variant

With the implementation of the product as a service business model, the majority of the risks and financial expenditures will lie with the manufacturer. Therefore, it was considered that, in this case, the most suitable type of governance structure would be the lead organization.

Sell and buy-back design variant

In this scenario the risks are shared between the manufacturer, contractor and (depending on the involvement of recycling partners) companies establishing materials recycling. Therefore, it was

considered that the most suitable type of governance structure would be a participant-governed or network administrative organization

User-oriented design variant

In this scenario the majority of the risks stay with the housing association. The housing association becomes the lead-organization that hires new contractor(s) for the maintenance of the circular extension. In terms of relationships with parties that form secondhand markets, no governance structure is required as parties do not have any common processes (housing association just sells the extension and they co-create only during the co-design phase).

(2) Define communication channels

Using the industry experience (based on Hopkinson, De Angelis, & Zils, 2020; Ünal, Urbinati, & Chiaroni, 2019; informal interviews), the following communication channels could be listed:

1. Digital: Support by phone or email; website (mobile app) featuring the possibility to order customization and upgrades and/or submit a breakage notification.
2. Physical: Exhibition space presenting the available customization and upgrade options; periodical physical inspection of the condition of the modules to detect failures; catalogues presenting options for customization and upgrade;

(3) Upkeep the process

This sub-step does not include/require the listing of options.

(4) Based on the available new technologies and users' feedback, improve the process

Depending on the availability of options for process/product improvement the parties should reconsider the process/product design (go to co-design step of the process map)*.

**In the case of user-oriented design variant, it is impossible to directly review the process, as the co-creation network no longer exists. The only option in this case is the development of a new network.*

Summing up, the co-maintenance phase for all design variants differs in recommended governance structures and the presence of a process iteration loop. Figure 31 represents the design developed for the product as a service design variant. The sell and buy-back variant differs from it only in the recommended governance structure; therefore, it is not showed separately. Figure 32 represents the design developed for the user-oriented design variant. This phase does not have a final result (the process is upkept) unless one of the parties quits the network.

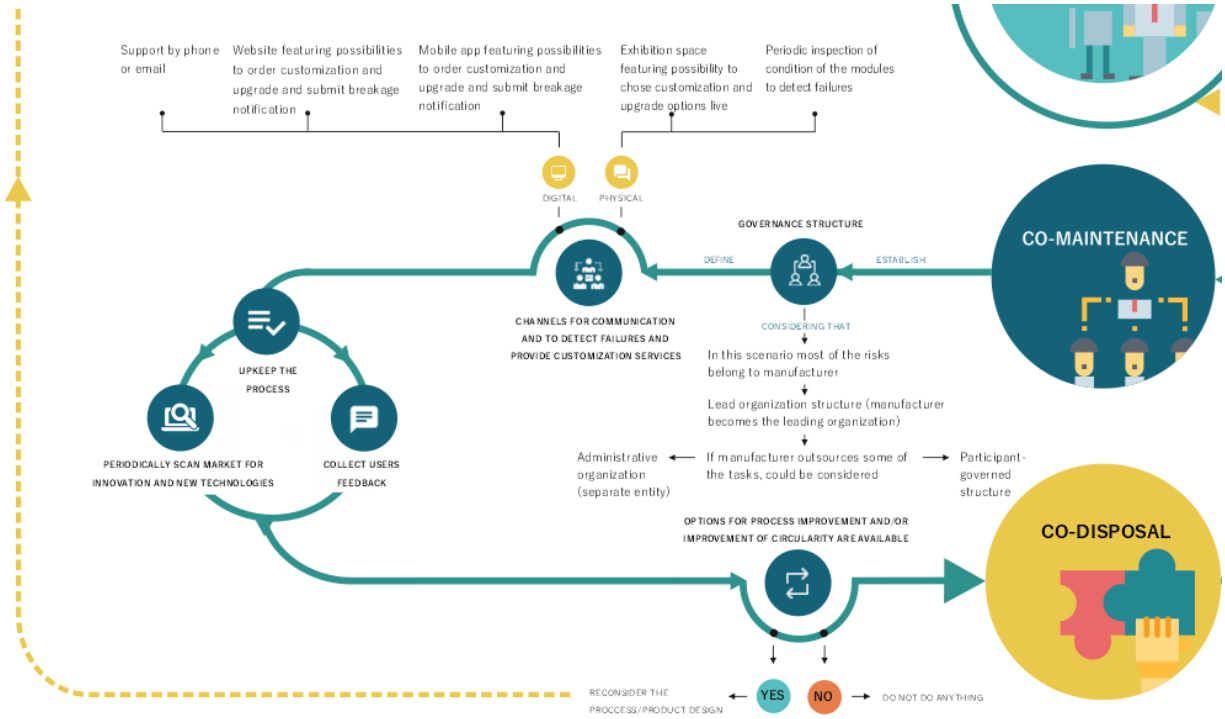

Figure 31. Co-maintenance phase in product as a service design variant

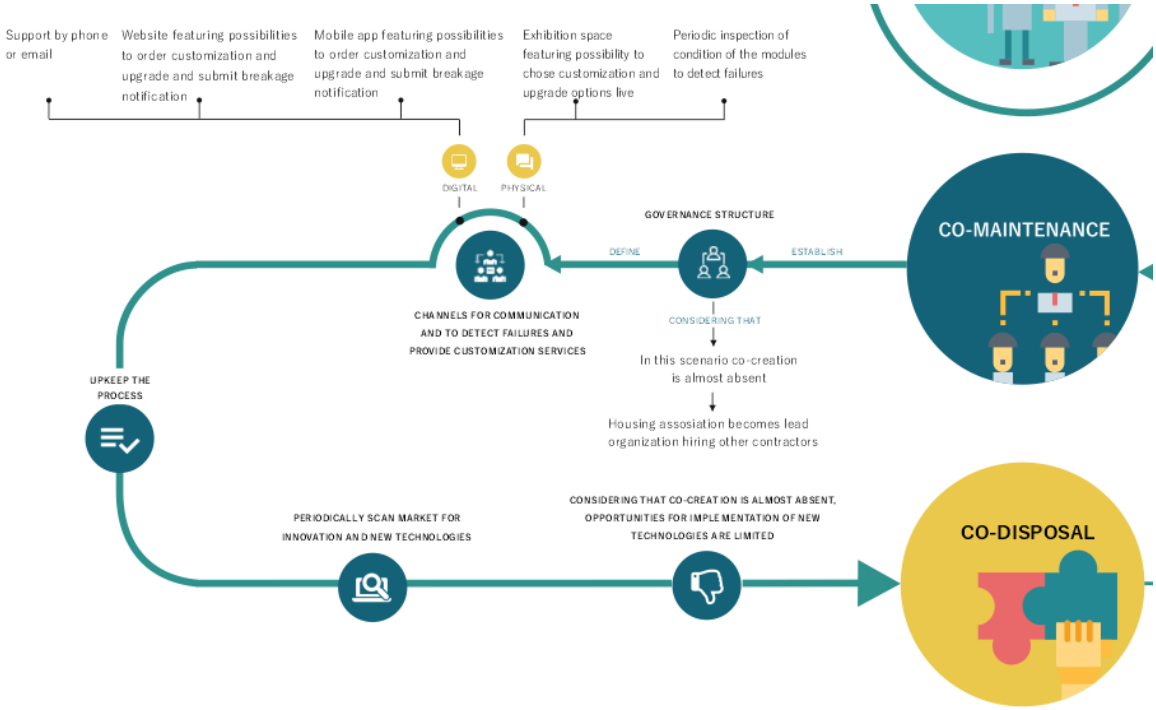

Figure 32. Co-maintenance phase in user-oriented design variant

6.2.6. Co-disposal/Knowledge transfer

6.2.6.1. Development of co-creation path

As mentioned earlier, development of circular building products should be coupled with the definition of knowledge transfer mechanisms. This largely differs with the traditional practices, in which knowledge is often not sufficiently secured. We need to guarantee that even after a long time period, parties will be able to access the data on the used materials and modules. In fact, the definition of mechanisms of knowledge transfer is done during the co-design step. However, considering that the actual knowledge transfer will take place only after a long period of time, this step was moved to the last phase to highlight its importance because if the re-looping process is interrupted the circular extension is no longer circular. Another reason to map it separately is because the components of the business model that need developing in the co-design phase are mapped. Including of knowledge transfer mechanisms would create a discrepancy between showed elements.

One could say that while in the previous phase co-creation ended, in this phase it could start again. In case one of the parties cannot continue to be part of the process other stakeholders should scan the market to find a new partner. If a new partner(s) resources allow them to become part of the process without any changes to it, then parties reimplement the process. If not, then the co-conception phase is again initiated and a new co-creation team is formed. Summing up, the steps of the co-creation path for the co-disposal phase are the following:

(1) Implement knowledge transfer mechanisms.
(2) If one of the parties is no longer part of the process, scan the market for a new partner.
(3) Depending on the new partner's resources reconsider the design (go to co-design step) or implement the process again (go to co-production step)

6.2.6.2. Mapping options/activities of the sub-steps

(1) Implement knowledge transfer mechanisms

The literature suggests that the most promising tools to secure the knowledge transfer are the material passports (Luscuere, 2017) and BIM-based material passports (Honic, Kovacic, & Rechberger, 2019). Another option is the development of standard practices for the reuse and recycling of circular extension modules and materials.

Steps (2) and (3) do not include/require the listing of options

Summing up, Figure 33 shows the components of this phase. The main difference between the design variants lies in the presence of process iteration loops. It is impossible to show it here because the loops go through the whole process map (e.g. from co-disposal to co-conception phase) and, therefore, the quality and resolution of the figure would be too low (the difference could be found in full process map, see Appendices I, J and K). The final result of this step is finding of a new partner and the continuation of the process.

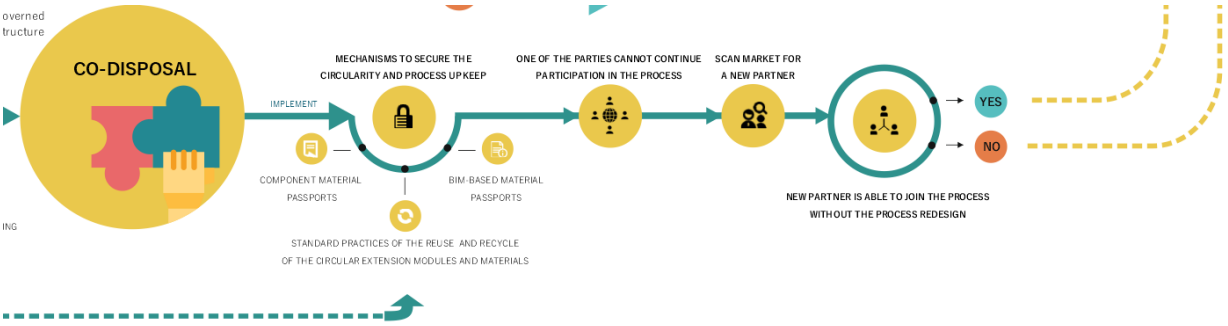

Figure 33. Co-disposal phase

Additionally, all the sources directly used for the design are presented in Table 8. The number in the table corresponds to the number mapped on the process map in Appendix L.

Table 8. Sources used for the design

#	Part of the map	Source(s)
1	Steps of the co-conception phase	Based on DeLosRíos-White, Roebeling, Valente, & Vaittinen (2020); Kruger, Caiado, França, & Quelhas (2018); Žlender, Erjavec, & Goličnik Marušić (2020).
2	Tools mapped	Based on Žlender, Erjavec, & Goličnik Marušić (2020); U4IoT. User engagement toolkit; UNaLab. UNaLab Co-Creation Toolkit (2020); MindTools. Management Training and Leadership Training
3	Steps of the co-design phase	The idea is based on DeLosRíos-White, Roebeling, Valente, & Vaittinen (2020); Kruger, Caiado, França, & Quelhas (2018); Žlender, Erjavec, & Goličnik Marušić (2020). Business model components are based on Bocken, Short, Rana, & Evans (2014).
4	VRPs blocks	Based on Russell (2018); Săceanu (2021).
5	Value realization cascade	Based on Hopkinson, De Angelis, & Zils (2020) Russell (2018).
6	Elements of costs and revenue streams	Based on Averkamp (2013); MOSIMTEC (2020)
7	Steps of co-production phase	Based on DeLosRíos-White, Roebeling, Valente, & Vaittinen (2020); Hopkinson, De Angelis, & Zils (2020); Pieroni, McAloone, & Pigosso (2020); Ünal, Urbinati, & Chiaroni (2019)
8	Suggested type of contract	Based on Baldiri Salcedo Rahola & Straub (2013)

9	Channels for communication of circularity	Based on Centobelli, Cerchione, Chiaroni, Del Vecchio, & Urbinati (2020); Ünal, Urbinati, & Chiaroni, (2019).
10	Steps of co-maintenance phase	Based on DeLosRíos-White, Roebeling, Valente, & Vaittinen (2020); Hopkinson, De Angelis, & Zils (2020); Ünal, Urbinati, & Chiaroni (2019); and informal interviews.
11	Types of governance structures	By Provan & Kenis (2007).
12	Types of channels for communication with residents	Based on Hopkinson, De Angelis, & Zils (2020); Ünal, Urbinati, & Chiaroni (2019); and Informal interviews.
13	Steps of co-disposal phase	Based on Kruger, Caiado, França, & Quelhas (2018).
14	Knowledge transfer mechanisms	Based on Luscuere (2017); Honic, Kovacic, & Rechberger (2019).

7. Semi-structured interviews with the partners. Evaluation and lessons learned

This section describes the procedure and results of the evaluation interviews. It aims to answer the fourth sub-question of the research: Which variants of the developed co-creation process maps are useful and feasible, and can they be used for other circular building components? Further, based on the analysis of the interviewees answers it answered the fifth sub-question of the research: Which lessons can be identified on how the co-creation process could be organized for the development and implementation of VRPs of circular building components from the case of the circular extension?

7.1. Structure and participants

The developed process maps of the co-creation process for the development of VRPs of circular extension were evaluated during the semi-structured interview conducted with the parties participating in the project. The interviewees were asked open questions that leave room for discussion and stimulate free expression of opinions and ideas. The process maps together with the description of their content were provided to the interviewees in advance. The interviews consisted of two phases. First, the interviewer (the researcher) presented the developed process maps and in case the interviewees still had any questions, the interviewer answered them. Next, the interviewees were asked to evaluate the usefulness, feasibility and transferability of the developed process maps. To guide the interviewees through the evaluation procedure, a list of questions, that can be found in Section 2.2, were developed. Four partners were approached, resulting in four perspectives: manufacturer, contractor, architect and housing association. The list of interviewees is presented in the Table 9.

Table 9. Interviewees, their company, field, position and the date of the interview

Name(s)	Company	Field/Role in the project	Position(s)	Conducted on
Rob van den Oudenrijn	Van den Oudenrijn	Carpentry factory (manufacturer)	DGA (managing director)	25.05.2021
Terry Pater	Door Architecten	Architect	Architect	26.05.2021
Nils Vanwesenbeek and Saskia van der Weerd	ERA Contour	Contractor	Project leader and Concept developer	28.05.2021
Ilse van Andel	Eigen Haard	Housing association	Sustainability and circularity strategy manager	08.06.2021

Further, the interviewees' answers are summarized by each question in detail. The summary does not include any analysis and provides the shortened version of the answers. Additionally, Table 10 provides the main points (in quote form) from the answer of each interviewee and shows the correlation between them. Answers that have the same point and have a similar or very close argument are highlighted by the same color. The detailed analysis of the answers could be found in Section 7.4.

7.2. Summary of the answers of the interviewees

7.2.1. Evaluation of usefulness

Do the developed process maps provide the knowledge needed for the organization of co-creation in context of the development of VRPs of circular extension? Why or why not?

All the interviewees considered that the developed process maps provide the knowledge necessary for the development of VRPs of circular extension. The contractor representatives pointed out that, in fact, they are currently somewhere in between the sell and buy-back and user-oriented design variants. The architect remarked that for the people who have circular knowledge the developed process maps are very clear. However, if they are used for co-creation between people who are still thinking along linear lines, there should be at least one person (among the parties or an external advisor) who completely understands what the maps are for and what they show. The representative of the housing association remarked that they experience difficulties in communication with companies that do not have circular experience yet, and the process maps are good for helping to build a dialogue and for explaining what they want to do.

Would you use the developed process maps (and/or which one of them would you use) during the development and implementation of VRPs of circular extension? Why or why not?

The contractor representatives considered that it would be good to use the developed process maps because you can see the differences between them and can choose to use one part of one map and one part of another map. Additionally, they suggested to combine the developed designs into one, which had all options and could choose between them. The manufacturer considered that he would consult them, and which one depends on the particular case. The representative of the housing association as well as the manufacturer remarked that which one they used would depend on the product. The architect and representative of the housing association pointed out that (in case of circular extension) they would primarily use the sell and buy-back variant. The architect found them attractive for his clients to buy stuff with a guarantee that they could sell it again later because it would secure the quality of the products and provide an additional financial stream. Moreover, he remarked that he had already sent the process maps to his colleagues.

7.2.2. Evaluation of feasibility

Do you consider that the engaging actor (or problem owner) would be able to implement the designed process?

The contractor representatives pointed out that in the case of circular extension, the manufacturer does not have organizational set to implement services; therefore, implementation of a product as a service design variant becomes questionable. In the case of sell and buy-back and user-oriented variants, the problem owners (meaning the contractor and housing association respectively) have their own service teams that are involved in other projects; therefore, they should be able to organize the process. The architect pointed out that manufacturers, contractors and housing association (meaning not specifically the case of circular extension) are going for more and more extensive relationships, developing maintenance and operational contracts for 10, 20 and 30 years; therefore, under the new conditions the problem owner will be changing, and parties should be able to adapt to the new conditions. The manufacturer considered that the scarcity of the materials and rise in material prices would force the parties to implement the changes. The housing association representative remarked that she is not sure about the manufacturers and contractors but, speaking about themselves, they can do it. She pointed out that it is a difficult process because, in fact, it is the implementation of innovative approaches, but they (as a housing association) look forward to implementing such solutions, but they still need time to do it and acquire more knowledge.

Do you consider that organization of (product as a service, sell and buy-back and user-oriented) the co-creation process and implementation of VRPs would be economically feasible? Why or why not?

All the interviewees except the housing association representative considered that all of the variants could be feasible, but they do not think it is feasible today. Their argument was quite similar, although the arguments differ a bit. The architect remarked that with the implementation of a circular economy and development of circular practices, it will become more common practice. The contractor representatives emphasized that it would be feasible, but largely depends on the cost of the materials. If they continue to rise, it will become feasible. The manufacturer emphasized that there is no market yet for the process to be feasible. The housing association representative only found the sell and buy-back and user-oriented variants feasible. She explained that if something is offered as a service directly to their tenants, they already have experience in co-creation with BOSCH to provide sustainable, high quality washing machines as a service for their tenants. They found that considering the income of the tenants it is not an attractive option for them, because after using it for six years they would in fact pay more than buying a regular washing machine. If something is offered as a service to them (meaning the housing association) it is also not attractive, because they can get very low interest rates and it is cheaper for them to buy the product. She also pointed out that sell and buy-back is a very attractive option, because it would allow them to lower their investments and would stimulate the implementation of circular options.

Could you highlight any strengths and weaknesses of the developed designs, in your opinion?

The architect considered that the strongest part of the design was the clear representation and allocation of multiple parameters that are part of circular co-creation. The weakness, in his opinion, is that the process maps could be overwhelming for the unprepared reader, but at the same time he pointed out that he would not change them. The manufacturer pointed out that the developed designs are a good support for the process development, but at the same time the practice is not always predictable. The contractor representatives remarked that in the products as a service and sell and buy-back variants the solution for remanufacturing and recycling is developed in the co-design phase and proposed to change it. They suggested to combine the three process maps into one, developing more phases, in this case the first phases would be the same, then would be the phase with the choice of leasing/sell and buy-back and then somewhere (e.g. co-maintenance part) would be the organization of recycling and remanufacturing. The housing association representative did not remark on any strengths or weaknesses of the designs.

What opportunities and threats, in your opinion, do the developed designs bring to the problem owner?

The architect pointed out that it is nice that the problem owner can follow the whole process map and acquire an understanding of the whole process. Six years ago, when they built their circular office, there was not any literature or examples available. They had to do the things as pilot projects just to try out how they will work. *"With maps like this you know in advance what will happen, or not completely what will happen, but what you can expect".* The manufacturer considered that the biggest threat is financial feasibility of the developed designs. The concept developer* (contractor) remarked that the main opportunity is basically in co-creation itself. The problem owner acquires the opportunity to use their knowledge together with the knowledge of other parties. The project leader (contractor) considered that the biggest opportunities and threats lie outside the developed process maps in the size of the market. The housing association representative remarked that she already mentioned the biggest threat (for product as a service) in one of the previous questions. It is not attractive for their tenants or for them. Also, she pointed out that another threat lies in the fact that they are not used to working in the new ways and their financial system works differently, so they would need to adapt. Further, they do not know what the price will be in 15 years and cannot use it in their calculations. They are still trying to figure it out. Another thing is that they, as a company, owned assets, but in the case of a house as a service then the question arises what do they own? Speaking about sell and buy-back she pointed out that the main opportunity was also discussed earlier and that it was lower investments. The main threat lies in the probability of the manufacturer going bankrupt.

*Earlier the opinion of the contractor representatives was the same; therefore, they were presented as the same entity (contractor). In this question their opinions divided, therefore instead of "contractor" their project roles are used.

The developed designs also include process iteration loops (feedback loops). How would you rate/evaluate their effect on the economic feasibility of the process?

The contractor representatives considered that the effect of the process iteration loops was high because it allows them to evaluate the process and improve it. But, at the same time, there needs to be a clear definition of when you should stop the iteration or start it again, because each iteration requires investment of time and resources. The architect also evaluated their effect as high, explaining that for the stakeholders the process is primarily about the costs and process iteration loops allow them to revise them. The manufacturer did not rate their effect. The housing association representative remarked that they affect feasibility in general (not only economic), because it narrows the process and makes it more efficient and clear.

7.2.3. Evaluation of transferability

Do you consider that the developed process maps could be used for co-creation in context of other circular building components? Why or why not?

All the interviewees considered that the developed process maps could be used for other circular building components and in another context. The manufacturer also pointed out that although he considers they could be used in another context, this requires testing in practice. Additionally, the architect pointed out that they could be improved to fit different projects. He suggested, that in this case, there should be base components which could be combined depending on the project. It would be possible to map the stakeholders or co-creators throughout the processes (also defining their importance in a particular process), what could stimulate their commitment. The housing association representative considered that the process maps can be used not only for circular building components, but in the context of circular build environment in general, although this would require to significantly change their content (meaning mapped options, third layer of the map).

7.2.4. Additional comments

During the presentation architect proposed several ideas to make the design of the maps more intuitive (e.g. such as change the order of VRPs to emphasize their importance, etc.). The maps presented in the research already include these ideas.

Both architect and housing association representatives asked to translate the process maps in Dutch for they could further use it more effectively.

7.3. Correlations between the interviewees' answers

Table 10 presents the main points (in quote form) from the answers of each of the interviewees and looks for correlations between them. The answers that have the same point and same (or slightly different) argument are highlighted by the same color in each line.

Table 10. Interviewee answers and the correlations between them

Questions \ Interviewee	Architect	Contractor	Manufacturer	Housing Association	Correlations and Contradictions
Do the developed process maps provide the knowledge needed for the organization of co-creation in context of the development of VRPs of circular extension? Why or why not?	"I really think they could help a team with the contractor, the client, the architect, the installation guy through it."	"I think they are really clear. Three really different options. But, I think there is also something in between of the three options."	"Yes, they are a good guide for the various options."	"I think they do, because it is a good representation, you do not miss anything."	All the interviewees considered that the process maps provide the knowledge necessary for the development of VRPs.
Would you use the developed process maps (and/or which one of them would you use) during the development and implementation of VRPs of circular extension? Why or why not?	"Yes, I would like to use one of them, I think the sell and buy back… and I already sent it to one of my colleagues."	I think it's good to use it at the current moment for the development process… you can see the differences between them and you can choose to use one part of the one map and one part of another map."	"I would consult them, and which one depends on the case."	"Yes, but I also recommend you translate them in Dutch… And which one? That does not matter. That depends on what we want with the product and it is different for different products."	All the interviewees said that they would use/consult them. Architect and contractor considered the sell and buy-back to be the best option. Manufacturer and housing association representative considered which one depends on the case.
Do you consider that the engaging actor (or problem owner) would be able to implement the designed process?	"Manufacturers and contractors and housing corporation are going to more extensive relationship… they are more involved than in the past … so, I think the problem owner can change and it will change a bit."	"when you look at the process we experienced you see the same steps looking back. In this case (meaning circular extension case), the manufacturer does not really have an organization set for service… but housing association and contractor could do it."	"Yes, because the scarcity of raw materials and the associated price consequences will force the manufacturer and contractor to do so."	"I think we are all able to do this, but we need time, we must give each other time, even inside our own organizations."	Both the architect and manufacturer considered that, in the future, manufacturers and contractors will be forced to become problem owners. Housing association representative remarked that more time is needed to adapt to the new processes. Contractor pointed out that in the case of circular extension, the manufacturer would not be able to become problem owner.
Do you consider that organization of (product as a service/sell and buy-back/user-oriented) co-creation process and implementation of VRPs would be economically feasible? Why or why not?	"Right now, it's rather hard to implement, but I think in 10, 15 years especially when the circular economy will be grown up and it will be way more standardized."	"Maybe it's feasible, but I don't think we want it at this moment. The problem in housing in the Netherlands is that we need to have it affordable. The costs are getting higher and at this moment circularity is still more expensive. If the cost of materials will continue to rise, in renovation cases it will be feasible."	"Not in the short term because there is no market for it (yet)."	"I think so, but not all the variants… product as a service… is problematic."	Contractor, architect and manufacturer considered that circularity, in general, is not feasible right now. However, all of them also considered that it will be feasible in the future. Housing association representative does not consider the product as a service variant feasible.

Could you highlight any strengths and weaknesses of the developed designs, in your opinion?	"the color scheme that you have chosen, also nice icons, really easy to read and to see… buy, when you don't know enough about the topic it could be a bit overwhelming."	I would suggest that organization of remanufacturing and recycling should be a separate phase."	"Strong: good handle. Weak: practice is not always predictable."	No comment.	Strengths: Architect and manufacturer remarked that the designs are easy to follow. Contractor suggested to make organization of recycling and remanufacturing a separate phase. Weaknesses: Architect pointed out that the design could be overwhelming for the unprepared reader. However, he also insisted that he would not change it. Manufacturer remarked that the practice is not always predictable.
What opportunities and threats, in your opinion, do the developed designs bring to the problem owner?	"You can follow through the whole scheme… With schemes like this you know in advance or on forehand what's going to happen or not completely what's going to happen, but what you can expect."	"The main opportunity is that the problem owner can use others' knowledge … the biggest opportunities and threats are outside of your schemes … the biggest question is the market size."	"Opportunities: well organized process. Threat: financial feasibility of the process."	"The main opportunity is in buy-back, as I told you, because you have lower investment costs" Threat: "If we have a house as a service, then it is not ours. So what do we have then?" "What if manufacturer is broke after 10 years?"	Both architect and manufacturer considered that that the main opportunity lies in mapping of the process itself. You can know what to expect. Manufacturer remarked that the main threat lies in financial feasibility. Contractor considered that the main opportunities and threats lie outside the process maps in the market size. Housing association representative found many threats in the product as a service variant. In her opinion, most opportunities provide sell and buy-back.
The developed designs also include process iteration loops. How would you rate/evaluate their effect on economic feasibility of the process?	"I think they would improve feasibility."	"I think it is high, because you need to evaluate your process to make it better, to make a step forward."	No answer.	"I think they are very important to improve the process."	Architect, contractor and housing association representative considered that the process iteration loops (or feedback loops) improve the feasibility.
Do you consider that the developed process maps could be used for the co-creation in context of other circular building components? Why or why not?	"I think they can be quite easily transferred to not only the extension, but as well for a window or an installation thing. I can imagine that stakeholders will differ a bit, but I think it would be quite easy to change it."	"I think you can use them in another context. It doesn't matter if you talk about the roof or the extension or the kitchen. The process is the same."	"I think so, but practice will have to prove it."	"I think they can be used everywhere in context of circular buildings developments."	All the interviewees considered that the process maps could be used for other circular building components.

7.4. Conclusion and lessons learned

This chapter was aimed to answer the fourth research sub-question: *Which variants of the developed co-creation process maps are* ***useful*** *and* ***feasible****, and* ***can they be used for other circular building components****?*

It presented the results of the evaluation of the process maps developed for the organization of development and implementation of VRPs of circular extension. The research was guided by the design goal and research goal that were formulated as follows:

Design goal:

> *Develop a useful and feasible co-creation process map for the development of VRPs of circular extension.*

Research goal:

> *To map how the co-creation process could be organized and what steps need to be included for the development and implementation of VRPs of circular extension and to further identify what lessons learned could be derived for the case of circular building components from the case of the circular extension.*

The evaluation was based on the three aspects highlighted above: **useful, feasible and "can they be used for other circular building components" (meaning transferable)**. Although the developed process design still needs to be tested in practice, interviews showed that partners consider the developed process maps provide the knowledge necessary for organization of co-creation of VRPs and remarked that they would use them to develop VRPs of circular extension. The interviewees considered that the developed process maps are not feasible today (except housing association representative); however, they also emphasized that they consider that today circularity, in general, is still more expensive than the linear process and, as the architect pointed out: "For stakeholders it is primarily about the costs". However, all the interviewees also remarked they considered that the developed process maps will be feasible in the future when circular practices become more common and the market is fully ready to accept circularity. Moreover, with the current trend of rising prices of building materials (especially wood and steel), this moment might be closer than one would think a year or two ago. Summing up, based on the interviewees' answers, it can be considered that the design goal of this thesis was successfully fulfilled.

Next, the developed process maps integrate the structure of the co-creation process and the steps of the design and realization of circular extension, creating a broader picture of the process. The design was developed keeping in mind that it should be applicable not only for the case of circular extension, but for the circular building components in general. Moreover, as the interviews showed, all the partners considered that the developed process maps could be applied for other circular building components after minor changes. Therefore, at this moment, it can be considered that the research goal of this thesis was also partly fulfilled.

Interpreting the interviewees' answers and looking closer at the correlations and contradictions between them, lessons learned could be drawn that finalize the fulfillment of the research goal and answer the fifth research sub-question:

> *Which lessons can be identified on how the co-creation process could be organized for the design and realization of VRPs of circular building components from the case of the circular extension?*

The interviewees' answers provided their opinion on multiple aspects:

- Whether process maps provide knowledge necessary for the organization of co-creation process for circular extension.
- If they would use them.
- If they consider that the engaging actor could implement the process.
- Their opinion on feasibility of the process.
- Strength, weaknesses of the designs and opportunities and threats that the mapped processes create.
- Effect of feedback loops.
- Transferability of the developed design.

The first thing that catches your eye when you carefully consider the interviewees' answers is that partners tend to mix the co-creation process with applied business model. The question about feasibility was developed in such a way to get their opinion about both: the feasibility of the co-creation process as a process, and the feasibility of the design mapped in co-design phases (or feasibility of business model). However, all of them answered only from the point of view of a business model, in most cases saying that it will be feasible only in the future. None of the partners evaluated the outcomes that are created through the co-creation (e.g. knowledge, relationships, innovation, etc.). It shows that although partners look forward to the potential outcomes of co-creation, their primary driver is still cost-efficiency. Analyzing this pattern, the first lesson learned could be formulated as follows:

> In the end, partners look primarily on the feasibility of the co-creation process from the perspective of final feasibility of the whole business model. None of them considered co-creation outcomes although they were mentioned during informal interviews.

Taking step back, it can also be concluded, that this fact limits both co-creation and circularity because parties follow their own interest of reaching cost-efficiency (as for example, contractor emphasized that they do not consider participating in the buy-back of the extension), not considering other potential benefits.

Based on the identified lesson learned, can be also concluded that in order to stimulate circular transition, future research should focus on the cost estimation of developed processes, including both: transaction costs incurred by the engaging actor to organize co-creation and costs incurred during the implementation of different business models.

Further, both the contractor and architect mentioned several times how valuable the participation of Anne van Stijn was in their workshops. She guided them through the topic of circular economy and helped develop solutions. This fact lies in line with the co-creation literature that suggests involving consultants throughout the process. Here the next lesson learned could be formulated:

> Organization of circular co-creation process requires involvement of a human interaction specialist and circular economy consultant (which could also be one party) that will guide the parties through the whole process.

Although the existing circular literature suggests that leasing of the product is the most circular option that we should strive to achieve, the interviewees find it less realistic under current market conditions. As the contractor mentioned, the process design they are currently working on lies somewhere between the user-oriented and the sell and buy-back designs. They are probably going to provide the maintenance, but currently there is no take-back agreement and no work on remanufacturing or recycling of the extension (not even speaking about the implementation of product as a service business model). The reality (compared to the research) forces them to continue the work without working on these aspects because the main goal of the project is to complete the renovation. Deadlines are in place and the properties need to be renovated. This discrepancy between an ideal world and the real one also endangers the circularity of the product because right now, the product is designed as circular, but its circularity is not secured. This conclusion was drawn during the design of the user-oriented process map. Although it does not represent the current reality, the only difference lies in the fact that the current contractor will most probably continue to participate in the project as the service provider. However, other parties (with the manufacturer being the most important one) will not continue to be part of the process. This limits the co-creation by definition because, in this case, the feedback loops probably will not take place. Moreover, the housing association will need to find who they can sell the extension to later and, of course, the remanufacturing of the extension also becomes questionable because the manufacturer is no longer involved in the process. Based on these aspects it is possible to draw two lessons:

- The potential circularity of the whole process is highly dependable on the party that initiates the process and becomes the engaging actor (or problem owner). The resources and capabilities of this party determine the business models that could be implemented and highly affect the potential of cascading of the materials and modules.
- Looking from the perspective of the current reality (in which the housing association is the client), development of VRPs requires involvement of parties that could take on the role of the secondhand market to secure the circularity of the process because it is questionable that such a market will appear by itself.

Further, during the development of the design variants, the author considered that mapping of the different business models would cause radical changes in the co-creation process. However, from the perspective of co-creation as a process (meaning that we stay on the more abstract level

of the co-creation model or co-creation path), not a lot of things change. The steps of the process stay the same and what really changes are the options that should be considered and the possibility of iterating the process (or the presence of feedback loops).

> The co-creation process would be similar for different business models and different circular building components. Together with the change of studied circular building component and business model, changes the problem owner and network composition, what further affects the possibilities of process improvement and, circularity and feasibility of the process.

Last, but not the least, it is important to mention, that the interviewees find product as a service business model least feasible or even not realistic. In the same time, partners considered the sell and buy-back option and development of take-back agreements to be a great option, mainly because it creates additional financial streams and secure the end value of the product, which is now unknown. Therefore, the next lessons learned, could be formulated as follows:

> Under the current market conditions, sell and buy-back option has the most potential for making circular building components truly circular. Therefore, it is suggested to attempt to develop the VRPs around this business model.

However, besides opportunities that could be created, this lesson also calls for the research of the end value of circular building components.

8. Validation

This section describes the procedure and results of the validation sessions.

Considering that the criteria of the "standard" science cannot be used to validate the research through design, a distinct validation procedure was developed by the author (see Section 2.2). To ensure the scientific validity of this research, two construction management and engineering students were approached: Stefanos Voglis (currently doing research in the framework of REHAB project) and Andrei Săceanu (completed his research in the framework of REHAB project). Both of them acquired extensive knowledge of the circular economy, circular supply chains and business models during their research. Moreover, one of them (Stefanos Voglis) is also doing research in the domain of co-creation but looks at it from another perspective.

The validation sessions consisted of two parts. First, the author presented the key parts of the research: problem statement, research and design goals, theoretical background, literature review, developed requirements and the parameters of co-creation, process maps and results of the evaluation interviews. Next, the students were asked to validate the problem statement, method and result of the research, answering six open questions that were developed in advance. All the proposed changes were implemented, and this report represents the finalized version. Further, their answers are summarized to each question.

Problem statement:

> *Do you consider the chosen knowledge gap and problem relevant? Why or why not?*

Both, Andrei and Stefanos considered that the identified knowledge gap and problem are relevant. Stefanos mentioned that he is doing research in a closely related topic and that he also identified this knowledge gap. Andrei mentioned that although his research was further away, he also has not seen literature on this topic. Additionally, Andrei proposed to narrow the problem statement more, mentioning not only circular building products, but also circular extension.

Method:

> *Do you consider the chosen methods appropriate to fulfill my design goal and research goal? Why or why not?*

Both, Andrei and Stefanos found the methods used to be appropriate to fulfill the design and research goals. Stefanos elaborated that it is appropriate primarily because the research through design methodology is used to develop something that does not exist.

Results:

> *Do you consider that the results I got during my research fulfill my design goal and research goal and (partly) fills the identified knowledge gap? Why or why not?*

Both students considered that the developed process maps were very explicit and can significantly help the reader understand the whole co-creation process. Additionally, Stefanos proposed to

reformulate the research goal and use “map the process” instead of “develop recommendations” because the later one is a broader term and could be understood differently.

Does the result of this research match your personal constructions about the topic?

In the opinion of Stefanos, the developed process maps include everything he came across during his literature review. He mentioned that the research is built up on the co-creation literature, further specifying various aspects of the processes. Andrei pointed out that the result matches his expectations, especially in the part developed based on the results of his thesis (value creation in co-design phase). Further, he noticed, that from his point of view, his design variants were analyzed from another angle and provide additional knowledge.

Do you consider that the developed process maps describe the co-creation process explicitly enough? If not, could you name other parameters that should be included in your opinion?

Both students agreed that the developed process maps describe the co-creation process explicitly enough. Further, they elaborated, that although there is always room for improvement, in the time frame of the validation session they cannot come up with any other parameters.

How would you improve the developed designs?

Both students again noticed that although nothing is ideal, they considered the designs to be very well developed and do not require any improvements. Stefanos remarked that considering that he does research on a very similar topic, after a detailed study of the designs he might come up with some suggestions; however, it would take much more time than the duration of a validation meeting. Additionally, Andrei mentioned that speaking about the whole research, not only the designs, but each thesis also has its limitations and there are always plenty of things that could be improved, such as the number of interviews or design variants. Further, he pointed out, that he would not change the design, because it shows a complete path.

9. Discussion

9.1. Research in the wider academic context

The aim of this research was to (partly) fill the gap in the co-creation literature particularly for circular co-creation mapping for circular extension. In the first steps of this research, it was considered that the co-creation literature is scattered and there were no models or frameworks that would combine it into one picture. During the literature review it was found that in recent years several scholars made attempts to systemize co-creation knowledge by developing new models and frameworks (e.g. DeLosRíos-White, Roebeling, Valente, & Vaittinen, 2020; Kruger, Caiado, França, & Quelhas, 2018; Žlender, Erjavec, & Goličnik Marušić, 2020). This partly simplified the task, but at the same time made it more difficult, because it required analysis of these models to identify what parts should be added or removed to build a circular co-creation process map based on them. The research deliverables are represented by the three process maps of the co-creation process for the development and implementation of VRPs of circular extension and the evaluation of their usefulness, feasibility and transferability. Based on the results of the evaluation it was considered that the design and research goal where fulfilled.

The main difference between the result of this thesis and other existing co-creation models lies in the fact that in this thesis process maps were developed, not models. Existing models stay on the abstract level and where designed for the application in a broader context (e.g. co-creation for sustainability, co-creation in urban public space development), while the process maps that were developed are much more detailed and address primarily a specific case — circular extension. However, it is also important to mention that the design was developed keeping in mind that the process maps should be applicable for circular building components in general, not only circular extension.

The “layers” approach used during the design allows to say that the developed design represents the structure of the co-creation process, a co-creation model and a co-creation process map at the same time. If you separate the first layer (phases) you would get the generic structure of the co-creation process for the process design. If you separate first and second layers (drawing the co-creation path) you would get a model of co-creation similar to those developed by other scholars. These layers are based on the parameters of co-creation identified during the literature review and merge different aspects of the existing co-creation models and frameworks. This “model” could be useful not only for the co-creation in context of circular extension, but for the circular build environment in general. Therefore, the first and second layers correspond with the existing academic knowledge at the same time and also adapt it for the case of circular building components.

Finally, all three layers represent the process map, listing phases, steps and options for the development and implementation of VRPs of circular extension, providing a future reader a clear picture of what the co-creation process includes. Therefore, although the process maps are based on existing literature, they complement the existing academic knowledge by specifying and adapting it for the case of circular extension. Additionally, through the interpretation of

interviewees' answers are derived the lessons learned that could be applicable for the co-creation for other circular building components, what complements the domain of circular co-creation and knowledge on how circular transition could be achieved.

9.2. Limitations

Undoubtedly, there are several limitations that affect the results of this research.

The research was started when the REHAB project was already ongoing. This fact implies three limitations. First, the stakeholders were already familiar with the concept of the circular economy. Therefore, it was not established how clear the developed designs are for the people that do not have experience within the circular economy topic. Second, during the informal interviews, it was established that the level of trust and commitment among the stakeholders was high. They either have a long story working together on many projects or it was developed while developing the design of circular extension. Due to this fact, two of the identified co-creation parameters (that have the most effect on trust and commitment) where not included in the design, namely "co-creation motive" and "factors influencing stakeholder engagement". Third, the project has a concrete set of stakeholders and was initiated by the housing association, which limits the generalizability of the results.

The next limitation lies in the duration of this research. Due to the length of this project only three process maps were developed, while there were many more business model configurations that could be adopted for the design.

Additionally, the evaluation of the research was limited by the number of interviews conducted. All directly involved partners were interviewed, namely four; however, four interviews cannot provide a statistically reliable set of data.

9.3. Recommendations

Future studies could improve the developed design by applying it in another project with a set of stakeholders that had not worked together before. Ideally, it should be done at the beginning of the project. This would allow the inclusion of parameters that were excluded from the design and identify how clear they are for the people that are not familiar with the topic of circular economy. Additionally, the process maps could be extended for the use in the whole project (including the product development phase). Further, a study could be conducted involving a larger set of interviewees to analyze the usefulness and feasibility of the design on a wider scale.

Next, during the literature review and evaluation, several other research opportunities where noticed by the author. First, several possibilities for the design improvement where mentioned during the interview. A study could be conducted identifying the importance of each party per step of the co-creation process, this would allow the inclusion of this data in the process map to show stakeholders in which parts of the process they play a vital role, and what could improve their commitment. Further, the process maps could be combined into one design (possibly interactive) to create a roadmap of circular co-creation that does not focus on one business model.

It would show different possible options in each step. During the preparation for the evaluation phase it was noticed that co-creation literature lacks KPIs or parameters to evaluate co-creation which could be another interesting domain to further research. Finally, considering that investors are primarily interested in the costs, it is suggested to calculate the costs that the engaging actor would incur to organize the process. Moreover, it is suggested to conduct as study estimating the end value of circular building components, as this knowledge gap limits the business models that could be implemented.

10. Conclusion

After the study of the theoretic concepts and analysis of the REHAB project, three process maps were developed. These were evaluated with the stakeholders and lessons learned were derived. The research was guided by the research goal, that was formulated as follows:

> *Develop a useful and feasible co-creation process map for the development of VRPs of circular extension.*

The research started with the analysis of the co-creation literature to draw the co-creation requirements, parameters and tools, and identify the models that could be partly used for the development of co-creation process maps. Based on the literature findings, a preliminary list of requirements was developed first that was further completed after the informal interviews with the partners. Further, a morphological scheme of co-creation parameters was developed which included 11 parameters: co-creation motive, co-creation form, engaging actor, engagement platform, level of engagement, duration of engagement, types of outcomes, factors influencing stakeholder engagement, co-creation toolkits, knowledge transfer and co-creation models.

In fact, preparation of the theoretical background of the research was conducted simultaneously with the study of the REHAB project and informal interviews, because problem formulation required acquiring an understanding of the main project problem and how stakeholders are currently collaborating. The analysis showed that the current main gap is a lack of clarity about the development and implementation of the VRPs of circular extension. Further, the stakeholders were mapped and what VRPs could be implemented for the circular extension was analyzed.

Based on the three business models and assumptions about stakeolders' willingness to continue co-creation after the design of the extension was finalized, three process maps of co-creation for the development and implementation of VRPs of circular extension were developed. The developed process maps consist of three layers. First, using the parameters identified in the previous step and looking on the development and implementation of VRPs from the process perspective, the phases of the co-creation process were developed (first layer). Further, using the identified parameters and design examples available in the literature, the co-creation path was developed (second layer). This identified the sub-steps of the co-creation phases. Finally, using the co-creation literature, CBM literature, VRPs literature and supply chain variants developed by the student that earlier completed the research in the framework of the REHAB project, options and activities that should or could be part of each step were mapped.

The developed process maps were presented to the project stakeholders during the semi-structured interviews. They were asked to evaluate the usefulness, feasibility and transferability of the developed designs. All the interviewees considered the developed designs to be useful and remarked that they would use them for the development and implementation of VRPs. The interviewees did not find them feasible under the current market conditions; however, they also remarked that they consider circularity not feasible (or more expensive), in general, in the current market conditions. They pointed out that the developed process designs would be feasible in the

future if circular practices become more common or if the current trend of rising material prices continues. Further, all the interviewees considered that the developed designs could be used for other circular building components after small changes.

Interpreting the interviewees' answers and analyzing the correlations and contradictions between them, six lessons learned were derived that could be applicable for circular building components in general:

1. In the end, partners look primarily on the feasibility of the co-creation process from the perspective of final feasibility of the whole business model. Cost efficiency is the main aspect in the implementation of co-creation process, none of them considered co-creation outcomes (e.g. innovation, knowledge) although they were mentioned during informal interviews.
2. Organization of circular co-creation process requires involvement of a human interaction specialist and circular economy consultant (which could also be one party) that will guide the parties through the whole process.
3. The potential circularity of the whole process is highly dependable on the party that initiates the process and becomes the engaging actor (or problem owner). The resources and capabilities of this party determine the business models that could be implemented and highly affect the potential of cascading of the materials and modules.
4. Looking from the perspective of the current reality (in which the housing association is the client), development of VRPs requires involvement of parties that could take on the role of the secondhand market to secure the circularity of the process because it is questionable that such a market will appear by itself.
5. The co-creation process would be similar for different business models and different circular building components. Together with the change of studied circular building component and business model, changes the problem owner and network composition, what further affects the possibilities of process improvement and, circularity and feasibility of the process.
6. Under the current market conditions, sell and buy-back option has the most potential for making circular building components truly circular. Therefore, it is suggested to attempt to develop the VRPs around this business model.

The main results of this research are the process maps developed and the lessons learned identified. These could be both applicable not only for the circular extension, but for circular building components in general. As it is explained in the discussion, this research goes one step further compared to previous co-creation research by developing co-creation process maps instead of a co-creation model. By specifying the co-creation process for the case of circular extension, the developed process maps show a route that stakeholders could follow. Evaluation of the process maps and interpretation of the interviewees' answers allowed to derive lessons learned that, together with the process maps themselves enrich the knowledge in the domain of circular building components and circular co-creation. By answering the research questions and

accomplishing the design goal, this research complements the domain of the co-creation knowledge and partly fills the gap in the co-creation knowledge related to the circular build environment and, particularly, circular building components.

By taking a step back to look at the research as a whole and the lessons learned, several more conclusions could be made. First, the transition of the construction industry to the circular economy requires big system changes. Implementation of a fully circular solution requires changes in the roles of the parties in the supply chain and adapting to new ways of working. As the interviews showed, circularity is still more expensive than the linear processes, and pioneering a circular economy can be achieved only by companies that possess enough resources to invest. On the other hand, these companies' investments could create a significant competitive advantage in the future, when the market adopts more circular practices.

Another important point is that the industry still approaches projects as projects. Transition of the construction industry to the circular economy in the current market requires a change in approach. Probably the process should start with the manufacturers, because if they do not make a step forward and agree to adapt to leasing or buy-back options circularity will not be secured. We can see this from the case of circular extension: it was designed to be circular; however, the existing system (or network) limits the number of business models that could be implemented (because the bills are paid by the housing association) and correspondingly limits the circularity. The contractor does not want to participate in the buy-back of the extension and the manufacturer's ability to take on the role of the supplier of services is also doubtful, also the manufacturer's desire to buy-back the extension is also doubtful. Thus, although circular extension was developed as a circular product it is not yet a fully circular product. Right now, there is a DB contract and no certainty about the future of the product. Moreover, transition based on these business models requires further research in the end value of circular building components. The implementation of circular building products at the current time requires a set of "big" players that are ready for the large investments required to develop fully circular solutions that start from production to develop the products with a particular circular business model in mind, rather than try to find a way to make the final product circular.

At the same time, if the circular practices become more common and, especially, if the cost of material prices continue to rise, we could see the formation of secondhand material markets. In this case it will be possible to implement solutions that could be considered "less" circular today because of uncertainties. If we are sure that we can sell the product in 10 years to recover the materials, we consider this product is circular, but this is not applicable today.

Circular economy transition in the construction industry is a complex issue that will require further research and knowledge to be developed. Today the first steps towards this goal are done and we continue to move forward. This research supports this transition and contributes to the limitation of unsustainable practices in the built environment.

11. Reflection

It seems that my one-year long journey (or 7 months starting from kick-off) of writing this master thesis is coming to an end, and it is time to draw a line and reflect on the graduation process.

To be fair, initially I was not going to conduct the research on circular economy. All the knowledge I had about this topic was limited to a couple of thesis presentations I attended out of curiosity. I think it is important to mention, that before starting to work on this research, I was going to do a study in a completely different domain. Due to coronavirus the company I was working with could not continue to collaborate. I can say, that looking for a new topic I was depressed, because it was the first time in my life when things went completely not as I planned them. Of course, I had faced good and bad luck before, but had not experienced anything that would set me back a few months or even almost half a year. Probably the first thing I learned when starting this thesis is that everything bad that happens remains bad only as long as you think about it.

After the first meeting with the project supervisors I was really happy, because I felt that working with these people will be great and, going ahead, my feelings did not deceive me. When I started to work on this project I felt extremely passionate about it and dove into reading. I was reading everything I could find about the circular economy and getting more and more knowledge on this topic. Before the summer break we decided that I will do the research in the domain of co-creation, but here I made my first and probably the biggest mistake throughout the whole research: I continued to read everything I could find, although it was time to focus on my topic. It took me almost two months to realize that I am doing something wrong, because I was getting more and more knowledge but was not getting any closer to finishing my research proposal. To be honest, with how much I read during that period I probably could do other research in the domain of circular supply chains or circular business models. On the one hand, it was a bad thing because I could use this time more efficiently but, on the other hand, the knowledge I gained supported me throughout my research. Here, I would like to thank Anne, Gerard and Tuuli, because they pointed out that I spent my efforts on too many topics and to continue to stay on the abstract level. They explained to me how to read correctly and how to focus on the concrete things. That was the second thing I learned: how to correctly read and choose relevant information.

Correct reading greatly accelerated the process of writing of my research proposal and after a couple of weeks it was ready. The third thing I learned was how to correctly write or how to write for any reader. During the kick-off meeting, John, my graduation chair told me that what I wrote is completely unclear for a reader unfamiliar with the project. This resulted in the need of conducting of the second kick-off meeting after which the research was officially started. Further, during the whole research I kept this in mind and tried to write in such a way that readers of any background would understand my research.

Further, I started working on the development of the process maps. Although, I consider that I always thought structurally, I unlocked the next level of this ability during this research. Structuring the enormous amount of co-creation knowledge that I learned and combining it with other knowledge domains (such as circular supply chains, business models, network governance types, knowledge transfer methods, etc.) required a lot of time and effort. What is more, at some point I structured all the information in my head but did not know how to deliver it to the reader in such a way that it would not require too much time to understand. Being a person with a civil engineering background and working before only in the structural engineering department of a company, I was used to drawing things according to a plan or the "rules". During this step of the research, I learned how to design. How to use graphical design software and how to present information in such a way that it would be accessible to the reader. Here I would like to thank again my project supervisors, because they helped me to walk through this path and arrive to my final design.

Next, through almost all my life I was used to self-imposing unrealistic deadlines to motivate me to work more and harder. A project of this length taught me that it is not always the best practice, because it results in periods of hard work followed by the periods of loss of motivation.

Last, but not least, I learned a lot about the circular economy, circular co-creation, circular supply chains, circular business models, etc. Above I described the skills that I developed during my research, but I think that the most important thing is the knowledge I gained during this research.

When I applied to TU Delft, I was interested in management and saw myself acquiring a junior position in a big construction company after graduation. However, now, I want to take the skills and knowledge I have developed and continue my path to becoming a highly qualified and sought-after specialist, but in a different domain.

I plan to take the skills and knowledge and continue to develop them. Probably the main thing I liked is working on developing solutions, on finding unconventional ways to answer the questions and developing something that no one had before. I believe that I can do it in the consulting industry (and ideally in the firms working on the implementation of circular economy solutions). I believe that there I will make use of the skills and knowledge that I developed during this research.

Summing up, I did my bachelor in Russia and, due to this background, I definitely did not have the skills required to complete it at the beginning of the research. Writing a thesis in Russia is very different. For example, during my previous thesis we were assigned to develop the design of an industrial building and there was a limited choice of types of building that you can develop. In short, you have something very concrete that you need to develop, and you follow existing guidelines to do it. I would say, this is very different from developing something that does not exist. However, I acquired the required skills during the research and I also acquired a lot of knowledge about the circular economy. I will take these skills and knowledge further to continue my development as a specialist. I consider that I can call this thesis a successful academic piece, partly contributing to the scientific knowledge. Finally, I hope that my findings will help the REHAB

project stakeholders in achieving their circular goal and help other businesses that aim to make the circular transition.

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Appendices

Appendix A – Protocol of definition of the search term

The overall goal of the research is designing of the co-creation process map for the development of the VRPs of circular extension. Thus, the expected outcome of the literature review was setting up the basis of the conceptual model. Following the questions that the review aims to answer, it was expected to derive models and practices of co-creation both in the built environment and in other industries, involvement strategies and techniques and tools that could be used during the co-creation process. An integrative literature review was considered a suitable approach as its aim is to assess, critique, and synthesize the literature on a research topic in an integrated way such that new frameworks and perspectives on the topic are generated (Snyder, 2019). The literature review was conducted following the steps described by Snyder (2019).

The search of the literature was performed using the Scopus database. The review was conducted in stages by reading abstracts first and making selections and then reading full-text articles before the final selection.

First, the search terms were defined based on the aim of the review. First, following search term was formulated:

TITLE-ABS-KEY((co-creation OR collaboration OR partnering) AND (framework OR model OR strategy) AND (construction OR production) AND circular) AND (LIMIT-TO (LANGUAGE,"English"))

This search resulted in the list of 74 articles, which considering the limitations of the research was found feasible. However, the initial scan of the articles showed that most of them are irrelevant for the goal of the literature review, as largely they address circular design, IT and environmental effect and other topics, rather than co-creation and process mapping. “Playing” with search did not help. Excluding term “circular” and limiting the search to the areas of *Business, Management and Accounting, Engineering* and *Social Sciences* resulted in a too big number of articles (over 16000).

Therefore, the search was reformulated. Through the analysis of the titles, keys and abstracts of the irrelevant articles from the previous search, it was concluded that the majority of irrelevant articles contain the search terms in their abstract. The terms “construction” and “production” were considered to be too generic to arrive to the necessary results. Moreover, the term “co-creation” is also used by scholars to often define different things. Taking this into account, and the fact that the search without these terms would be even less feasible, the search was once again reformulated.

Analyzing the titles and key patterns in the literature that was found during the development of the theoretical background section, the following search rules were formulated:

- They keys should contain co-creation OR value co-creation

- The title should contain (co-creation OR collaboration) AND (model OR framework OR process OR management OR circular economy OR strategy)

Combining these rules and excluding book chapters and notes and limiting the results to English language, we arrive to the following search term:

(TITLE ((co-creation OR collaboration) AND (model OR framework OR process* OR manag* OR "circular economy" OR strateg*)) AND KEY ("co-creation" OR "value co-creation")) AND (LIMIT-TO (LANGUAGE , "English"))

This search resulted in 360 articles. The literature review was continued with the analysis of abstracts. Based on the knowledge gained during the preparation of the theoretical background of this research and scan of the articles during the previous searches the following selection rules were formulated:

- Article is selected if it addresses co-creation in the built environment or other industries, except:
  - IT, game development industry, "experience" co-creation, crowdfunding and tourism, as these articles address only the co-creation with the user (client), what was considered not relevant, as this research studies co-creation in multi-stakeholder environment
  - Education and brand co-creation, as these articles look on co-creation from the perspective of organization (co-creation between students and stuff, co-creation between employees of the firm)

Analysis of the abstracts resulted in the selection of 82 articles, 20 of which could not be downloaded due to the access restrictions or "broken" links. Finally, the 62 articles were read to do the final selection. This resulted in dropping 31 more article due to the various reasons:

- Article used the co-creation term in other sense, than the one required for the research
- Results were limited to English language, however a couple of articles were in Spanish
- Some of the articles were mentioning the concepts that the author was unfamiliar with and after gaining understanding of this topic were considered irrelevant (e.g. DEMO model)

Appendix B – First informal interview with the representative of contractor

The interview with the representative of ERA Contour – Projectleader Nils Vanwesenbeek was held online on 11.02.2021

Participants

Interviewer: Denis Chiosea (DC)

Interviewee: Nils Vanwesenbeek (NV)

Interview transcript

DC: First questions are about the concepts that I became part of my research. What is your understanding of circular economy and circular economy in the built environment? In a few words.

NV: I understand it as the ultimate goal of reducing of the use of our planet in a wide scale of ways. Not just from materials perspective, but also business models and materials that are already in place, reusing them, keep them cycling. It's all about the environment and the smart use of materials, smarter use than we do now, because there is so much value that we don't use or throw out or never use again, which is getting wasted.

DC: Next question is: are you familiar with the co-creation term and how do you understand it?

NV: You work with, different partners with different skills, which can also be, different companies. You work towards the same goal and use everybody's skills in the most efficient way. The goal could be different: make something or sell something, but the idea is that you work together.

DC: What is the role of your company in the project?

NV: We are the contractor for the renovation. But in fact, we have a few different roles. It's design build and maintenance of the project. In this case, we are also the contractor for the design and development phase.

DC: Why are you involved in the project and what is personally your role in the project?

NV: I'm the project manager from the contractor and my role is to make the plan fit within budget and desires of the owner of the houses. My role was: before I used to be the advisor for this project, just for the energy part. It's not just a circular project, it is going to be full electric, no connection with gas connection.

DC: Do you mean it is a zero-energy project?

NV: Yes, exactly. That used to be my role in the project and then I was asked to take the contract by ERA Contour.

DC: Could you name essential parties or essential stakeholders in the project.

NV: That's our architect, which is a DOOR Architects, which joined at the start of the project. They had more experience than we had in circular renovations and circularity is in their genes. TU Delft and Anne van Stijn which guided us through the project from design and development. Then we have the subcontractor (manufacturer), that normally make frames and wooden building parts in

hallways. They helped us develop circular extension. They basically make 90% of the circular extension. The name of the company is Van den Oudenrijn.

DC: Are all the required stakeholders already in place? Or some of them are still absent?

NV: For the current goal all the suppliers are in place, but if you want to go on with the development we could use a party, who can search more materials which we can reuse in our circular extension. Of course, behind that company will be other suppliers that we could involve. Additionally, could be involved a company who could lead us to making this a workable business model. A company that would help us to see what the chances are of making it bigger. Because this is not something that we are used to do so we could use help with that.

DC: How do you collaborate with other stakeholders? What is the project organization? Who is taking the leading role? Who is making all the workshops? So, who is leader and how do you collaborate?

NV: Our company is leading. It's our responsibility within this cooperation with the house owner. We work as a team, so we organize team meetings. I make the agenda for them and set the goals. We used to do this with the guidance of Anne van Stein who would help us to set the goals and keep the planning straight. We make contracts. All the partners are involved in the meetings. The architect is also within these team meetings, so he does the drawing and the designing stuff. More technical questions we address the supplier. That's basically how it works. And also, I inform the end-user about our steps.

DC: How often do you meet how often do you have these meetings?

NV: The minimum is once in every two weeks.

DC: What tools and methods to you currently use for your collaboration?

NV: Yeah, for the meetings we use Microsoft Teams, otherwise without Corona, we would just meet up at the place, which is most effective to meet at. This could be at our office or at the office of the architect or at the office of the supplier or at the site, where we have two homes which are currently empty. One we use as the office and the other one is model house, which we also show to the habitats of the complex to show them what it's going to look like. We have a BIM model, of course, which is pretty basic right now. We have shared disc spaces, several actually, that's about it.

DC: What is the level of trust in the project and if it's high, how was it established the level of trust?

NV: Very high the supplier is a company we work with for many years. We had many successful projects with them. They are really trustworthy for us. The architect is also selected by us because they have good credentials in circularity. The collaboration is going well, so the trust is also very high. Everybody gets their goals pretty much so there are no trust troubles or any case.

DC: Do you have any contractual arrangements in terms of costs and risks?

NV: We are the main contractors, so the most risk is at our place. We make contracts with other parties. With the supplier for what he is making and what it costs. But during the development

phase we collaborated without any contracts. Everyone was involved with the sense that they are going to be the one who is also going to deliver it. Further along everything is in contracts.

DC: What, in your opinion, are the main barriers that are present in the project right now?

NV: The budget. The budget for the circular extension isn't that big. We also have a time barrier. The project should be finished within this year. The homes that we are renovating are still occupied. We have many parties. Plus, we have own quality management, time management, financial management which could become barriers if goals are not met.

DC: What do you consider critical for the success of the project?

NV: We have a really nice collaboration within the team. Circularity is really hot topic right now. Everybody wants to learn about it. So, everybody is also motivated to learn about it. Another key factor for the success is that it's pretty small to develop. It's not like a really intelligent thing to make a circular extension. It needs some intelligence but it's still practical to get there. And the barrier, which we just spoke about is that the project has to be done by the end of this year which is also a key factor to keep going and keep the pressure on and get it done.

DC: I know that during the workshop you developed a preliminary design of the supply chain and business model. Could you please describe them?

NV: The business model is not completed yet. Actually, only designing it circular and implementation of reuse of materials is done. But how we are going to maintain it and what's going to happen within these 30 or 40 years is still in progress. That's also not the main focus for this project. Because the circular extension is a replacement of an old extension which has to be replaced now. That is basically goa number one. The business model after replacement is not completely developed yet.

DC: Let's talk about what happens after you installed the circular extension. As I know in literature we can find 10 VRPs: Refuse, Reduce, Resell/reuse, Repair, Re-furbish, Re-manufacture, Re-purpose, Re-cycle, Recover, Re-mine.

NV: The reduce principle has been used in the development phase. I do not think that the extension is going to be reselled. It is going to be there for 40 years. A minimum of 40 year. So that's quite a long time and at that point, maybe the houses with the circular extension are going to be demolished and then the circular extension, if it's still good enough could be placed anywhere else as a circular extension again or you can reuse parts of it. I don't think we are going to look on the long loops right now (meaning repurpose, recycle, recover, remine)

DC: What about other loops, for example repair, who will be responsible for repair/refurbish?

NV: We, but we are not the owner. The owner will be the owner of the houses and we are getting paid to get it placed right now. And afterwards we might be getting paid for the maintenance of it.

DC: Is it going be refurbished or remanufactured or are you going only to take the parts as you've just said?

NV: Depends on if it can be replaced as a whole, as circular extension for another house. But you can also take it apart and use pretty much all the parts in something else, maybe another form of

circular extension. It mainly consists of the elements of made of wood and isolation. Which you can use in all kinds of projects or another extension, or you can use it as isolation on the insight or stuff like that.

DC: Let's talk about recycling. Did you find the partners for recycling of the materials that are in circular extension and can all the materials in circular extension be recycled?

NV: All the materials used in circular extension could be recycled. There almost no any materials which you can't use anymore or recycle, but there are no contracts made on who is going to do this and what this is going to cost. In general, we don't want to recycle it we want to repurpose it or reuse the whole thing.

DC: You just said that your company has the main role in the project, that the responsibilities are on you, that you are the leading party. In your opinion, to successfully realize the VRPs, should you stay as the leading party or the leading roles should be transferred to somebody else?

NV: There is no other circular extension. If there was any I would have said use that one. Then they could have a contact with the supplier directly without us in between. You could just get the best one for the project and that would be the perfect way. Because now we have to develop it within a team from scratch. There are many sorts of prefabricated extensions or small homes for example, but none of them fits in the project. They are not smart enough or not circular.

DC: In this case, based on the example of PSS I have a question about ownership. Should the ownership stay with manufacturer too in this case, and the extension will be provided as a service?

NV: I think they should keep it as a product. Because the extension is just a small part of a whole house, which also should be maintained. If you provide it a service, it is going to be inefficient. It is going to be all kinds of different services instead of complete ownership for maintaining the whole complex. That's going be less efficient. Because from the perspective of all the different services, if you see the extension as one surface and the roof or the installation on the roof, so nobody is keeping it together, I think the end-users are not going to be too happy about the efficiency of the maintenance. May be this could grow, but I do not see this as an option right now

DC: Do you see any other barriers for the development of value retention processes?

NV: Basically, it is still in development. Things with circular extensions and circularity as a whole are pretty new to us. At least the things we did. It costs us a lot of times and a lot of money to develop it. Would be nice if there were more business models already running which you could relate to. To make it more efficient, to develop a new business model just for this circular extension.

DC: Do you have any additional comments?

NV: Yeah, it has been really interesting, and it has been the best course I've ever had because I've learned by doing it and of course it's cool that it's not just theoretical, because we already placed two circular extensions. But also, all the other 60 houses within the project. All the habitants have seen it, felt it and are excited about it and about getting it in a replacement of the extension they have now. This makes it more fun and makes it less theoretical which is also our goal. Our goal is to have happy habitants and a happy housing company in this case.

DC: You said that you built something like a prototype house and show it to the residents, right? How is this process going are they actively participating in this, are they really involved?

NV: It is a renovation project. It is not only circular extension and maintenance of the buildings. As I said earlier, it is going to be zero energy renovation project. There are a lot of changes in every house. This also affects the quality of living during the renovation and implies major changer. According to Dutch law 70% of all the inhabitants has to approve this renovation. That is why we made a prototype, not just for the extension, but for one house, which we show to all the habitants on appointment. They can see and feel what's going to happen, or what's going to be the end result for their own home after the renovation. Which is critical in this process because without them, we don't have a plan and we don't have a project

Appendix C – Second informal interview with the representatives of contractor

The interview with the representatives of ERA Contour – Nils Vanwesenbeek and Saskia van der Weerd was held online on 11.03.2021

Participants

Interviewers: Denis Chiosea (DC), Stefanos Voglis (SV)

Interviewees: Nils Vanwesenbeek (NV), Saskia van der Weerd (SW)

Interview transcript

Participants introduce themselves and interviewers introduce the projects they are working on.

SV: What is the end goal of the project from your perspective and why do you participate in it?

SW: We think it is important, the market asks for it. Housing association asks to solve this problem. Our goal is to answer this question.

NV: It is important for us to learn what the best response is to answer that question. This could be: develop a circular extension. We knew it is a larger project and in combination with Anne van Stijn we saw a great opportunity to participate in this project and learn from it. So, it is pretty low risk for us to do it.

SW: We have a contract with the TU Delft and they guide us, which provides us knowledge.

SV: So, you would say that the main goal is societal, but in the same time you also want to get competitive advantage?

SW: Yeah, it is both, we think it is important for our future and that the market is going to change eventually. As Nils said it is a great opportunity within the collaboration with TU Delft.

NV: We would not have done the same if we were asked to develop a new fuel engine or something, that needs to be ecological. Nobody is going to ask us for a new fuel engine, but we think in the future housing owners are going to ask more questions about circularity and it is good for us.

SW: We have an advantage to our competitors

SV: Let's talk about business model. What kind of contracts do you have with the partners?

NV: It is split in two. We are asked to design and build the extension and the maintenance is optional

SW: The maintenance is not yet in the contract but could be.

SV: So, are you trying to follow a specific business model for circular extension?

Introduces different types of business models

NV: We are most proficient in development and building and other parties are better in maintenance or application of business models with the buyback options.

SW: Yeah, that is something we are still analyzing. We are not really far with it yet. We need to have more information to make a decision about what we are going to do. We are not yet sure what we will do with the maintenance. As Nils said, normally we do not do maintenance, so it is difficult for us

SV: Could you describe in more details the technical model of the circular extension. A small overview of how you see the design of circular extension.

NV: I think it is split in three parts. First is design and technical specification of the module. Second, would be the materials that are used in the module. Third is how we are going to maintain it. We made an extension which is modular by itself. You can make a double extension from two extensions both in depth and width. So, it is really easy to extend it or to use it somewhere else. We thought about making it on the factory instead of site, so we could move it with crane and pick it up later. The sizes are also standardized. It is designed using the grid with the steps of 60x60 centimeters. So, we use the same size that is used in the materials that we use, so there would be less waste. Moreover, it is practical because the things from the outside world also often use this grid. For example, washing machines are 60x60 if you look on top of it. This makes it easier to use it.

Second part of design is what materials we use. Here we thought about two things: we need to reuse what we can reuse from this project or other sources. For example, the finishing wood and windows, as well as doors are from another renovation project. Also, we try to repurpose the things, so we search for the wood that we could use for circular extension from somewhere else. For example, we already did it for the insulation. The third is maintenance. The ideal for the maintenance would be to make it low cost and easy to repair.

SW: Also, we do not glue it.

NV: You can easily take it apart if you want to fix one component. However, this is not our focus area, we are not in operation, because we do not do maintenance after renovation, but we have an eye for lower maintenance costs for the future.

SV: Do you use the tools for the materials? Such as material passport or material certification?

NV: We use a database for the environmental impact of materials. For example, if at some point you think about what board you will use for the floor, you choose some options that suit you and then you check this website and use the one with less environmental impact.

SV: So, you are not yet responsible for the maintenance?

NV: Yes, right now it is optional

SV: Do you know how many new partners you need to maintain the circular extension?

NV: I think we need three new partners. Somebody to do the painting of the doors, windows and frames. A partner which will do the roofing. And a partner, or it could be us, to do the carpenting.

SW: The carpenting could be done by the same party producing it, but it could also be another partner.

SV: About the design, so the extension consists of different parts such as roof, walls, windows, anything else? So, what are the modules of the extension?

NV: The circular extension is put on steel foundation and the components are floor, walls, roof, frames for the door and windows and the rest is outside: roofing, finishing wood and insulation layer and water drainage. So, you have the component, water resistant layer and finishing wood which we reuse from our other project.

SW: A lot of other materials are also from another project. For example, water drainage is also from other project, as well as doors.

NV: So, it is second hand, but still good enough.

SV: So, you collaborate with other partners. Could you describe information sharing with other partners. Do you share it and how?

NV: Our partners are carpenter, roofing specialist, construction specialist, architect, construction designer

SW: We share the knowledge with them. We have a lot of meetings and workshops dedicated to the circular extension.

NV: Everything is integrated. The development decisions are taken together with all partners, because it could influence them. So, we do it during the workshops.

SV: So, you say you are really open to each other?

SW: Yes, completely open, we think it is important, because otherwise we do not think we would be able to have this result. Or it would take much longer

SV: So, you strive to define the scope in the beginning in the best possible way by including all the partners?

NV, SW: Yes.

SW: And also, we consider it is important to involve the client, to ensure that what we make is what they want.

NV: It is also important to ensure that the parties we work with have the same motivation as we have. We told them it is going to take a lot of time, but they will learn from it and we are going to do it together.

SV: You mean you incentivize them by this?

NV: Yes, they have the same motives. The goal is to create competitive advantage by being first in circular economy. By doing things ecological and sustainable.

SW: Also, we have long time relationships with all the parties that we work have.

SV: Thank you, I would like to provide Denis time to ask you the questions:

DC: My first question is how much trouble would bring the necessity to change the supplier. Is it a bottleneck of the project or no?

SW: It is not a bottleneck, but we think it is better to keep the same supplier, because they know how the extension is built. But, well it can happen. In this case it is important to keep the information that will be needed for a new partner.

NV: In the development phase it is really hard to change the supplier, we would need to start the process from the very beginning. But when the project is finished, and we have all the information and data it will be easy to reproduce it. However, in the development phase you need each other to make it.

DC: I saw on the Eigen Haard website that you are building an exemplary house. Do you collect the users' feedback and how do you think the users (residents) could be involved in the process? For example, only for feedback or could they also be involved in the maintenance?

SW: I do not think we can expect too much from them. Because they just rent the house and they are not really involved. Nils had a stop and chat with all the resident, so we know them, but I do not think they could be involved in the maintenance.

SV: Did you think may be about development of groups from residents that would check the houses and if there are any malfunctions notify you.

SW: Yeah, we ask feedback after a half a year. We want to know what they think of it, what are the problems.

NV: The other system is if something is broken and needs to be repaired they call the owner and it needs to be fixed, because it is part of their contract.

SV: Did you think about creating a digital platform where residents could indicate their problem, for example through walking through the house and marking it?

SW: At ERA Contour we have a feedback system. People can upload the photo in the system, so we knew what the problem is, so we do not have to go there to check it. Instead we directly come with the materials

NV: But first, the housing owner gets these pictures, there is no direct connection between us and residents.

SV: Do you have any knowledge on the management of the supply chain of circular extension? About material sources or any other things? Do you have any management tools or requirements from the supply chain?

SW: Nils decides what materials we buy. Right now, our supply chain consists of the partners we named. We know this party for a long time. The choices: for example, what kind of wood we use we take together during the workshops, but the wood is ordered by our supplier (meaning the party manufacturing extension).

NV: Yeah, so carpenter as the most experienced party shares what options it is possible to use and then together we take the decision on which one we are going to use. Then we check for environment impact, costs and maintenance costs.

Appendix D – Semi-structured interview with the representative of manufacturer

The interview with the representative of Van den Oudenrijn – Rob van den Oudenrijn was held online on 25.05.2021.

Participants

Interviewer: Denis Chiosea (DC)

Interviewee: Rob van den Oudenrijn (RO)

Interview transcript

DC: Today I will present you the results of my thesis. They consist of three process maps that I developed.

The interviewer presents the developed process maps. Secretary translates unclear parts. Due to the language barrier, the interviewee asked to answer the questions in writing. The answers are presented below.

Evaluation of usefulness:

DC: Do the developed process maps provide the knowledge needed for the organization of co-creation in context of the development of VRPs of circular extension? Why or why not?

RO: Yes, they are a good guide for the various options.

DC: Would you use the developed process maps (and/or which one of them would you use) during the development and implementation of VRPs of circular extension? Why or why not?

RO: I would only consult them, and which one depends on the case.

Evaluation of feasibility:

DC: Do you consider that the engaging actor (or problem owner) would be able to implement the designed process?

RO: Yes, because the scarcity of raw materials and the associated price consequences will force the manufacturer and contractor to do so.

DC: Do you consider that organization of (product as a service/sell and buy-back/user-oriented) co-creation process and implementation of VRPs would be economically feasible? Why or why not?

RO: Not in the short term because there is no market for it (yet).

DC: Could you highlight any strengths and weaknesses of the developed designs, in your opinion?

RO: Strong: good handle. Weak: practice is not always predictable.

DC: What opportunities and threats, in your opinion, do the developed designs bring to the problem owner?

RO: Opportunities: well organized process. Threat: financial feasibility of the process.

DC: The developed designs also include process iteration loops. How would you rate/evaluate their effect on economic feasibility of the process?

RO: No rating.

Evaluation of transferability:

DC: Do you consider that the developed process maps could be used for the co-creation in context of other circular building components? Why or why not?

RO: I think so, but practice will have to prove it.

Appendix E – Semi-structured interview with the representative of architects

The interview with the representative of Door Architecten – Terry Pater was held online on 26.05.2021

Participants

Interviewer: Denis Chiosea (DC)

Interviewee: Terry Pater (TP)

Interview transcript

DC: Today I will present you the results of my thesis. They consist of three process maps that I developed.

TP: Could you clarify what the VRPs are? I think I get the process but know another word for it. So, could you explain it from your point of view?

The interviewer clarifies the meaning of VRPs and presents the developed process maps

Comments during the presentation:

TP: For me it is quite deeply what you have done in your research, mapping all the steps. Usually this kind of schemes are more general, like the main line with your phases. It is a really good research in my opinion about what you have done and really brought that. It can really help people that are interested in circular economy and more into the whole process and the steps you have to take. It could help them really well I guess.

TP: Wouldn't it be more logic mirror, reuse and recycle that whole piece (meaning the VRPs block in product as a service map). So, on the left, you have the most, circular element and more to the right, the less circular variant with a recycle and remanufacture. Because it starts with the refuse. Just do not do it. And recycle is the last one. We are in the Netherlands and we are not really good in it, but a lot of things are already been recycled and a lot of general people think, oh, recycling, oh, that's really good. But recycling is quite horrible. When you can refurbish it or repair it or refuse to. People always really lazy and start on the left. Ah, that that will be the first one. That's would be probably a good one. And if you start re reuse and then repair, refurbish, remanufacturing, recycle, I think is, at least for me, it would be more clear that's on the left, there is a better way of doing it.

TP: I think that the first two are really, usable in the circular economy for contractors and clients and socials corporations. Sometimes the user oriented could be used.

Evaluation of usefulness:

DC: Do the developed process maps provide the knowledge needed for the organization of co-creation in context of the development of VRPs of circular extension? Why or why not?

TP: Yeah, like I said earlier, I really think they could help a team with the contractor, the client, the architect, the installation guy through it. I think, one of those people really should understand what the scheme is for, or maybe external people, to spread the knowledge. For example, what Anne did in our projects. She went to some meetings and really explain to the rest of us how a circuit building could be or what our research was about. So, I think it's not knowledge that everybody already has, that it's really easy to implement. With a little bit of help, it will be really useful and an eye-opener for a lot of people, because a

lot of people are still thinking linear instead of circular. I think if you provide it to people who have more knowledge on circularity, they should understand it quite easily because what you have done with your scheme is a really clear. It's quite deeply research with a lot of parameters and stakeholders. So, yeah, I think it's pretty far and pretty good. Yes.

DC: Would you use the developed process maps (and/or which one of them would you use) during the development and implementation of VRPs of circular extension? Why or why not?

TP: Yes, I would like to use one of them, I think the sell and buy back. That's one I am most interested in, because I would really like for my clients to buy stuff with guarantee that they can sell it again to the manufacturer to a) gain another financial aspect b) to gain a better quality of products; because the manufacturer in a way he knows that he will buy it back in 10, 20, 30 years. Therefore, he needs to deliver a really solid and good product. In other words, he needs to buy a product that he can resell again. So, yeah, that's one of the schemes I would use, and I already sent it to one of my colleagues to show what you are doing. So maybe I wouldn't be the only one who would use it, but as well, other colleagues of DOOR architects.

Evaluation of feasibility:

DC: Do you consider that the engaging actor (or problem owner) would be able to implement the designed process?

TP: For the social housing corporation and the product as a service. What's really difficult in there for the social housing corporation is that they will always ask: “Okay, what will it cost me at the end? What will it cost me in 10, 20 years?” For example, if they want to buy a heat pump or they want to lease a heat pump. Buying a heat pump and using it for 10 years, with all the maintenance would be way cheaper than leasing it for 10 years. So, in this case they will buy it themselves and not lease. But, that's due to that social housing corporations can rent money from the Dutch governmental bank of municipalities or whatever. They have their own banking system with a really low rate of rent. So, they can achieve money really, really, really cheap. In the same time, for example, when you have an investor or a private party that don't have this bank with a really low rent, but they have to pay 3/4/5% per year, then a lease construction could be way more feasible after some years. So, depends a bit on how they cooperate with each other. And what I really see is that manufacturers are not only trying to sell the products that last couple of years, but as well, the maintenance like the DBFMO kind of contracts that not only design build, operate maintenance et cetera, et cetera. When I was graduating, I joined a team. It was called the weekend of the empty building. There, we developed DBMFO and demolish it again contract. Where's my story going because it's rather long. Manufacturers and contractors and housing corporation are going to more extensive relationship for not only buying something, but as well, maintaining and operating for 10, 20, 30 years with contracts on it as well. So, they are already way more and more involved than in the past. I think that's really good for the circularity and quality of stuff. So, I think the problem owner can change and it will change a bit.

DC: Do you consider that organization of (product as a service/sell and buy-back/user-oriented) co-creation process and implementation of VRPs would be economically feasible? Why or why not?

TP: Yeah it will be, especially on releay specific parts or small parts, or when you have a good idea or when you have already a good selling opportunity when things are really coming together. Right now, it's rather

hard to implement, but I think in 10, 15 years especially when the circular economy will be grown up and it will be way more standardized.

DC: Could you highlight any strengths and weaknesses of the developed designs, in your opinion?

TP: I think the strength of your design are nice colors and the color scheme that you have chosen, also nice icons, really easy to read and to see. I think that's really the strong piece. What could be the weakness? When you don't know enough about the topic it could be a bit overwhelming. Yeah, but it depends. If you erase parts of it, then it may it will be too simplistic for a reader. No, I wouldn't change it. No.

DC: What opportunities and threats, in your opinion, do the developed designs bring to the problem owner?

TP: A nice thing could be that when they want to follow through the whole scheme. Right now, a lot of things are pilot projects and they're just done according the way 2/3/4/5 years. In our company, we build our own office, six years ago. There wasn't any literature or examples, we just did it. On the way we thought, oh, let's try this, oh, let's try that. So, I borrowed a steel container, put it on the roof and made some sort of contract for seven years that I can have it for seven years and then he will have it back. We just did things as a pilot, to try out. With schemes like this you know in advance or on forehand what's going to happen or not completely what's going to happen, but what you can expect. So, that's way better than what we tried five years ago.

DC: The developed designs also include process iteration loops. How would you rate/evaluate their effect on economic feasibility of the process?

TP: I think they would improve feasibility. Because for the stakeholders it is primarily about the costs and the economic impact and the impact on stakeholders and on the people that are living and circularity. What it will do on the balance, or on the cost side of the contractor or of the social housing client. So yeah, I think those iteration loops do really well.

Evaluation of transferability:

DC: Do you consider that the developed process maps could be used for the co-creation in context of other circular building components? Why or why not?

TP: Yeah, I think they can be quite easily transferred to not only the extension, but as well for a window or an installation thing. I can imagine that stakeholders will differ a bit, but I think it would be quite easy to change it. Furthermore, if you have some sort of base and you have the project, you could really make it project based. You could fill already in the clients that you're working with or with the co-creators. So, as well, you could gain some more commitment. For example, if you have a social housing company and you have a client and an architect in somewhere you see your name dropping. That would be a "Oh, in that process I have a big role, in that process I don't have a big role". It would only improve it as well, too improve the commitment for parties. I would start my own advisory firm if I were you in three months and just sell your scheme.

Additional comments:

TP: I would suggest translating your maps in Dutch, because clients and especially contractors and manufacturers are not familiar with reading English stuff, so their level of interest is a bit down. Translation to English would allow to spread it easier around them. Of course, if it is one of the goals.

Appendix F – Semi-structured interview with the representatives of contractor

The interview with the representatives of ERA Contour – Nils Vanwesenbeek and Saskia van der Weerd was held online on 28.05.2021

Participants

Interviewers: Denis Chiosea (DC)

Interviewees: Nils Vanwesenbeek (NV), Saskia van der Weerd (SW)

Interview transcript

DC: Today I will present you the results of my thesis. They consist of three process maps that I developed.

The interviewer presents the developed process maps

Evaluation of usefulness:

DC: Do the developed process maps provide the knowledge needed for the organization of co-creation in context of the development of VRPs of circular extension? Why or why not?

NV: I think they are really clear. Three really different options. But, I think there is also something in between of the three options and that's more if there is no lease contract or no buy-back contract, there's also a third option, which is what we are doing now. That is something in between your maps. There's something in the middle. I think it's about how the housing association asks the contractor or the market what you want, without any organization for leasing or buyback. So you can still develop a really circular extension without the contracts for leasing or buyback. That's how you ask the market for development of a circular extension. I think that is step one. I think the process we are in now, the process which we built is somewhere in between those. We have the task to develop a circular extension and we are helped by the TU Delft and some other advising parties that consult us on how to develop such an extension. So, it's easier to reuse in the end and easier for other parties to buy it at the end of use, easier to recycle and remanufacture everything.

Discuss the developed designs and what contractor is currently experiencing.

NV: I would suggest combining the maps into one. I mean the first two phases are the same and then you could map the various options such as lease or buy-back.

SW: Yeah. You can combine them.

NV: Yeah. So, you can make a choice to lease it or to buyback or some other arrangement, which maybe you're going to develop in the future, something between them.

SW: Yeah, I think at this moment, you're right Nils, we are in something between the user oriented and product as a service.

NV: Yeah, but we only did two phases from the map. Technically it's really good to arrange reuse or buyback. So we can still choose lease construction or buy-back option. Maybe we don't choose, but it's still a circular extension because this is what housing association requested us to do.

SW: I think our company is not going to buy it back.

NV: At this moment it's still optional. Maybe this could this be a good point for your maps? So, you would have a top half and a bottom half, and you can exchange it.

DC: Would you use the developed process maps (and/or which one of them would you use) during the development and implementation of VRPs of circular extension? Why or why not?

SW: What I think is good in the process maps, it's very clear what the options. So, I think it's good to use it at the current moment for the development process. As Nils said, you can see the differences between them and you can choose to use one part of the one map and one part of another map. I think you can use it in that way.
NV: I also agree.

Evaluation of feasibility:

DC: Do you consider that the engaging actor (or problem owner) would be able to implement the designed process?

SW: Well when you look at the process we experienced you see the same steps looking back. Well, not exactly the same, but very similar.

NV: In this case (meaning circular extension case), the manufacturer does not really have an organization set for service, because it is a factory with a couple of people who will place it and then service is pretty much over. We, as a contractor, we do have service teams which are doing technical service for other housing associations. So, we could get it organized if needed. The housing association is a really big one in Holland, basically it is one of the biggest. They also have their own service teams, so they should also be able to organize it. The manufacturer in this case does not have them.

DC: Do you consider that organization of (product as a service/sell and buy-back/user-oriented) co-creation process and implementation of VRPs would be economically feasible? Why or why not?

NW: Maybe it's feasible, but I don't think we want it at this moment because we're not that far yet. The problem in housing in the Netherlands is that we need to have it affordable. The costs are getting higher and at this moment circularity is still more expensive.

NV: I think the sell and buy-back option is actually a pretty good option, because we are also using second hand materials for this circular extension, which you can also see as a sell and buyback option. But in this case, somebody else is going to buy them back. If the cost of materials will continue to rise, in renovation cases it will be easier to sell the materials you get and instead recycling them or throwing them like garbage.

SW: It depends on the costs and quality. Depends also on what is going to be in the future, because now the costs are rising, wood is really expensive, so people are looking more and more to use it again

NV: This is also the case for insulation materials

DC: Could you highlight any strengths and weaknesses of the developed designs, in your opinion?

NV: In your process maps in the sell and buy-back and product as a service, you already organize how to recycle and remanufacture the extension in the first or second phase.

DC: Yes and no. I would say how you look on this. On the one hand you can organize everything from the very beginning. On the other hand, you have process iteration loops that allow you to iterate the process and if you missed something to add it.

NV: I would suggest that it should be a separate phase. The first phases would be similar and then you have a separate phase where you have recycling and leasing or buy-back options. For example, you could put it in co-maintenance part.

DC: What opportunities and threats, in your opinion, do the developed designs bring to the problem owner?

SW: I think the main opportunity for the problem owner is that the problem owner is involved in the design together with the others. It is opportunity to use the knowledge, the knowledge problem owner has about the design and knowledge of other partners that could be used.

NV: I think the biggest opportunities and threats are outside of your schemes. I would say the biggest question is the market size. For example, there is also development for circular kitchen. Every house in the Netherlands has a kitchen, therefore the opportunities for the kitchen are much bigger than for the extension. The biggest threats are also outside. If is a one-off project, then the threats and risks a very low. But if you want for example to implement the lease construction in the whole market, then you need the numbers.

DC: The developed designs also include process iteration loops. How would you rate/evaluate their effect on economic feasibility of the process?

SW: I think it is high, because you need to evaluate your process to make it better, to make a step forward.

NV: I would say there also should be a green or red light. Who is responsible for the choice of getting back in the loop or going forward?

DC: I would say the team, in the design phase it is multidisciplinary team and later in the process it depends.

NV: Yeah, but it is never the team. It is always the one who buys it or the one who is going to use it or going to lease it.

DC: You mean the problem owner, right?

SW: That's why it is important to have the whole team

NV: Yeah, but they are going to say enough at some point.

SW: That does not matter, that is the point you reach.

NV: Yeah, but it is in time and time is money.

Evaluation of transferability:

DC: Do you consider that the developed process maps could be used for the co-creation in context of other circular building components? Why or why not?

SW: I think you can use them in another context. It doesn't matter if you talk about the roof or the extension or the kitchen. The process is the same. (NV agrees).

Appendix G – Semi-structured interview with the representative of housing association

The interview with the representative of Eigen Haard – Ilse van Andel was held online on 08.06.2021

Participants

Interviewers: Denis Chiosea (DC)

Interviewees: Ilse van Andel (IA)

Interview transcript

DC: Today I will present you the results of my thesis. They consist of three process maps that I developed.

The interviewer presents the developed process maps and answers the interviewee's questions.

Comments during the presentation

IA: You start your process maps in the moment when the design is almost finished. I am wondering, but do not know for sure, but my feeling says that it is better to start thinking about the business model during the design.

DC: I would say, that after completing my study I agree with you, but this is what the reality is about. The design was developed, but the decision on VRPs was not taken.

IA: Yeah, I understand that. But in general, I think that when we want things like this, that the starting point has to be the same as the design starting point. When we talk about what we are going to co-create with each other. So, there are two lines: you have to talk the product and about how do we manage it after the product is there. Because it gives another mindset and what you are implementing affects what the parties will have to do.

IA: Also, I would suggest that in Holland we talk about housing corporations rather than about housing associations. Because we do not have members.

Evaluation of usefulness:

DC: Do the developed process maps provide the knowledge needed for the organization of co-creation in context of the development of VRPs of circular extension? Why or why not?

IA: I think they do, because it is a good representation, you do not miss anything. Of course, I should look more specific on them, but from what I heard and what you showed me, I think they are very complete.

DC: Would you use the developed process maps (and/or which one of them would you use) during the development and implementation of VRPs of circular extension? Why or why not?

IA: Yes, but I also recommend you translate them in Dutch, then we can use them a little bit more. And which one? That does not matter. That depends on what we want with the product and it is different for different products. For example, we talk to BOSCH and we are trying to implement product as a service system for washing machines and we lack clarity. It helps if you have a good map like this, it helps to start conversation with the organizations involved, because in the beginning of talking about things like this you have to think about how we should do it every time and remind everything. But with such maps you can

present them to organizations that did not work with circularity before and explain them what you want to do.

Evaluation of feasibility:

DC: Do you consider that the engaging actor (or problem owner) would be able to implement the designed process?

IA: I do not really know when it comes to talk about manufacturer and contractor. I do not know how they do this kind of development. If I talk about housing corporation and look to the experience I have with BOSCH, then it is a new process comparing to everything we did before. It is not easy, because we are also working with the lean methods and look to all kinds of processes trying to make them efficient and if you come with a new process like this, everybody yells: ”Oh how are going to do this”. It is not very easy to change the things. This is innovation and innovations are never easy, but we have to get used to it. In some situations, we as a housing association we want the developments like this. We want the payback and improve financial side, so we have our wishes, but manufacturers and contractors also have their wishes. So, I think first we need to learn more about it and get more comfortable with it. So, I think we are all able to do this, but we need time, we must give each other time, even inside our own organizations.

DC: Do you consider that organization of (product as a service/sell and buy-back/user-oriented) co-creation process and implementation of VRPs would be economically feasible? Why or why not?

IA: I think so, but not all the variants. What we noticed with the product as a service which is offered to directly to our tenants, that’s problematic. They have low income. When we think about product as a service, so we could provide them good quality sustainable washing machine, in the end if they use it for six years, they will pay more than if they buy not sustainable low-quality product from market. So, offering product as a service directly to our tenants is not a good economical construction. If we speak about product as a service for us (meaning housing association) it is a little bit the same. The difficulty with this model is that if you buy it direct it is cheaper than using it as product as a service and we as housing corporation can get low interest rates, so for us it is cheaper to buy it. I think sell and but back is a very good option. Because all kind of circular materials and products cost more, but we also want to build more houses, so we need to consider what we spend the money on. If there is the buy-back, investments will go down, so I think buy-back is a way to make circular products easier to use and implement. And user oriented. I think it is the closest to what we do know. I think it is similar to sell and buy-back, but with less attractiveness for circularity.

DC: Could you highlight any strengths and weaknesses of the developed designs, in your opinion?

IA: I do not think I can answer that question, because it is a lot of information and I am not sure what I should say.

DC: What opportunities and threats, in your opinion, do the developed designs bring to the problem owner?

IA: Well about the product as a service, I just told you. I think that is a threat for it. Another threat I think is that we are not used to work with this. We have to change the way we our financial systems work. We are not used to work with TCO or sell and buy-back. We have to learn it. And what I hear when I talk with my financial colleagues, they all say: we do not know what the price will be in 15 years and we cannot use it

now, because we do not know what the value is at that time. This is something we need to figure out. And then opportunities, I think the main is in buy-back, as I told you, because you have lower investment costs. With the product as a service another thing is that we have to realize that now we own all the products and if we have a house as a service, then it is not ours. So what do we have then? We do investments in our products (meaning houses) and if the prices go up it is good for us, but if we do not own them, then what do we have? Nothing. Another threat which I heard from my colleagues is what if manufacturer is broke after 10 years, he cannot buy-back it anymore. And the opportunity is again that we get a very good interest rates.

DC: The developed designs also include process iteration loops. How would you rate/evaluate their effect on economic feasibility of the process?

IA: Not only the economic. I think they are very important to improve the process. They tighten the co-creation process, this also has good effect on the economic side. Because you support each other and improve the process.

Evaluation of transferability:

DC: Do you consider that the developed process maps could be used for the co-creation in context of other circular building components? Why or why not?

IA: I think they can be used everywhere in context of circular buildings developments. Why not? I think it is about going the co-creation together and talking about the right things. Then you can use them with every circular developments, showing the right things.

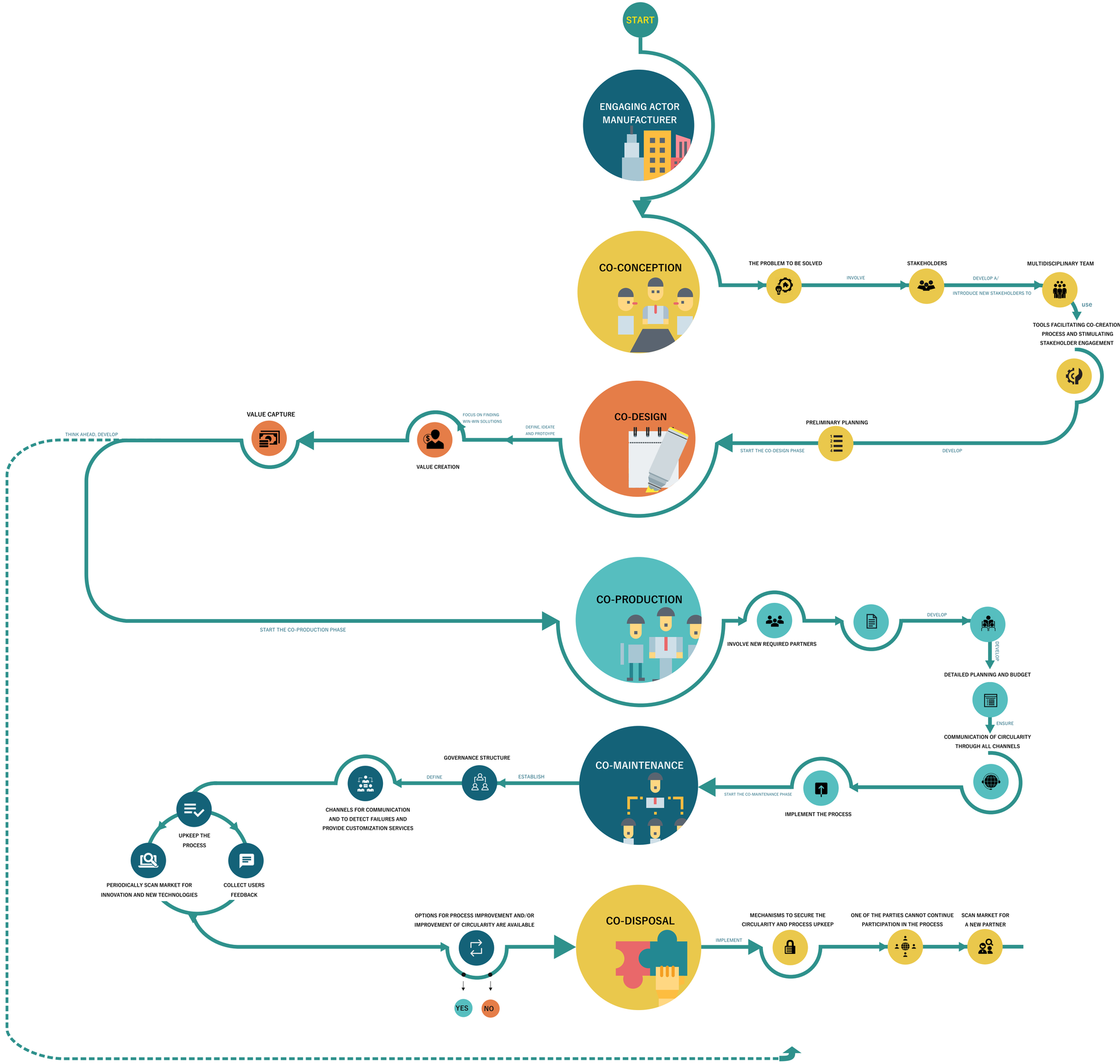
Additional comments:

IA: Are you going to translate them in Dutch?

DC: Hopefully, but I will need to find someone to help me.

IA: If you do so, I would like to have them when you finish.

Appendix H – Co-creation path



Appendix I – Product as a service design variant

ASSUMPTIONS FOR THE PROCESS MAP:

- based on product as a service supply chain/business model
- current stakeholders are willing to further collaborate

PRODUCT AS A SERVICE

START

ENGAGING ACTOR MANUFACTURER

FUNCTIONS AS A BRIDGE THAT CONNECTS ALL VALUE CHAIN PARTNERS FOR THE COMMON GOAL OF CIRCULAR ECONOMY

READING GUIDE

The process map consists of 3 layers:
1)Co-creation phases (represented with big icons)
2)Sub-steps of the co-creation phases (represented with smaller icons and the green line, combining them into a co-creation path)
3)Options and activities available and/or recommended for the sub-steps (represented with thinner black lines and text)

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A dashed line that is the same color as co-creation path, represents that the mechanisms that secure the circularity and process upkeep need to be implemented during the co-design phase.
Other dashed lines represent the iteration cycles of the process.

LEGEND

- Co-creation phase (1st layer)
- Co-creation path
- Sub-steps of the co-creation phases (2nd layer) (or steps of the co-creation path)
- Options and activities available (3rd layer) and/or recommended for the steps of the co-creation path
- Process iteration loops
- Link between co-design and knowledge transfer mechanisms

CO-CONCEPTION

THE PROBLEM TO BE SOLVED — INVOLVE — STAKEHOLDERS — DEVELOP A/ INTRODUCE NEW STAKEHOLDERS TO — MULTIDISCIPLINARY TEAM — use — TOOLS FACILITATING CO-CREATION PROCESS AND STIMULATING STAKEHOLDER ENGAGEMENT

DEVELOPMENT OF VRPS OF CIRCULAR EXTENSION
Develop guidelines for the involved parties
Decide what VRPs will be implemented
Find win-win solutions

CURRENT STAKEHOLDERS
1. Housing association
2. Manufacturer
3. Architect
4. Contractor
5. Scientific advisor
6. Residents

OTHER STAKEHOLDERS THAT COULD/SHOULD BE INVOLVED
1. Raw material suppliers
2. Recycling advisor/consultant
3. Human interaction specialist
4. Subcontractors

TOOLS FACILITATING CO-CREATION PROCESS AND STIMULATING STAKEHOLDER ENGAGEMENT
- DIGITAL TOOLS
  1. Cloud storages
  2. Planning support systems
  3. Tools for online discussions (also make it possible to use physical tools in online format)
  4. Interactive sites for customer involvement
  5. Electronic mailing, news group etc.
- PHYSICAL TOOLS
  1. Workshops
  2. Brainstorming
  3. Actors map
  4. Wall of ideas
  5. Task analysis grid
  6. Role scripts etc.

PRELIMINARY PLANNING
1 2 3 4
START THE CO-DESIGN PHASE — DEVELOP

CO-DESIGN

DESIGNING CIRCULAR, CUSTOMIZABLE PRODUCT
Design includes possibilities for customization and upgrade
STAKEHOLDERS COULD
Further explore using of used materials as input

The reuse principle is already embedded in the design of the circular extension. The modules are modular, reusable and recyclable. Moreover, used/ recycled materials are used as production input

DEFINE, IDEATE AND PROTOYPE — FOCUS ON FINDING WIN-WIN SOLUTIONS — VALUE CREATION — VALUE CAPTURE — THINK AHEAD, DEVELOP

MANUFACTURER KEEPS OWNERSHIP OF EXTENSION

REVENUE STREAMS
- RECYCLING COMPANIES — RECOVERED MATERIALS
- RESIDENTS — CUSTOMIZATION AND UPGRADE — Subscription / One-time payment
- HOUSING ASSOSIATIONS — LEASING/RENTING OF THE EXTENSION

COSTS
- MANUFACTURING — Direct materials; Direct labor; Manufacturing overhead (indirect cost, e.g. equipment depreciation, repairs, salaries of supervisors)
- LOGISTICS — Direct labor; Warehousing costs; Inventory storage and allocation; Shipping; Indirect costs
- INSTALLATION — Direct labor; Indirect costs
- REPAIR
- REFURBISHMENT — Direct materials; Direct labor; Indirect costs
- REMANUFACTURING
- REQUIRED INFRASTRUCTURE/ FACILITIES DEVELOPMENT
- OTHER INDIRECT COSTS

CO-PRODUCTION

START THE CO-PRODUCTION PHASE

IITERATE THE DESIGNED PROCESS — KPI'S AND FEEDBACK SYSTEM

IF PARTIES NEED AND COULD BECOME PART OF THE PROCESS USING THEIR KNOWLEDGE or IF PARTIES WILL NOT BE PART OF CO-CREATION, DEVELOP

Depending on parties willingness and necessity to participate in the co-creation of the extension

INVOLVE NEW REQUIRED PARTNERS — CONTRACTING — DETAILED GUIDELINES FOR EACH PARTY INVOLVED — DEVELOP

USE: NON-TRADITIONAL CONTRACTS, FOCUSING ON OUTCOMES AND AMBITIONS

DETAILED PLANNING AND BUDGET — ENSURE — COMMUNICATION OF CIRCULARITY THROUGH ALL CHANNELS
- SALES PERSONNEL
- COMPANY WEBSITE
- ADVERTISING
- CIRCULAR ECONOMY-RELATED FAIRS, TALKS, SEMINARS
- CE-CULTURE INSIDE THE COMPANY

RECONSIDER THE PROCESS DESIGN

CO-MAINTENANCE

IMPLEMENT THE PROCESS — DEVELOPED PROCESS DESIGN — IMPLEMENT — REQUIRED INFRASTRUCTURE — BUILD — PERSONNEL TEAMS — ORGANIZE — START THE CO-MAINTENANCE PHASE

FACE CHALLENGES/PROBLEMS

GOVERNANCE STRUCTURE — DEFINE — ESTABLISH

CONSIDERING THAT
In this scenario most of the risks belong to manufacturer
Lead organization structure (manufacturer becomes the leading organization)
If manufacturer outsources some of the tasks, could be considered
- Administrative organization (separate entity)
- Participant-governed structure

CHANNELS FOR COMMUNICATION AND TO DETECT FAILURES AND PROVIDE CUSTOMIZATION SERVICES
- DIGITAL: Support by phone or email; Website featuring possibilities to order customization and upgrade and submit breakage notification
- PHYSICAL: Mobile app featuring possibilities to order customization and upgrade and submit breakage notification; Exhibition space featuring possibility to chose customization and upgrade options live; Periodic inspection of condition of the modules to detect failures

UPKEEP THE PROCESS
- PERIODICALLY SCAN MARKET FOR INNOVATION AND NEW TECHNOLOGIES
- COLLECT USERS FEEDBACK

GO TO CO-PRODUCTION PHASE

GO TO CO-CONCEPTION PHASE

CO-DISPOSAL

OPTIONS FOR PROCESS IMPROVEMENT AND/OR IMPROVEMENT OF CIRCULARITY ARE AVAILABLE

RECONSIDER THE PROCCESS/PRODUCT DESIGN — YES — NO — DO NOT DO ANYTHING

IMPLEMENT — MECHANISMS TO SECURE THE CIRCULARITY AND PROCESS UPKEEP
- COMPONENT MATERIAL PASSPORTS
- BIM-BASED MATERIAL PASSPORTS
- STANDARD PRACTICES OF THE REUSE AND RECYCLE OF THE CIRCULAR EXTENSION MODULES AND MATERIALS

ONE OF THE PARTIES CANNOT CONTINUE PARTICIPATION IN THE PROCESS — SCAN MARKET FOR A NEW PARTNER

NEW PARTNER IS ABLE TO JOIN THE PROCESS WITHOUT THE PROCESS REDESIGN — YES — NO

EXTENSION INSPECTION PROCESS

RECYCLE

New user ← Reassembley ← Repair ← Cleaning ← Inspection ← Dissasembley ← Collect for remanufacturing
Reassembley → Possible upgrade

CAN (PART OF) THE EXTENSION BE REMANUFACTURED? — YES — NO

Return to the original user or new user ← Aesthetic touch-ups ← Repair for functionality ← Collect for refurbishment

CAN (PART OF) THE EXTENSION BE REFURBISHED? — YES — NO

Repair

CAN (PART OF) THE EXTENSION BE REPAIRED? — YES — NO

Reuse/Continue to use

CAN THE EXTENSION BE REUSED WITHOUT ANY INTERVENTIONS? — YES — NO

GENERIC STRUCTURE
VALUE REALIZATION CASCADE
DEVELOP
VRPs
MANUFACTURER

REUSE
REPAIR — or
- Involve residents — DEVELOP
  - Education schemes and repair guidelines
  - Incetive schemes
- Outsource to the current contractor

REFURBISH — GENERATE — Refurbishment scenarios — IF CAN BE DONE ON SITE — Required infrastructure

REMANUFACTURE — DEVELOP — Remanufacturing scenarios — IDENTIFY — Required partners

RECYCLE — EXPLORE — Recycle possibilities of materials — IDENTIFY — Required partners

Appendix J – Sell and buy-back design variant

SELL AND BUY-BACK

ASSUMPTIONS FOR THE PROCESS MAP:

- based on sell and buy-back supply chain/business model
- current stakeholders are willing to further collaborate

READING GUIDE

The process map consists of 3 layers:
1)Co-creation phases (represented with big icons)
2)Sub-steps of the co-creation phases (represented with smaller icons and the green line, combining them into a co-creation path)
3)Options and activities available and/or recommended for the sub-steps (represented with thinner black lines and text)

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A dashed line that is the same color as co-creation path, represents that the mechanisms that secure the circularity and process upkeep need to be implemented during the co-design phase.
Other dashed lines represent the iteration cycles of the process.

LEGEND

- Co-creation phase (1st layer)
- Co-creation path
- Sub-steps of the co-creation phases (2nd layer) (or steps of the co-creation path)
- Options and activities available (3rd layer) and/or recommended for the steps of the co-creation path
- Process iteration loops
- Link between co-design and knowledge transfer mechanisms

START

ENGAGING ACTOR CONTRACTOR

FUNCTIONS AS A BRIDGE THAT CONNECTS ALL VALUE CHAIN PARTNERS FOR THE COMMON GOAL OF CIRCULAR ECONOMY

THE ROLE OF THE CONTRACTOR SHIFTS TO THE SYSTEM ENABLER

VRPs

Required infrastructure
IDENTIFIES
Warranty policy for new and remanufactured product
DEVELOPS
MULTIDISCIPLINARY TEAM
EXPLORES
RECYCLE POSSIBILITIES OF MATERIALS
IDENTIFIES
RECYCLE
ARRANGE RECYCLING OF MATERIALS THAT CANNOT BE REUSED
REQUIRED RECYCLING PARTNERS
SELL RECYCLED MATERIALS
RECOVERS MATERIALS FOR RECYCLING
Reuse materials that can be directly reused
Remanufacturing scenarios
DEVELOPS
REUSE AND REMANUFACTURING
ARRANGES
MANUFACTURER
SELLS NEW AND REMANUFACTURED EXTENSIONS
DELIVERY AND TAKE-BACK IS DONE BY THE CONTRACTOR
Refurbishment sceanarios
DEVELOPS
REPAIRS AND REFURBISHMENT
ARRANGES
CONTRACTOR
Monitors the condition of the extension and repairs it
IDEALLY SHOULD BE KEPT THE SAME CONTRACTOR
DELIVERY
TAKE-BACK AGREEMENT
HOUSING ASSOSIATIONS
Deposit
Price is discounted from the sale price

The reuse principle is already embedded in the design of the circular extension. The modules are modular, reusable and recyclable. Moreover, used/recycled materials are used as production input

Design includes possibilities for customization and upgrade

DESIGNING CIRCULAR, CUSTOMIZABLE PRODUCT

STAKEHOLDERS COULD

Further explore using of used materials as input

CO-CONCEPTION

THE PROBLEM TO BE SOLVED
INVOLVE
STAKEHOLDERS
DEVELOP A/
INTRODUCE NEW STAKEHOLDERS TO
MULTIDISCIPLINARY TEAM
use
TOOLS FACILITATING CO-CREATION PROCESS AND STIMULATING STAKEHOLDER ENGAGEMENT

DEVELOPMENT OF VRPS OF CIRCULAR EXTENSION
Develop guidelines for the involved parties
Find win-win solutions
Decide what VRPs will be implemented

CURRENT STAKEHOLDERS
1. Housing association
2. Manufacturer
3. Architect
4. Contractor
5. Scientific advisor
6. Residents

OTHER STAKEHOLDERS THAT COULD/SHOULD BE INVOLVED
1. Raw material suppliers
2. Recycling advisor/consultant
3. Human interaction specialist
4. Subcontractors

1. Cloud storages
2. Planning support systems
3. Tools for online discussions (also make it possible to use physical tools in online format)
4. Interactive sites for customer involvement
5. Electronic mailing, news group etc.

DIGITAL TOOLS
PHYSICAL TOOLS

1. Workshops
2. Brainstorming
3. Actors map
4. Wall of ideas
5. Task analysis grid
6. Role scripts etc.

CO-DESIGN

PRELIMINARY PLANNING
START THE CO-DESIGN PHASE
DEVELOP

VALUE CAPTURE
THINK AHEAD, DEVELOP
VALUE CREATION
FOCUS ON FINDING WIN-WIN SOLUTIONS
DEFINE, IDEATE AND PROTOYPE
COSTS
MANUFACTURER KEEPS OWNERSHIP OF EXTENSION

REVENUE STREAMS
RECYCLING PARTNERS
BUYING RECOVERED MATERIALS AND SELLING RECYCLED MATERIALS
MANUFACTURER
BUYING NEW AND REMANUFACTURED EXTENTION MODULES
HOUSING ASSOCIATION
BUYING EXTENTION MODULES
CONTRACTOR
BUYING CUSTOMIZATION AND UPGRADES
RESIDENTS

MANUFACTURER
MANUFACTURING AND REMANUFACTURING
Direct materials
Direct labor
Manufacturing overhead (indirect cost, e.g. equipment depreciation, repairs, salaries of supervisors)
LOGISTICS
Direct labor
Warehousing costs
Inventory storage and allocation
Indirect costs
REQUIRED INFRASTRUCTURE/ FACILITIES DEVELOPMENT
OTHER INDIRECT COST

CONTRACTOR
LOGISTICS
Direct labor
Inventory storage and allocation
Shipping
Indirect costs
INSTALLATION
Direct labor
Indirect costs
REPAIR REFURBISHMENT
Direct materials
Direct labor
Indirect costs
OTHER INDIRECT COST

IITERATE THE DESIGNED PROCESS
KPI'S AND FEEDBACK SYSTEM
IF PARTIES NEED AND COULD BECOME PART OF THE PROCESS USING THEIR KNOWLEDGE
or
IF PARTIES WILL NOT BE PART OF CO-CREATION, DEVELOP
Depending on parties willingness and necessity to participate in the co-creation of the extension

RECONSIDER THE PROCESS DESIGN

CO-PRODUCTION

INVOLVE NEW REQUIRED PARTNERS
CONTRACTING
USE
NON-TRADITIONAL CONTRACTS, FOCUSING ON OUTCOMES AND AMBITIONS
DEVELOP
DETAILED GUIDELINES FOR EACH PARTY INVOLVED
DEVELOP
DETAILED PLANNING AND BUDGET

START THE CO-PRODUCTION PHASE

Support by phone or email
Website featuring possibilities to order customization and upgrade and submit breakage notification
Mobile app featuring possibilities to order customization and upgrade and submit breakage notification
Exhibition space featuring possibility to chose customization and upgrade options live
Periodic inspection of condition of the modules to detect failures

DIGITAL
PHYSICAL

CHANNELS FOR COMMUNICATION AND TO DETECT FAILURES AND PROVIDE CUSTOMIZATION SERVICES

GOVERNANCE STRUCTURE
DEFINE
ESTABLISH
CONSIDERING THAT
In this scenario most of the risks belong to manufacturer and contractor
Participant-governed
Administrative organization (separate entity)
Other possible network structures
Lead organization structure

UPKEEP THE PROCESS
PERIODICALLY SCAN MARKET FOR INNOVATION AND NEW TECHNOLOGIES
COLLECT USERS FEEDBACK

CO-MAINTENANCE

DEVELOPED PROCESS DESIGN
IMPLEMENT
REQUIRED INFRASTRUCTURE
BUILD
ORGANIZE
PERSONNEL TEAMS
START THE CO-MAINTENANCE PHASE
IMPLEMENT THE PROCESS

ENSURE
COMMUNICATION OF CIRCULARITY THROUGH ALL CHANNELS
SALES PERSONNEL
COMPANY WEBSITE
ADVERTISING
CE-CULTURE INSIDE THE COMPANY
CIRCULAR ECONOMY-RELATED FAIRS, TALKS, SEMINARS

FACE CHALLENGES/PROBLEMS

GO TO CO-PRODUCTION PHASE
GO TO CO-CONCEPTION PHASE

OPTIONS FOR PROCESS IMPROVEMENT AND/OR IMPROVEMENT OF CIRCULARITY ARE AVAILABLE
RECONSIDER THE PROCCESS/PRODUCT DESIGN
YES
NO
DO NOT DO ANYTHING

CO-DISPOSAL

IMPLEMENT
MECHANISMS TO SECURE THE CIRCULARITY AND PROCESS UPKEEP
COMPONENT MATERIAL PASSPORTS
BIM-BASED MATERIAL PASSPORTS
STANDARD PRACTICES OF THE REUSE AND RECYCLE OF THE CIRCULAR EXTENSION MODULES AND MATERIALS
ONE OF THE PARTIES CANNOT CONTINUE PARTICIPATION IN THE PROCESS
SCAN MARKET FOR A NEW PARTNER
YES
NO
NEW PARTNER IS ABLE TO JOIN THE PROCESS WITHOUT THE PROCESS REDESIGN

Appendix K – User oriented design variant

USER ORIENTED

ASSUMPTIONS FOR THE PROCESS MAP:

- based on user oriented supply chain/business model
- current stakeholders are NOT willing to further collaborate

READING GUIDE

The process map consists of 3 layers:
1)Co-creation phases (represented with big icons)
2)Sub-steps of the co-creation phases (represented with smaller icons and the green line, combining them into a co-creation path)
3)Options and activities available and/or recommended for the sub-steps (represented with thinner black lines and text)

Start reading the process map in the "start" point in the top middle of the image. Follow the co-creation path (green line), as you read. Following co-creation path, you will see the sub-steps of the process, as well as options and activities mapped for these sub-steps.
A dashed line that is the same color as co-creation path, represents that the mechanisms that secure the circularity and process upkeep need to be implemented during the co-design phase.

LEGEND

- Co-creation phase (1st layer)
- Co-creation path
- Sub-steps of the co-creation phases (2nd layer) (or steps of the co-creation path)
- Options and activities available (3rd layer) and/or recommended for the steps of the co-creation path
- Link between co-design and knowledge transfer mechanisms

START

ENGAGING ACTOR

Housing assosiation (or contractor on behalf of housing assosiation)

FUNCTIONS AS A BRIDGE THAT CONNECTS ALL VALUE CHAIN PARTNERS FOR THE COMMON GOAL OF A CIRCULAR ECONOMY

SUCH PROCESS SCHEME RESULTS IN MULTIPLE BARRIERS

- The circularity is not secured. The second-hand brokers will buy the modules only after many years. It is not guaranteed that this will happen
- The extension is not remanufactured. This potential value is lost
- The co-creation opportunities are very limited, as well as opportunities for process iteration

VRPs

Refurbishment sceanarios → DEVELOPS → REUSE AND REFURBISHMENT

(distinct) contractor(s) for installation, maintenance and dissesmbling of the extension → HIRES / OR / DEVELOPS → Personnel teams for installation, maintenance and dissembling of the extension

REUSE AND REFURBISHMENT → ARRANGES → HOUSING ASSOSIATIONS

HOUSING ASSOSIATIONS → SELLS THE EXTENSION MODULES → MANUFACTURER

HOUSING ASSOSIATIONS → SELLS THE MODULES → SECOND-HAND MATERIAL COMPANIES

SECOND-HAND MATERIAL COMPANIES → ARRANGE → RECYCLE → SELL RECYCLED MATERIALS → MANUFACTURER

IDENTIFY → The value of the extension after the end of use

The reuse principle is already embedded in the design of the circular extension. The modules are modular, reusable and recyclable. Moreover, used/recycled materials are used as production input

DESIGNING CIRCULAR, CUSTOMIZABLE PRODUCT → Design includes possibilities for customization and upgrade

CO-CONCEPTION

THE PROBLEM TO BE SOLVED → INVOLVE → STAKEHOLDERS → DEVELOP A → MULTIDISCIPLINARY TEAM

MAIN PROBLEM DEVELOPMENT OF VRPS OF CIRCULAR EXTENSION

Develop guidelines for the involved parties ← ? → Decide what VRPs will be implemented

Find win-win solutions

CURRENT STAKEHOLDERS ARE NO LONGER INVOLVED IN CO-CREATION

1. Housing association
2. Manufacturer
3. Architect
4. Contractor
5. Scientific advisor
6. Residents

OTHER STAKEHOLDERS THAT COULD/SHOULD BE INVOLVED

1. Raw material suppliers or Waste management operators as parties that could become (part of) second-hand market
2. Human interaction specialist
3. New contractors/ subcontractors

use → TOOLS FACILITATING CO-CREATION PROCESS AND STIMULATING STAKEHOLDER ENGAGEMENT

- DIGITAL TOOLS
  1. Cloud storages
  2. Planning support systems
  3. Tools for online discussions (also make it possible to use physical tools in online format)
  4. Interactive sites for customer involvement
  5. Electronic mailing, news group etc.
- PHYSICAL TOOLS
  1. Workshops
  2. Brainstorming
  3. Actors map
  4. Wall of ideas
  5. Task analysis grid
  6. Role scripts etc.

CO-DESIGN

PRELIMINARY PLANNING → START THE CO-DESIGN PHASE

DEVELOP → PRELIMINARY PLANNING

DEFINE, IDEATE AND PROTOXYPE → FOCUS ON FINDING WIN-WIN SOLUTIONS → VALUE CREATION

VALUE CREATION → VALUE CAPTURE

VALUE CAPTURE → REVENUE STREAMS

VALUE CAPTURE → COSTS

REVENUE STREAMS

HOUSING ASSOSIATION → SELLS EXTENTION MODULES AFTER THE END OF USE → SECOND-HAND MATERIAL COMPANIES

HOUSING ASSOSIATION → BUYING CUSTOMIZATION AND UPGRADES → RESIDENTS

HOUSING ASSOSIATION → SELL THE EXTENSION MODULES → MANUFACTURERS/ OTHER PARTIES

SECOND-HAND MATERIAL COMPANIES → SELL RECOVERED MATERIALS → MANUFACTURERS/ OTHER PARTIES

COSTS

HOUSING ASSOSIATION

- PROCUREMENT OF THE EXTENSION
- LOGISTICS: Direct labor; Shipping; Indirect costs
- INSTALLATION AND DISSEMBLING: Direct labor; Indirect costs
- REPAIR
- REFURBISHMENT: Direct materials; Direct labor; Indirect costs
- OTHER INDIRECT COST

SECOND-HAND MATERIAL COMPANIES

- REQUIRED INFRASTRUCTURE/ FACILITIES DEVELOPMENT
- OTHER INDIRECT COST
- REFURBISHMENT: Recycling; Direct labor; Indirect costs

THINK AHEAD, DEVELOP → START THE CO-PRODUCTION PHASE

KPI's and feedback system for involved contractors (or personnel groups)

CO-PRODUCTION

DEVELOP → INVOLVE NEW REQUIRED PARTNERS → CONTRACTING → DEVELOP → DETAILED GUIDELINES FOR EACH PARTY INVOLVED

CONTRACTING → USE → ITERATIVE MINOR RENOVATION CONTRACTS

DETAILED GUIDELINES FOR EACH PARTY INVOLVED → DEVELOP → DETAILED PLANNING AND BUDGET

DETAILED PLANNING AND BUDGET → ENSURE → COMMUNICATION OF CIRCULARITY THROUGH ALL CHANNELS

COMMUNICATION OF CIRCULARITY THROUGH ALL CHANNELS

- SALES PERSONNEL
- COMPANY WEBSITE
- ADVERTISING
- CE-CULTURE INSIDE THE COMPANY
- CIRCULAR ECONOMY-RELATED FAIRS, TALKS, SEMINARS

Support by phone or email

Website featuring possibilities to order customization and upgrade and submit breakage notification

Mobile app featuring possibilities to order customization and upgrade and submit breakage notification

Exhibition space featuring possibility to chose customization and upgrade options live

Periodic inspection of condition of the modules to detect failures

DIGITAL / PHYSICAL → CHANNELS FOR COMMUNICATION AND TO DETECT FAILURES AND PROVIDE CUSTOMIZATION SERVICES

GOVERNANCE STRUCTURE → DEFINE → CHANNELS FOR COMMUNICATION AND TO DETECT FAILURES AND PROVIDE CUSTOMIZATION SERVICES

GOVERNANCE STRUCTURE → ESTABLISH → CO-MAINTENANCE

CONSIDERING THAT → In this scenario co-creation is almost absent → Housing assosiation becomes lead organization hiring other contractors

CO-MAINTENANCE

DEVELOPED PROCESS DESIGN → IMPLEMENT → IMPLEMENT THE PROCESS

REQUIRED INFRASTRUCTURE → BUILD → IMPLEMENT THE PROCESS

PERSONNEL TEAMS → ORGANIZE → IMPLEMENT THE PROCESS

START THE CO-MAINTENANCE PHASE

UPKEEP THE PROCESS

PERIODICALLY SCAN MARKET FOR INNOVATION AND NEW TECHNOLOGIES

CONSIDERING THAT CO-CREATION IS ALMOST ABSENT, OPPORTUNITIES FOR IMPLEMENTATION OF NEW TECHNOLOGIES ARE LIMITED

CO-DISPOSAL

IMPLEMENT → MECHANISMS TO SECURE THE CIRCULARITY AND PROCESS UPKEEP

- COMPONENT MATERIAL PASSPORTS
- BIM-BASED MATERIAL PASSPORTS
- STANDARD PRACTICES OF THE REUSE AND RECYCLE OF THE CIRCULAR EXTENSION MODULES AND MATERIALS

MECHANISMS TO SECURE THE CIRCULARITY AND PROCESS UPKEEP → ONE OF THE PARTIES CANNOT CONTINUE PARTICIPATION IN THE PROCESS → THE CIRCULARITY BECOMES QUESTIONABLE, BECAUSE IF SECOND-HAND MARKET COLLAPSES, MODULES WILL NOT BE RECYCLED

Appendix L – Sources used to map the steps and components of the process maps

PRODUCT AS A SERVICE

ASSUMPTIONS FOR THE PROCESS MAP:

- based on product as a service supply chain/business model
- current stakeholders are willing to further collaborate

START

ENGAGING ACTOR MANUFACTURER

FUNCTIONS AS A BRIDGE THAT CONNECTS ALL VALUE CHAIN PARTNERS FOR THE COMMON GOAL OF CIRCULAR ECONOMY

READING GUIDE

The process map consists of 3 layers:
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Other dashed lines represent the iteration cycles of the process.

LEGEND

- Co-creation phase (1st layer)
- Co-creation path
- Sub-steps of the co-creation phases (2nd layer) (or steps of the co-creation path)
- Options and activities available (3rd layer) and/or recommended for the steps of the co-creation path
- Process iteration loops
- Link between co-design and knowledge transfer mechanisms

5

RECYCLE

New user ← Reassembley ← Repair ← Cleaning ← Inspection ← Dissassembley ← Collect for remanufacturing → YES → CAN (PART OF) THE EXTENSION BE REMANUFACTURED? → NO

Possible upgrade

Return to the original user or new user ← Aesthetic touch-ups ← Repair for functionality ← Collect for refurbishment → YES → CAN (PART OF) THE EXTENSION BE REFURBISHED? → NO

Repair → YES → CAN (PART OF) THE EXTENSION BE REPAIRED? → NO

Reuse/Continue to use → YES → CAN THE EXTENSION BE REUSED WITHOUT ANY INTERVENTIONS? → NO

GENERIC STRUCTURE

VALUE REALIZATION CASCADE

DEVELOP

VRPs

EXTENSION INSPECTION PROCESS

4

MANUFACTURER

REUSE | REPAIR | REFURBISH | REMANUFACTURE | RECYCLE

Involve residents (DEVELOP) or Outsource to the current contractor

Education schemes and repair guidelines

Incetive schemes

GENERATE: Refurbishment scenarios (IF CAN BE DONE ON SITE) → Required infrastructure

DEVELOP: Remanufacturing scenarios (IDENTIFY) → Required partners

EXPLORE: Recycle possibilities of materials

The reuse principle is already embedded in the design of the circular extension. The modules are modular, reusable and recyclable. Moreover, used/ recycled materials are used as production input

Design includes possibilities for customization and upgrade

DESIGNING CIRCULAR, CUSTOMIZABLE PRODUCT

STAKEHOLDERS COULD → Further explore using of used materials as input

CO-CONCEPTION

1

THE PROBLEM TO BE SOLVED → INVOLVE → STAKEHOLDERS → DEVELOP A/ INTRODUCE NEW STAKEHOLDERS TO → MULTIDISCIPLINARY TEAM → use → TOOLS FACILITATING CO-CREATION PROCESS AND STIMULATING STAKEHOLDER ENGAGEMENT

DEVELOPMENT OF VRPS OF CIRCULAR EXTENSION

Develop guidelines for the involved parties

Decide what VRPs will be implemented

Find win-win solutions

CURRENT STAKEHOLDERS

1. Housing association
2. Manufacturer
3. Architect
4. Contractor
5. Scientific advisor
6. Residents

OTHER STAKEHOLDERS THAT COULD/SHOULD BE INVOLVED

1. Raw material suppliers
2. Recycling advisor/consultant
3. Human interaction specialist
4. Subcontractors

PRELIMINARY PLANNING

START THE CO-DESIGN PHASE

DEVELOP

2

1. Cloud storages
2. Planning support systems
3. Tools for online discussions (also make it possible to use physical tools in online format)
4. Interactive sites for customer involvement
5. Electronic mailing, news group etc.

DIGITAL TOOLS

PHYSICAL TOOLS

1. Workshops
2. Brainstorming
3. Actors map
4. Wall of ideas
5. Task analysis grid
6. Role scripts etc.

CO-DESIGN

3 VALUE CAPTURE

THINK AHEAD, DEVELOP

MANUFACTURER KEEPS OWNERSHIP OF EXTENSION

VALUE CREATION

FOCUS ON FINDING WIN-WIN SOLUTIONS

DEFINE, IDEATE AND PROTOYPE

REVENUE STREAMS

RECYCLING COMPANIES: RECOVERED MATERIALS

RESIDENTS: CUSTOMIZATION AND UPGRADE → Subscription / One-time payment

HOUSING ASSOSIATIONS: LEASING/RENTING OF THE EXTENSION

COSTS

MANUFACTURING: Direct materials; Direct labor; Manufacturing overhead (indirect cost, e.g. equipment depreciation, repairs, salaries of supervisors)

LOGISTICS: Direct labor; Warehousing costs; Inventory storage and allocation; Shipping; Indirect costs

INSTALLATION: Direct labor; Indirect costs

REPAIR

REFURBISHMENT: Direct materials; Direct labor; Indirect costs

REMANUFACTURING

REQUIRED INFRASTRUCTURE/ FACILITIES DEVELOPMENT

OTHER INDIRECT COSTS

6

START THE CO-PRODUCTION PHASE

IITERATE THE DESIGNED PROCESS

KPI'S AND FEEDBACK SYSTEM

IF PARTIES NEED AND COULD BECOME PART OF THE PROCESS USING THEIR KNOWLEDGE or IF PARTIES WILL NOT BE PART OF CO-CREATION, DEVELOP

Depending on parties willingness and necessity to participate in the co-creation of the extension

RECONSIDER THE PROCESS DESIGN

CO-PRODUCTION

7

INVOLVE NEW REQUIRED PARTNERS → CONTRACTING → DEVELOP → DETAILED GUIDELINES FOR EACH PARTY INVOLVED

USE → NON-TRADITIONAL CONTRACTS, FOCUSING ON OUTCOMES AND AMBITIONS

8 DETAILED PLANNING AND BUDGET

ENSURE → COMMUNICATION OF CIRCULARITY THROUGH ALL CHANNELS

DEVELOPED PROCESS DESIGN → IMPLEMENT

REQUIRED INFRASTRUCTURE ← BUILD ← ORGANIZE → PERSONNEL TEAMS

START THE CO-MAINTENANCE PHASE

9

SALES PERSONNEL

COMPANY WEBSITE

CE-CULTURE INSIDE THE COMPANY

ADVERTISING

CIRCULAR ECONOMY-RELATED FAIRS, TALKS, SEMINARS

FACE CHALLENGES/PROBLEMS

GO TO CO-PRODUCTION PHASE

GO TO CO-CONCEPTION PHASE

Support by phone or email

Website featuring possibilities to order customization and upgrade and submit breakage notification

Mobile app featuring possibilities to order customization and upgrade and submit breakage notification

Exhibition space featuring possibility to chose customization and upgrade options live

Periodic inspection of condition of the modules to detect failures

12

DIGITAL | PHYSICAL

CO-MAINTENANCE

10

GOVERNANCE STRUCTURE

DEFINE | ESTABLISH

CHANNELS FOR COMMUNICATION AND TO DETECT FAILURES AND PROVIDE CUSTOMIZATION SERVICES

CONSIDERING THAT

In this scenario most of the risks belong to manufacturer

Lead organization structure (manufacturer becomes the leading organization)

If manufacturer outsources some of the tasks, could be considered

Administrative organization (separate entity)

Participant-governed structure

11

UPKEEP THE PROCESS

PERIODICALLY SCAN MARKET FOR INNOVATION AND NEW TECHNOLOGIES

COLLECT USERS FEEDBACK

OPTIONS FOR PROCESS IMPROVEMENT AND/OR IMPLEMENTMENT OF CIRCULARITY ARE AVAILABLE

CO-DISPOSAL

13

IMPLEMENT

MECHANISMS TO SECURE THE CIRCULARITY AND PROCESS UPKEEP

COMPONENT MATERIAL PASSPORTS

BIM-BASED MATERIAL PASSPORTS

ONE OF THE PARTIES CANNOT CONTINUE PARTICIPATION IN THE PROCESS

SCAN MARKET FOR A NEW PARTNER

YES / NO

NEW PARTNER IS ABLE TO JOIN THE PROCESS WITHOUT THE PROCESS REDESIGN

14

STANDARD PRACTICES OF THE REUSE AND RECYCLE OF THE CIRCULAR EXTENSION MODULES AND MATERIALS

RECONSIDER THE PROCCESS/PRODUCT DESIGN ← YES / NO → DO NOT DO ANYTHING