URBAN SYMBIOSIS OF BUILDING MATERIALS IN AMSTERDAM

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Nono

SUMMARY

The large growth of cities over the years has led to a greater resource demand in urban areas. Subsequently, after usage, those resources end up in large waste flows to be transferred to the outskirts of the city and its hinterlands. Moreover, those resources put high pressure on existing urban systems which have to deal with more complexity. An integration of systems is needed to move towards more sustainable cities.

The construction sector can be seen as one of the largest contributors to the problem. Although cities are aware of the urgency, their building plans often seem to be in tension with the environmental aims set. The city of Amsterdam has for example planned a significant number of new building projects in the coming years; however, it also has to comply with the national vision set which states the ambition to decrease the amount of raw materials that are used. In order to meet both aims, interventions have to be found for Amsterdam's building projects in which raw materials can be substituted by reused materials.

This research investigated whether urban symbiosis, a strategy that focuses on the reuse of waste streams in an urban local network of stakeholders, is applicable to construction materials. More specifically it researched which designs can be created that facilitate conversations between symbioses' stakeholders while valorising those construction waste flows in the city of Amsterdam.

By adopting the "Research through Design" methodology as a larger framework, the study has performed research with respect to both its research and design objectives. Within this framework, the study has made use of a case study, a renovation project in Amsterdam, to which the urban symbiosis strategy was applied. By literature research, interviews and a focus group data was gathered.

The study shows the potential for the urban symbiosis strategy to be applied to building materials. However, also some challenges have been indicated with respect to the complexity of the process, costs and the to-be-reused material's quality and requirements. The study presents several prerequisites to overcome those challenges.

In order to move towards an urban symbiosis and start reusing construction materials, the reuse process of those materials was investigated. The study derived a five-phase reuse process, including the indication of supply, harvest, design, processing and implementation. Furthermore, stakeholders in a construction material symbiosis have been identified and have been mapped in a value flow model clarifying the particular relationships and exchanges between them. In comparison to the traditional organisation of stakeholders, mainly changes at the supply side can be observed. Lastly, design criteria for each step in the reuse process have been derived for a design that could help establish an urban symbiosis.

Combining the design criteria with the reuse process and the stakeholders' network, a design for a platform was proposed that is able to start and facilitate the conversations in a symbiosis' network. It can be concluded that the platform can play a major role in the first two phases of the reuse process and so in the connection of supply and demand in the urban mine. The study finally presented a framework which shows the possible interactions between the stakeholders and the platform. The platform design can be seen as a first step towards the successful application of the urban symbiosis strategy for construction materials that helps the building sector in achieving a more sustainable performance.

Keywords: urban symbiosis, systems innovation, construction materials, material reuse, platform design

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1

INTRODUCTION

1.1 Background

Over the years, cities in the world have grown of which some even developed into metropolitan regions (UN DESA, 2018). Nowadays, their growth continues due to commerce and employment opportunities, physical security and the relative high number of attractions (e.g. cultural) among other reasons (Glaeser, 2008 & Kotkin, 2005, as cited in Horta & Keirstead, 2017). This leads to a greater resource demand in urban areas. After usage, most of these resources end up in large waste flows leaving the city. Kennedy et al. (2015) state that the share of water, electricity, energy and solid waste flows of 27 megacities (in 2010) is respectively equal to 3,0%, 9,3%, 6,7% and 12,6% of the total amount of that type of waste produced in the world. This stresses the importance of the reduction of all these types of waste flows in cities, but also mainly the one of solid waste.

In contrast to the sustainable development goal on responsible consumption and production as set by the United Nations (2015) describing the need for the reduction of waste generation through prevention, reduction, recycling and reuse, the current metabolism of cities is still characterised as linear; materials are produced, used and disposed (Kennedy, Cuddihy, & Engel-Yan, 2007). A major challenge for cities is therefore to transform this linear urban metabolism into a circular one, by which waste is seen as a resource and can be input for production processes again. According to the ladder of Lansink (Parto, Loorbach, Lansink, & Kemp, 2007), cities therefore have to look for opportunities to 'reduce', 'reuse' and 'recycle' resources respectively. Those steps can also be found back in the framework for the Circular Economy (Ellen MacArthur Foundation, 2013).

Besides, these large material flows also put a high pressure on existing systems that are operating in the cities of today. They become more complex and are challenged because of the amounts of materials going in and out the city. As recent research has shown, a reconfiguration of all technological systems is needed in the development towards sustainable cities (Vernay & Mulder, 2016). Systems normally emerge as independent entities (Mulder & TU Delft, 2017). When urban infrastructures and building types are reconfigured more effectively, resource flows can be managed (Dobbelsteen, Wisse, Doepel, & Tillie, 2012; Hodson, Marvin, Robinson, & Swilling, 2012; Monstadt, 2009). As stated by Mulder (2016b) a new mindset should therefore be adopted that focusses on the connection of existing systems rather than on the production of new systems and products. Also Pandis Iverot and Brandt (2011) mention that, "in order to reduce the metabolic flows in future urban districts even further, it is important to facilitate the integration of technical innovations into existing integrated systems" (p. 1043).

Also the waste transport has been identified as a challenge that cities are facing regarding waste management (Eisted, Larsen, & Christensen, 2009). The current system is centralized in most cities; waste is being transported to the outskirts of the city or to their hinterlands to be processed, recycled or incinerated. Therefore, possibilities for the processing of the resources close by need to be discovered.

The sector that has the largest share in the production of greenhouse gasses is the building sector (Raynsford, 1999). In the Netherlands, the construction industry accounts for 50% of the raw materials that are used in the Netherlands; construction and demolition waste has a share of 40% of the total amount of the nation's waste (The Ministry of Infrastructure and the Environment & The Ministry of Economic Affairs, 2016). Apart from this, the sector also has a large share in energy (40%) and water (30%) consumption, resulting in a major contribution to the CO2 emissions (35%). Therefore, the Dutch government formulated a vision for the building sector which reads as follows: "By 2050, the construction industry will be organised in such a way, with respect to the design, development, operation, management, and disassembly of buildings, as to ensure the sustainable construction, use, reuse, maintenance, and dismantling of these objects" (The Ministry of Infrastructure and the Environment & The Ministry of Economic Affairs, 2016, p. 59). In order to achieve this, many improvements in the field of circularity and management are needed. For most of the cities in the Netherlands this challenge is even larger because of their growth; the city of Amsterdam has for example planned an increase of 70.000 new homes by 2040 (Circle Economy, TNO, & Fabric, 2015). Construction and demolition waste are therefore an urgent and adequate material flow for this study to be researched.

Urban symbiosis, a strategy that focuses on the reuse of waste streams in an urban local network of stakeholders, is therefore interesting to apply for material flows in cities. Instead of reinventing new systems, it aims to connect existing ones (Mulder & TU Delft, 2017; Van Berkel, Fujita, Hashimoto, & Geng, 2009; Vernay, 2013). The establishment of a symbiosis requires, apart from flow data, communication to establish connections and working together to generate value (Cohen-Rosenthal, 2000). However, these aspects are often not a matter of course in current systems. Previous research has shown that the alignment of interests of parties in a symbiosis is a challenge (Mulder & TU Delft, 2017).

1.2 Problem statement

As presented in the previous section, an increase in the number of building projects is planned in Amsterdam for the coming years. On the other hand, the national government has developed a vision which states the ambition to decrease the amount of raw materials used during a similar time path. Meeting these two objectives seems to be a challenge when the conventional way of construction is persisted in which resources are used in a linear way. In order to realise the planned number of buildings within the boundaries of the vision that is set, new ways have to be found for Amsterdam's building projects in which required raw materials can be substituted by reused materials.

1.3 Study's objectives & research questions

1.3.1 Study's objectives

This study investigates in what way urban symbiosis can stimulate the transition to circular usage of construction and demolishing waste materials in Amsterdam. The main objective of this study is therefore creating a proposal for a design that supports the establishment of a sustainable urban symbiosis of construction materials between urban stakeholders, such as private parties, citizens and governmental organisations by facilitating conversations between these actors. On the one hand, this design should serve as a tool to open up the conversation about flows in the city and to make these flows visible, whereas on the other hand it aims to facilitate the conversation between stakeholders to establish connections and to change the autonomic approach stakeholders and companies usually adopt. Both the awareness and collaboration are crucial parts in the development goal on the reduction of waste generation set up by the UN (2015).

In the study, the assumption is made that the urban symbiosis strategy is applicable to construction materials. Based on the study's results, there will be reflected upon this assumption in the discussion chapter at the end of this report.

1.3.2 Research questions

The main research question of this study is formulated on the right page. Concepts in the research questions are further explained in the grey blocks.

Sub questions

The following sub questions can be formulated when operationalise the main research question into smaller research areas.

1. What is the state-of-the-art in the field of urban symbiosis?
2. What does the reuse process of construction materials look like when applying urban symbiosis?
3. Who are the potential urban symbiosis stakeholders in the context of construction materials in the city of Amsterdam?
4. How can the conversations between the stakeholders of an urban symbiosis be started and facilitated?

Main research question

Within the framework of urban symbiosis, which designs can be created that facilitate conversations between symbioses' stakeholders while also valorising construction waste flows in the city of Amsterdam?

As defined by Van Berkel, Fujita, Hashimoto, & Geng (2009), **urban symbiosis** is "the use of by-products (wastes) from cities (or urban areas) as alternative raw materials or energy sources in industrial operations" (p.1545). In this study this concept is adopted as a framework. Here, the term 'waste' will be used rather than 'by-product' since the study focusses specifically on materials that once have been used turning up as waste streams and thus often valuable resources. Instead of industrial applications, this research rather looks for local application opportunities in the building sector.

In order to start and facilitate the conversation between stakeholders of a construction material symbiosis, a **design** will be developed which intertwines with the research that is done. Examples of a design can be an interactive tool showing the possibilities of exchange and stimulating the communication between stakeholders or a physical installation that brings stakeholders together and makes them aware of the possible collaborations. The type of design that will be chosen depends on the outcomes of the research activities.

The boundaries for the construction waste flows that can be reused in the symbiosis of this research is the municipality of **Amsterdam.** The study strives to find applications for the resources in buildings within the city's boundaries.

The type of urban flow to which the urban symbiosis strategy will be applied is **construction waste.** This includes construction materials that are extracted when a building is demolished or renovated. The study has a particular focus on the extraction and reuse of **'components'**, being building parts or elements, such as doors and windows (Icibaci, 2019). This focus on the reuse of components can be motivated by the use of the ladder of Lansink, in which the 'reuse' stage is positioned in between the 'reduce' and 'recycling' phase, aiming for the highest reuse value of a material possible (Parto et al., 2007). It also aims to keep the material cycles as tight as possible to achieve greatest reduction in raw materials, labour and energy (Ellen MacArthur Foundation, 2013). Reuse of goods can also be defined as "the use of a product again for the same purpose in its original form or with little enhancement or change" (Ellen MacArthur Foundation, 2013, p.25).

Two main types of **stakeholders** will play a role in this research: the suppliers of valuable construction waste materials and the purchasers of these materials who will use these as their input resources. These will be identified when waste streams and opportunities for reuse of these materials are analysed and mapped. Moreover, other parties, such as public parties, might appear to be important players. These stakeholders commonly have different interests. This study aims to develop a design that (partly) overcomes this challenge.

1.4 Relevance

1.4.1 Societal relevance

In the problem statement the urgency for interventions is stricken to deal with the contradicting ambitions in the building sector. If those interventions will not be realised any soon, further extraction of raw materials and generation of waste can put major burdens on the environment. Researching strategies for closing resource cycles at a local scale, like urban symbiosis, can contribute to a reduction in raw material usage, waste production and transport in urban areas, resulting in more sustainable and liveable cities.

Apart from the overarching societal relevance mentioned above, this study also aims to reveal how stakeholders in the construction sector and their partners can be reorganised into a symbiosis network and how the alignment of their interests can be supported by the design.

1.4.2 Scientific relevance

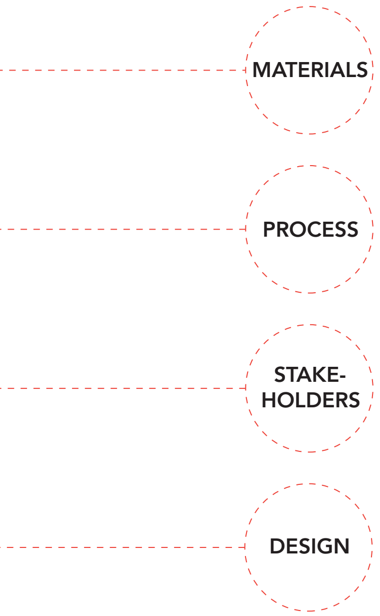
Urban symbiosis has been applied to several types of resource flows over the last years. Past research has shown the relevance of the application of this strategy in cities, however mainly examples for flows of energy and water can be found (Lenhart, Van Vliet, & Mol, 2015; Mulder & TU Delft, 2017; Vernay & Mulder, 2016). Kawasaki (Japan) is one of the few examples where urban symbiosis is applied to material flows; here, it is used as a strategy for municipal solid waste management (Geng, Tsuyoshi, & Chen, 2010). So far, urban symbiosis has not been applied to construction material flows. This study will offer insight in whether the strategy is applicable to construction materials and in what way. Results can be compared to symbioses applied to other materials flows. In this way similarities, differences and lessons can be derived, which will result in a better understanding of the applicability of urban symbiosis in general. Furthermore, it might also stimulate the spreading of the urban symbiosis approach to other material flows.

Additionally, being in line with the main research question, the study will reveal what the role of the design can be in the establishment of a symbiosis. Results will give insight in whether such tools can be used for the creation of other symbiosis structures.

1.5 Outline of report

Figure 1.1 visualises the outline of this research report. Furthermore, it indicates in which chapters answers are given to which research questions.

First, chapter 2 describes the methodology that is adopted by this study. Afterwards, the report presents several chapters in which research and results are reported. Chapter 3 presents existing literature on symbiosis and in this way sketches the framework for the study. To gain an understanding of the context in which this study is executed, chapter 4 introduces the construction sector and its characteristics. After the framework and context are illustrated, chapter 5 reports the findings of a baseline assessment that is done for the case study. Chapter 6 reveals the envisioned implications of the adoption of an urban symbiosis strategy for construction materials. Next, chapter 7 can be characterised as an interim reflection on the results from previous chapters in which design criteria are derived to be evaluated in the further course of the study. Results of this evaluation among other findings with respect to the design proposed can be found in chapter 8. When all results are reviewed, the discussion reflects on the study's findings in relation to existing literature, the methodology and its limitations and the stakeholders' network and the design found. Finally, the core findings as well as the answers to the sub questions and eventually the main research question are presented in the conclusion in chapter 10.



Based on the study's main research question and sub questions, four core concepts can be defined that will frequently return in the course of this report: materials, process, stakeholders and design. When one of these topics is addressed, the corresponding sphere (see spheres left) will be presented in the margin of the page.

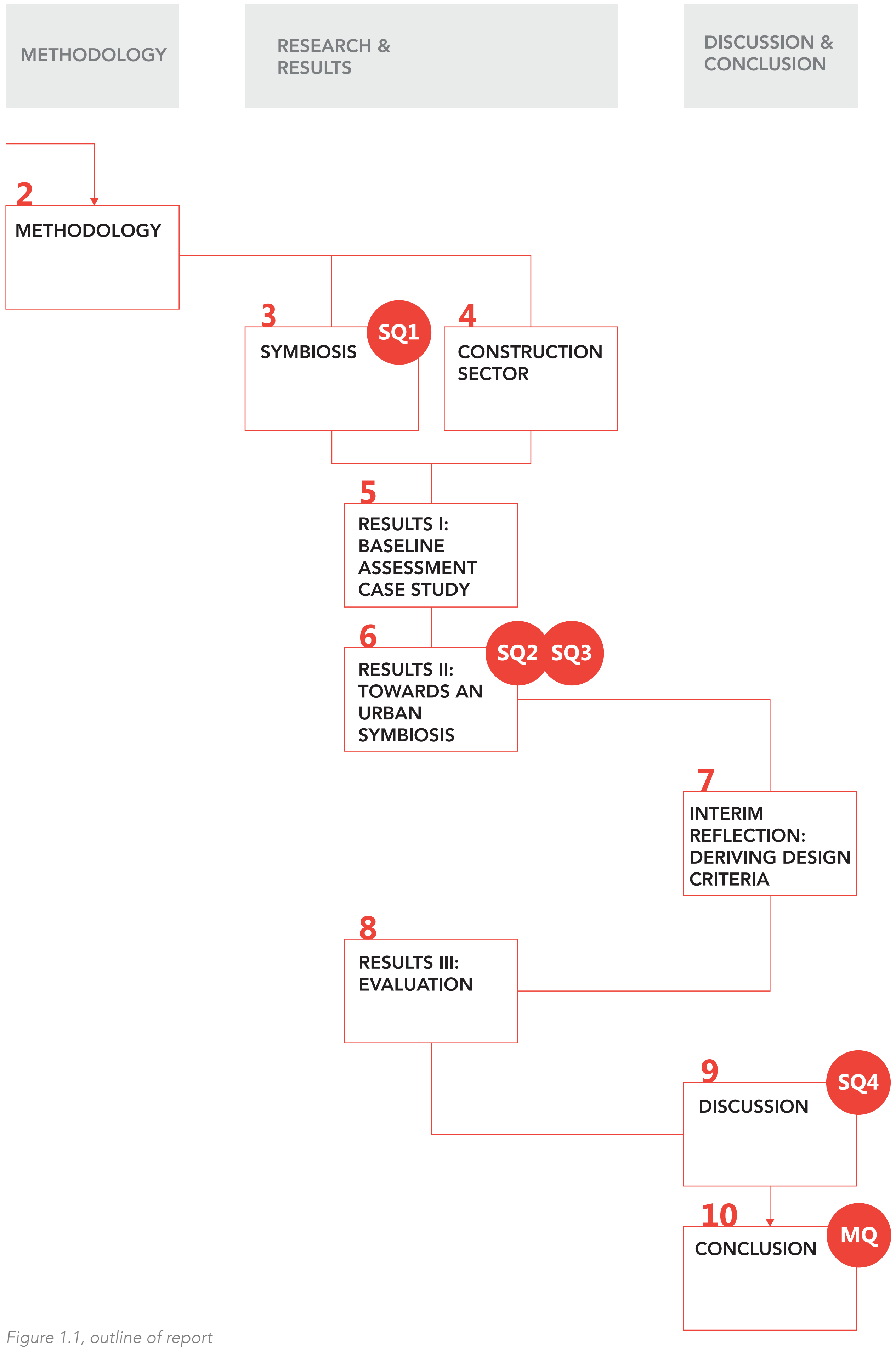


Figure 1.1, outline of report

2

METHODOLOGY

The aim of this study is to research whether the urban symbiosis approach is a useful approach to apply to increase the reuse of building materials and what design can be created to stimulate the collaboration between involved stakeholders in this. It comprises a research-oriented part as well as a design-oriented part. Additionally, as reported in the introduction, the sub questions can either be from a qualitative and quantitative earth. Because of this multilateral identity of the research questions, a mixed method approach is used. The 'Research through design' (RtD) approach is adopted as a larger framework here that enables the study to touch upon both the research and design aspects. Within this framework, there has been made use of a case study. Several data collection methodologies are adopted in order to analyse both research and design objectives.

First, the RtD approach is further explained, after which the case study is presented. Finally, the data collection, including the qualitative and quantitative methods, are described.

2.1 A 'Research through Design' approach

This study will be conducted according to the 'Research through Design' (RtD) method. The RtD method is part of design research (Frayling, 1993). Next to RtD, design research includes 'research about design' and 'research for design'. More concretely, RtD is "a research approach that employs methods and processes from design practice as a legitimate method of inquiry" (Zimmerman, Stolterman, & Forlizzi, 2010, p.310). RtD brings together research and design, which are often still seen as two separate worlds (Frayling, 1993). This approach fits this study since it has both a research and a design goal that are very closely connected and therefore cannot be reached by addressing them separately; on the one hand it aims to define whether urban symbiosis is a valuable strategy to be applied for building materials to reduce the environmental impact of the building sector, whereas on the other hand it researches how stakeholders in this process can collaborate more frequently and effectively by creating a design. The RtD methodology enables that the required and important connections between the two fields can be made in order to achieve both objectives.

Additionally, the method has its focus on the future as it reframes current problems to come to new insights for change, giving it an iterative character (Zimmerman et al., 2010). Design artefacts can be seen here as a mean to transform a current state into a preferred one (Zimmerman, Forlizzi, & Evenson, 2007). It also has an interdisciplinary approach since it aims to integrate knowledge and theories across different fields, giving it a holistic character (Zimmerman et al., 2010). These two characteristics make RtD an appropriate method to overcome complex, or so called 'wicked', problems. RtD therefore fits this study in terms of its interdisciplinary origin and the metropolitan region being the study's complex context.

Basballe and Halskov (2012) describe the course of the methodology and the interconnectedness of 'research' and 'design' by three different phases: coupling, interweaving and decoupling (figure 2.1).

In the first phase, research and design are coupled by which interests from both fields are combined and a framework for the research is created. Also, constraints are introduced. Roggema (2017) states that this coupling phase might also include pre-design research or certain types of analyses that need to be done first.

In the second phase, research and design are combined and from here an intertwined process starts (Basballe & Halskov, 2012). Important for this phase is that the objectives of each of the fields are clearly defined. Based on these objectives, a general outline for activities in this phase can be agreed upon. Material outcomes and/or activities not only generate input for the research and design interests on itself but the two fields also mutually influence each other's results.

Finally, findings for each of the two fields are separated, are reflected upon and are taken further (Basballe & Halskov, 2012). Initially, this phase focusses on each of the two fields separately. However, their interplay often appears to be ongoing since their results can be brought together e.g. in future projects.

This study's course is divided into phases according to the RtD course described by Basballe and Halskov (2012). An overview of the methodology and all accompanying steps is given in figure 2.2. It also shows which of the sub research questions are based on a research interest and which on a design interest and by which step in the methodology they are answered.

First, the research and design interests are coupled. literature research on (urban) symbiosis sets the framework of the research.

Secondly, in interviews, subjects are asked questions regarding symbiosis and designs that might help to establish connections and facilitate communications in an urban symbiosis; interests from both fields are combined and mutually influence each other. Subsequently, an interim interpretation is done by separating the interests from the two fields, though taking place within the interweaving phase. In this phase, the particular reuse process in an urban symbiosis setting and the design criteria are derived. Afterwards, those are evaluated in a focus group, combining again the research and design interests, which leads to the proposal of a final design. Although not described by the theory on RtD, this in-between step is required in order to meet the study's main objective. It namely enables the researcher to validate the symbiosis' reuse process and the design criteria and to bring together the findings from the research and design interests to come to a proposal for a design. The discussion (chapter 9) will further reflect on the benefits and limitations of this choice.

In the decoupling phase, there is reflected upon the research and design interests separately. On the one hand, findings on the applicability of urban symbiosis to construction materials is discussed. On the other hand, a design is presented that shows how connections between stakeholders can be established and in what way communications between them can be facilitated. Based on these findings, the main research questions can be answered.

After the case study is presented, each of the steps is explained in further detail.

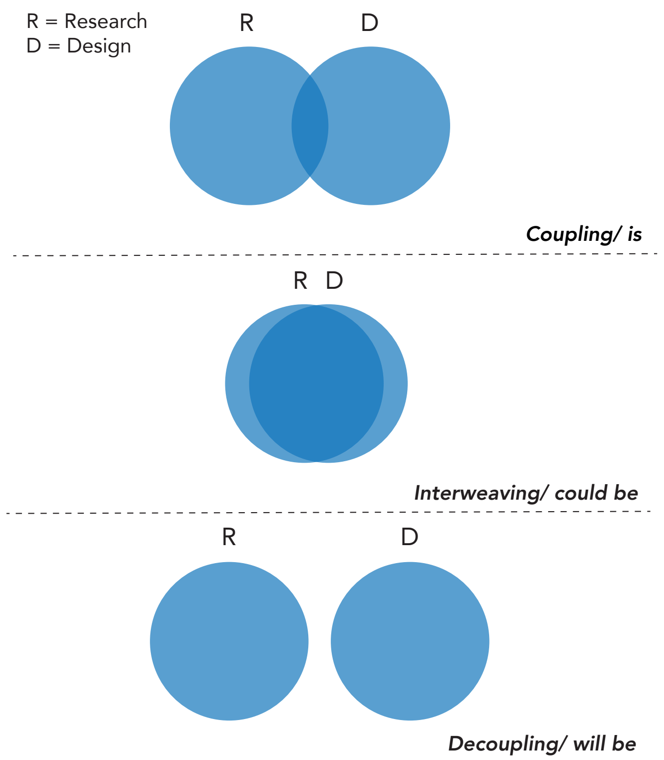


Figure 2.1, visual of the course of the RtD methodology (adapted from Roggema (2017)).

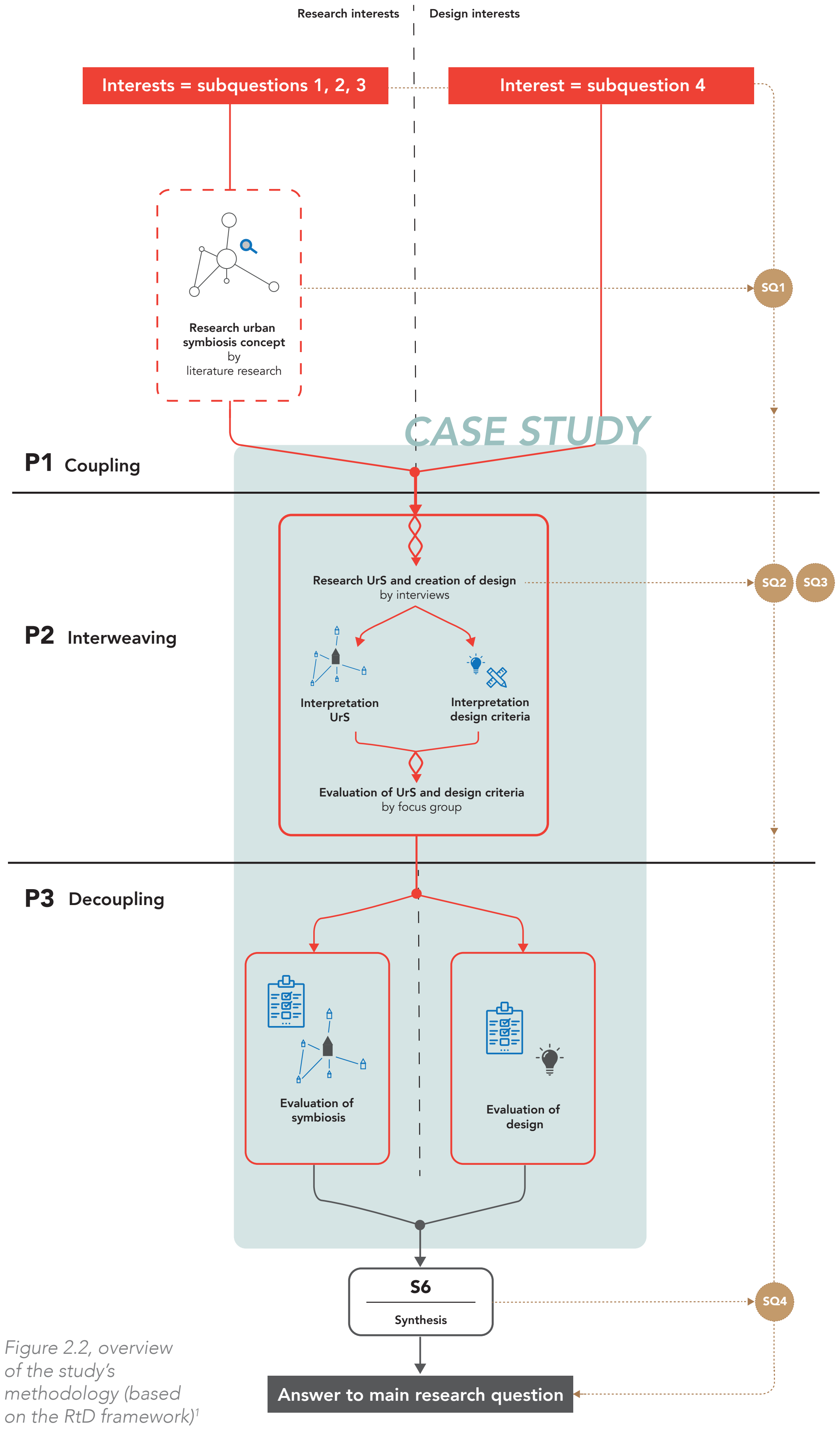


Figure 2.2, overview of the study's methodology (based on the RtD framework)[1]

1 See for credits for some of the icons in the figure chapter 'References'.

2.2 Case study

2.2.1 Literature & motivation

In order to reflect on the feasibility of an urban symbiotic building material system in Amsterdam, a case study is adopted. A case study can be defined as "an empirical inquiry that investigates a contemporary phenomenon in depth and within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident" (Yin, 2009, p.18). One of the reasons for making use of a case study in this research is the fact that it aims to paint a picture of the conventional construction process and how this can be reorganised for the reuse of materials. Relating this to literature, Swanborn (2003) argues that retrieving detailed information about a social phenomenon by following a real-life process over time can be seen as the most important consideration to choose for a case study as a method. In case of this study, the construction project is not followed real-time, but is 'reconstructed' afterwards together with the interviewees (Swanborn, 2003). Another reason that is named by Swanborn and complies with a reason for the adoption of case study as a method in this study that it can give insight in the social relationships that the actors within the case study have. An understanding of the current relationships is needed to develop ideas on reorganising and designing a new system. Additionally, also the exploration and determination of the divergent visions of those actors study is another motivation for applying this method (Swanborn, 2003) .

The case study is instrumentally used, that is to say to research and explain a more general phenomenon, in this case urban symbiosis (Stake, 2005). When case studies are used to research more specific phenomena (intrinsic case study's (Stake, 2005)), the method can also help to come up with design suggestions or policy advices for that specific case (Swanborn, 2003). Although the case study is instrumentally used here, this study aims to derive design possibilities for a more general system, relating back to the main research objective of this study.

Regarding the use of data collection methods, Yin (2011) supports the use of a variety of sources for information in one case study,. He also argues that quantitative and qualitative data can be combined in case studies. This validates the compatibility of this study's multiple data sources including interviews, a focus group and material flow data.

The research focusses on a single case study. An important argument that can be given for the use of single case study is that this research is from an explorative nature; the in-depth analysis of the case study is more important than a quantitative statement on the study's performances. Another argument is the limited time scope of the study, in which a large variety of data collection methods is done, which is therefore not offering room for multiple cases to be studied. In terms of the selection of a proper case study, several criteria are set up for this case, which are presented next.

2.2.2 Case study selection

The case is selected based on content-driven and pragmatic criteria (Swanborn, 2003). First the content-driven criteria are discussed.

1. Regarding the aim and context of this research, the case study needs to be **a building or building block in Amsterdam.** Around this case study opportunities for the arrangement of an urban symbiosis network are explored.
2. Since urban symbiosis tries to process both in- and outgoing material flows, the case study ideally includes both. That is why **a renovation or a demolition/ rebuild project is most suitable for this study.**
3. Furthermore, because of the research into material flows, **3D models (e.g. BIM) of both the old and new building need to be available.**

From a pragmatic point of view, the following criteria are set up:

1. To be able to interview the stakeholders of the case study and to organise a focus group, the construction project has to run at the moment the research is conducted. Therefore, **the project needs to start or has to be running in February 2019 or later, with a maximum of two years** (as it is assumed that in general, detailed designs of buildings are not ready two years ahead of the actual constructions starts).
2. **The building has to be owned by a housing corporation in Amsterdam.** It is assumed that there is a greater chance of finding an appropriate building because of their large number of projects running. Additionally, due to this reason, it will also be easier to find a second project wherewith materials can be exchanged.

In the search for a case study, also factors such as reachability of corporations and the use of the researcher's known contacts have been of influence.

2.2.3 Case study: Burgemeester Focktraat (Amsterdam West)

The case study that is used for this research is the 'Burgemeester Fockstraat' (hereafter referred to as Burg. Fockstraat) project, located in Amsterdam West in the 'Dobbebuurt'. It concerns the apartments 21 - 47 of the Burg. Fockstraat (uneven) and the apartments 1 - 27 of the Speelmanstraat (uneven) (De Alliantie, 2016). The project is initiated by housing corporation 'De Alliantie' being the owner of the building and can be characterised as a renovation project (De Alliantie, 2016). The project will be finished in the summer of 2019.

According to the renovation plan (De Alliantie, 2016), the renovation concerns 112 social houses, equally spread over two porch flats (figure 2.3a-e). Furthermore, the plan states that those buildings are Airey buildings, prefabricated houses that were built after the Second World War. They were initially built as temporal complexes in order to deal with the housing shortage at that time. However, they are still in use. The construction is in good state though the apartments do not meet the needs and demands of today (De Alliantie, 2016). Due to the fact that the buildings have been there for a few decades, those have become municipal monuments, which forced De Alliantie to renovate the buildings (De Alliantie, 2016). During the renovation, apartments are modernised and made more energy-efficient (De Alliantie, 2016). They are totally renewed from the inside; only the skeleton of the building is kept.

The project meets all criteria formulated in the previous paragraph and is therefore an appropriate case study for this research.

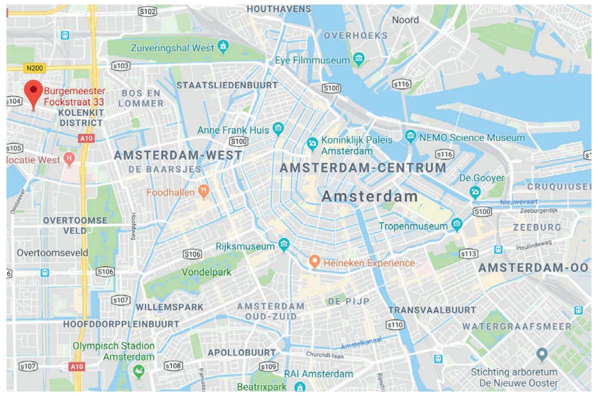


Figure 2.3a-e, case study's location on the map (a) (Google Maps, 2019), 3D model (b) (De Alliantie, 2016) and outlook (c-e)

(figure 2.3c-e)

2.3 Data collection

2.3.1 Topic list

In order to research all the concepts in the main research question and sub questions that should lead to their answers, a topic list is constructed (appendix A.1). Topics initially arise from the objectives of the study as well as literature research (Arthur & Nazroo, 2003). First, an overall goal is formulated: 'sustainable construction chain in Amsterdam'. Such a goal is often the overarching aim to which the research contributes yet is outside the study domain (Hendriksen, 2018). Subsequently a purpose is defined, equal to the objective of this study, being 'the creation of a design that supports the establishment of a sustainable urban symbiosis of construction materials between urban stakeholders. Afterwards, this purpose is broken down into concepts which are operationalised into topics and aspects (Hendriksen, 2018). In literature, there is a varying number of levels mentioned into which those concepts or topics can be operationalised and also the naming of those levels differs (like is the case for Arthur & Nazroo (2003) and Berg (2004)). The concepts, topics and aspects are either researched by a qualitative or a quantitative method or both (Hendriksen, 2018); the list shows which topics and aspects are researched by which method. For one of the concepts an example is given in figure 2.4.

While data is being collected, often additional topics arise (see 2.4.2 'Qualitative analyses' – 'data analysis'). Therefore, after the interviews and their analysis, the topic list is updated, which gives a complete overview of the topics discussed and their relation to the study's main objective. This final topic list can be found in appendix A.

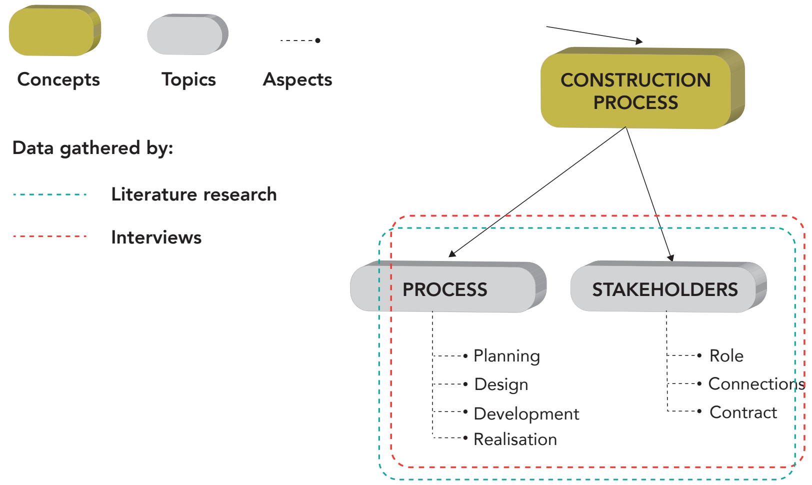


Figure 2.4 example of a concept, operationalised into topics and aspects (from topic list, appendix A).

2.3.2 Qualitative analyses

In this study, three qualitative research methods are used: literature research, semi-structured interviews and a focus group. This subsection will further elaborate on each of the three methods.

Literature research

The first data collection that is done is literature research. According to the first sub question, it studies the state-of-the-art of the symbiosis concept. In this way, a theoretical framework is established in which the rest of the research will be conducted. This is presented in in chapter 3 ('Literature Research'). Furthermore, to gain an understanding of current building practices, this method is used to conduct research regarding the construction sector. Results are reported in chapter 4 ('Construction Sector'). Books, scientific papers, reports, policy documents and other documents are the main sources from which the data is collected.

Semi-structured interviews

Most of the concepts and topics that were outlined in the created topic list are researched by interviews. The method is identified as "a conversation with a purpose" (Berg, 2004, p. 101). More specifically, this type of conversation has the aim to gather specific information.

Three main purposes for this study's interviews are identified: (1) gaining an understanding of the current construction process and the stakeholders' roles in this process; (2) exploring and comparing the stakeholders' visions on the exchange of materials; (3) defining design criteria for a tool or methodology to stimulate this exchange.

Interviews are widely applied in the field of sociology. Based on its frequent application in ethnographic research, Flick, Kardorff and Steinke (2004) mention that interviews as a method give a researcher the ability to ask the subject about his field-specific knowledge as well as to research his subjective perspective. This is emphasized by Berg (2004) & Dent Goodman (2011) who stress that interviews give insight in a subject's personal statements and perceptions. Therefore, this method is most appropriate to research the experiences of stakeholders in the construction process and their vision on future developments. Results are expected to meet above-mentioned purposes.

The interviews that were conducted were semi-standardised. A set of questions was prepared, pre-formulated and pre-ordered. Yet, as described by Berg (2004), in the semi-standardised interview the interviewer is allowed and expected to probe beyond the answers to these preformulated questions and to ask follow-up questions if the conversations directs to this accordingly. Also, the final order in which the questions were asked was subject to change, dependent on the course of the interview and the answers the subject provided. In this way, the semi-standardised interviews enabled the researcher to compare answers of the subjects on the one hand, whereas this method also offers the freedom to retrieve their more 'textured' answers (Berg, 2004).

Sampling

In terms of sampling, the study makes use of a non-probability sample, or a purposive sample (Ritchie, Lewis, & Elam, 2003). This is a typical type of sampling that is used for qualitative research studies as well as for small scale in-depth research like this study (Ritchie et al., 2003). In purposive samples, specific criteria are used for selecting the sample (Patton, 2002). The following criteria are used for the sampling of this study's population:

- In order to gain an understanding of the state-of-the-art and challenges in the traditional construction process, and more specifically that of the case study, interviewees need to be case study representatives of the in literature identified stakeholders in a traditional construction process.
- To connect the symbiosis framework with the construction sector, someone has to be interviewed who has knowledge in both fields, preferably someone who is connecting/ is able to connect them.
- To gain insight in best-practices of current designs that enable the exchange of materials, one of the interviewees has to represent a group of experienced designers.

In line with the criteria mentioned and the study's objective, the most appropriate way of sampling, within the area of purposive sampling, is 'expert sampling' (Etikan, 2016). This type of sampling is especially useful when one is exploring new research areas (Etikan, 2016). However the sampling applied here, especially in case of the subjects of the case study, can also partly be related to 'typical case sampling' (Patton, 2002). This method involves subjects that are representatives of typical or 'normal' positions to provide a detailed profile (Ritchie et al., 2003). For this study, it is expected that the case study's interviewees represent similar stakeholders in other traditional construction projects. Information about their a profile and their vision is acquired during the data collection.

In table 2.1 an overview is given of the interviewees in this study.

Date	Interviewees case study	In the further course of this report referred to as:
March 7, 2019	Architect and project coordinator of case study	Architectural firm[1]
March 7, 2019	Main constructor of case study and project planner	Main constructor, project planner
March 12, 2019	Project manager (De Alliantie) of case study	Project manager
March 15, 2019	Architectural designer	Architectural designer
April 12, 2019	Designer platform Harvestmap	Designer

Table 2.1, overview of the study's interviewees

Data collection

In order to make those topics workable for the interviews, parts of the topic list are reformulated into a topic guide. Such a guide can be seen as an interview agenda, or focus group agenda, and enables a researcher to conduct research in a structured way yet not limiting flexibility (Arthur & Nazroo, 2003). Since different topics are researched in different interviews (as not all topics are relevant for all stakeholders), the interview topic guides differ from each other. Nonetheless, they are all based on the same basic outline. Questions that were formulated can be categorised according to the four following themes:

1. construction process;
2. exchange of materials;
3. design tool;
4. other.

The themes refer back to the three initial interview goals set earlier; additionally, the theme 'other' includes questions to acquire specific additional information needed from the concerned subject to gain a broader understanding of its tasks in the process or its vision on aspects. At the start of the interview, the themes are introduced to each of the subjects. Furthermore, the order in which questions is asked is mainly based on the order of questions described by Patton (1990). He describes that interviewers have to ask questions regarding the subject's behaviour, knowledge, opinion, feelings and background information subsequently. This is in line with the topics to address, that is to say the questions about interviewees' experience (behaviour) in the construction process (1), their knowledge about the exchange (2), and their opinion about this exchange (2) as well as about a design tool (3).

The topic guides for the interviews are enclosed in appendix B Interviews are voice-recorded by the interviewer's phone. Their avarage duration is 45 minutes, with a minimum of 30 minutes and a maxium of 60 minutes.

Data analysis

After the interviews are conducted, an extensive summary is made of each conversation. In the making of those summaries, the researcher makes use of the voice records of the interviews. The main motivation for making extensive summaries instead of transcripts is the restricted time frame in which this study is executed.

Subsequently, the content of the interviews, captured by the extensive summary, is 'decoded' in order to make it useful and understandable for others (Dent Goodman, 2011). This is done by a qualitative content analysis. Berg (2004) describes content analysis as being the "careful, detailed, systematic examination and interpretation of a particular body of material in an effort to identify patterns, themes, biases, and meanings" (p. 338).

1 The architect and the project manager (from the same architectural firm) are together interviewed in one interview. No distinction is made between the information provided by the architect and the project coordinator. Therefore, the further course of this report will refer to this interview as 'Architectural firm'.

Qualitative analysis more specifically analyses the subjective interpretation of this data (Hsieh & Shannon, 2005).

Three main types of qualitative analysis can be identified (Hsieh & Shannon, 2005): conventional, directed and summative content analysis. The main difference between the three is the way the interview content is categorised. This also closely relates to the degree of theory that is known about the phenomenon to-be-researched. In conventional content analysis, the theory about the phenomenon is limited. Therefore, categories are derived from the interview data itself to describe the phenomenon. In contrast to the latter, the directed type makes use of predefined categories and are subsequently verified and complemented by categories that come forward out of the data. This is possible because theory of the phenomenon exists to a certain extend; results will expand the range of the phenomenon's theory or deepen it. The summative analysis also aims to deepen a phenomenon's theory, however it mainly tries to understand why certain words are used in a specific context (Dent Goodman, 2011; Hsieh & Shannon, 2005). The analysis is based on identification and quantification of words in order to define the specific use of a word in terms of content or context.

With respect to the main research question and aim of this study as has been formulated in chapter 2, this study on the one hand analyses the current state of the construction industry in order to find opportunities for the exchange of building materials, a field that is rather new. Therefore, as regards the amount of theory known about the phenomenon, it is most appropriate to make use of the directed analysis type. The study namely has the aim to extend the theory about circular use of building materials. Moreover, the topic list that has been made after initial research can be seen as a set of pre-defined categories. This medium is also input for the creation of the interview questions and therefore it is logical to redirect the answers to these categories; however, new topics that arise should not be excluded. That is what the directed type of qualitative content analysis supports.

Hsieh and Shannon (2005) describe that a directed content analysis can be executed according to the following steps:

1. Key concepts or variables are identified as initial coding categories (as has been done by the creation of the topic list) (Potter & Levine‐Donnerstein, 1999).
2. Based on the theory, each category is expressed by an operational definition.
3. In this step, the researcher has a choice: depending on whether he or she wants to capture general data or specific data, the text can be highlighted first (according to topics but also other important statements regardless the predefined categories) or can be coded immediately respectively. In this study, the extensive summaries are highlighted first to ensure no important statements about predefined and non-defined categories are left out and to increase trustworthiness. Afterwards, the text is categorised according to predefined categories; information that cannot be categorised is assigned to a new category. Also, subcategories can be made.

Afterwards, the coded information is compared for each of the categories and conclusions are drawn. Results are presented in chapter 5 ('Results I: Baseline Assessment Case Study') and chapter 6 ('Results II: Towards an Urban Symbiosis').

Focus group

After the interviews are done and analysed, a focus group is organised. A focus group can be defined as group interview, in which a moderator guides the conversation and a group of participants discusses on topics that are introduced by the moderator (Morgan, 1997). Using focus groups enables the researcher to generate data that is created by the interaction between participants of the focus group (Finch & Lewis, 2003; Morgan, 1997). Participants are able to share and compare their visions and ideas (Morgan, 1997). Furthermore, they become more aware of their own viewpoint (Finch & Lewis, 2003; Morgan, 1997). Differences between the participants' perspectives are pointed out more clearly (Finch & Lewis, 2003; Rabiee, 2004). According to Lewis (2003), focus groups are suitable as a method to "tackle abstract and conceptual topics" (p.60) and to support participants

to think creatively and generate solutions. This is in line with this study's aim since it asks the participants to think about what new cooperation forms between stakeholders can be established in a (new) reuse process and what design could be of help in an urban symbiosis of materials. Furthermore, the method is compatible with in-depth interviews and the two can also be combined. For example, in a the focus group findings from the interviews can be verified (Lewis, 2003). Based on the latter, this study uses the focus group as a method to evaluate the design criteria that resulted from the interviews.

With reference to the RtD method that has been adopted, the goal of the focus group is two-fold; on the one hand it aims to evaluate the design criteria which come forward out of the interviews and to apply those in a platform (1), whereas on the other hand it aims to co-create a communication structure between stakeholders (2). While the latter answers the third sub question regarding the facilitation of communication between stakeholders, the former touches upon the main research question.

Sampling

The same sampling method is adopted here as is done for the interviews, namely expert sampling (see subparagraph 'sampling' under 'semi-structured interviews' of this section for an explanation). Criteria for the sampling of the participants of the focus group are the following:

- **Part of the participants need to be case study representatives of the in literature identified stakeholders in a traditional construction process**
- Because the discussion on scale is an important part of the focus group discussion, o**ne or more participants have to have a strategic background or a managing role in multiple projects** in order to view the process from a wider perspective regarding scale.
- Since the discussion will address an innovative field and process, it is decided to keep the context of the case rather 'simple' and standard. Therefore, in order to increase the level of familiarity with the topic and to decrease the complexity of emphasising accordingly, **participants who are familiar with the case study or who are working for De Alliantie are preferred.**

Again, it is assumed that the case study's participants represent similar stakeholders in other traditional construction projects.

The ideal size of a focus group may differ, however is most ideally six to eight (Finch & Lewis, 2003; Krueger & Casey, 2000; Morgan, 1997) or ten (Rabiee, 2004); in this way, the group is able to sustain one conversation, whereas on the other hand it reflects a wide variety of perspectives (Rabiee, 2004). Often, the participants have similar backgrounds (Morgan, 1997).

Table 2.2 gives an overview of the participants of the focus group.

Date	Interviewees case study	In the further course of this report referred to as:
May 2, 2019	Architect of case study	Architect
	Project coordinator (from architectural firm) of case study	Project coordinator
	Main constructor of case study	Main constructor (F)
	Project manager (De Alliantie) of case study	Project manager (F)
	Area developer & manager Circular Economy (De Alliantie)	CE manager
	Strategic consultant Circular Economy (De Alliantie)	CE strategic consultant

Table 2.2, overview of the focus group participants

Four of the six participants are also interviewed for this study. This is seen as an advantage, regarding the first and third sampling criterion, their earlier involvement in the research and pragmatic reasons, rather than as a limitation.

Data collection

The focus group is organised according to 5-phase structure proposed by Finch and Lewis (2003), including scene setting and ground rules (1), individual introductions (2), opening topic (3), discussion (4) and ending discussion (5). Those are derived from the staging of group processes as described by Tuckman & Jenson (1977).

During the scene setting, the research is introduced and the goals of the focus group are presented to the participants. Afterwards, each of the participants is shortly asked to introduce himself. Subsequently, the topic is introduced by a short presentation given by the researcher. It presents the main findings of the interviews regarding the reuse of materials and its process. It ends with the introduction of a potential design (platform) that can be used and an example is given ('Harvestmap'). The discussion follows. It consists of two parts and is based on the to-be-researched topics in the topic list. It starts with an introductory discussion on a platform for De Alliantie as a housing corporation. Motivation for this is the fact that the participants are more or less familiar with De Alliantie. When this is applied to a more unfamiliar phenomenon, that is the exchange of resources, it is assumed that this might be a better start than when both aspects would be completely new to them. The second, more elaborate discussion is namely about a platform for Amsterdam, which addresses the actual aim of the study, in which is reflected on the whole reuse process from beginning to end as well as on the stakeholders' roles in this process. During this discussion, also the design criteria that resulted from the interviews are evaluated. Finally, the discussion is ended and the session is closed.

For an overview of the outline of the focus group, see appendix C.

Several tools are designed to assist in the discussion. Throughout the whole session there is made use of a PowerPoint presentation to guide the session. To direct the discussion on the Amsterdam platform, a scenario is written. This scenario can be read in appendix D. In short, it proposes a situation in which 200 doors are extracted from another building in Amsterdam and subsequently are offered by a platform at the moment the case study project would be built. The participants are asked to reflect upon the process when they would buy those doors and would implement them in the Burg. Fockstraat project. An accompanying process map is designed to present the phases of the reuse process and to invite the participants to think along and add notes and post-its. Also, coloured stickers representing various stakeholders are used so participants can indicate which stakeholders would be involved in which phases. Furthermore, for each participants a small booklet is made available that includes the design criteria that are set up per phase in

the reuse process. They can agree or not agree with each criterion and can make notes or suggestions. It functions as a kind of questionnaire which is filled in when each phase of the reuse process is addressed along the course of the scenario. The process map and booklets can be seen in are figure 2.5.

The focus group is voice-recorded. Its duration was one hour. Furthermore, during the discussion notes have been made by a secretary.

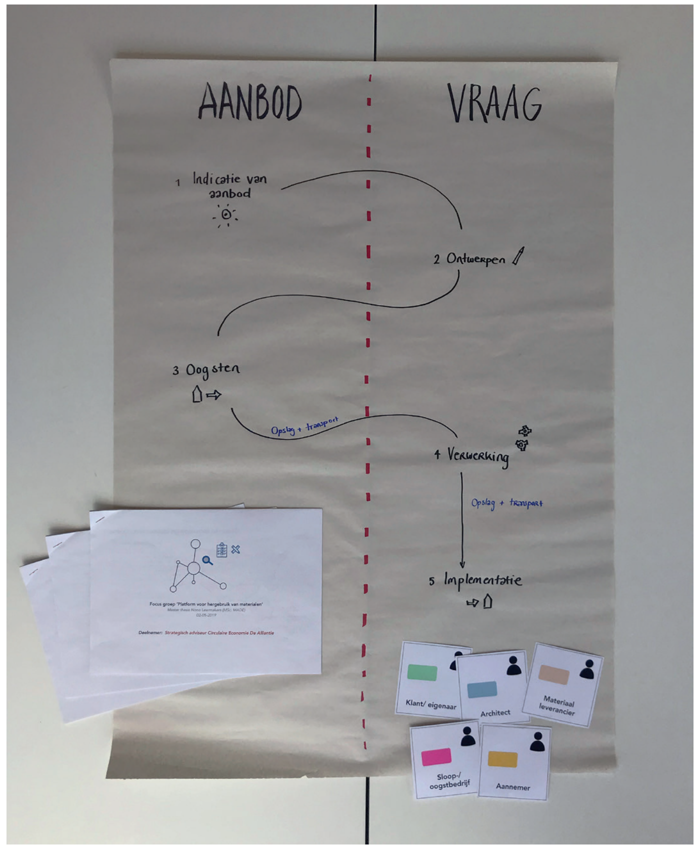


Figure 2.5, tools designed for the focus group, including design criteria booklets (left) and a process map (in Dutch) (center)

Data analysis

The focus group is analysed in the same way as the interviews are analysed. First, an extensive summary of the voice-recoding is made. Since the directed qualitative content analysis is also applicable to focus groups (Hsieh & Shannon, 2005; Kondracki & Wellman, 2002), this analysis is executed subsequently. For further information on this method and its way of execution, see subparagraph 'data analysis' under 'semi-structured interviews' in this section. The same coding scheme is used as for the interviews; however, the scheme has been adapted in between according to the results and codes that came out of the interviews. For the 'questionnaire' part on the design criteria goes that results are put next to each other and are compared after which conclusions are drawn.

Results, including the evaluation of the platform's process, expected users and scale, are reported in chapter 8 ('Results III: Evaluation'). In its second section, results are presented regarding the evaluated design criteria.

Summaries of the interviews and the focus group as well as their analyses are available upon request.

3

SYMBIOSIS

This chapter presents the framework of the study constructed by literature research on symbiosis. It concerns three types of symbiosis: natural, industrial and urban symbiosis. Section 3.1 first gives a general introduction to the urban metabolism approach that, just as industrial and urban symbiosis, found inspiration in natural processes. Urban metabolism forms the greater system in which industrial and urban symbiosis principles can be applied. The natural phenomenon of symbiosis as well as industrial and urban symbiosis are introduced in section 3.2, 3.3 and 3.4 respectively. It is followed by a comparison of the three types of symbiosis with regard to materials, process and stakeholders in section 3.4. Lastly, section 3.5 explains how the presented theories and metrics are used in this particular study.

3.1 Urban metabolism: cities being ecosystems

Urban metabolism was found by Wolman (1965). The concept is described as "the sum total of the technical and socioeconomic processes that occur in cities, resulting in growth, production of energy, and elimination of waste" (Kennedy, Cuddihy, & Engel-Yan, 2007, p. 44). Initially, the urban metabolism concept has been a response to the large amounts of resources that were consumed in cities, the waste streams that were generated by this and the growing concern about the unsustainable consumption behaviour at the time (Broto, Allen, & Rapoport, 2012). Since then it has found inspiration in nature and her sustainable processes. In this case the source of inspiration is the metabolism of ecosystems, being the production and consumption of organics matter (C. Kennedy et al., 2007; C. Kennedy, Pincetl, & Bunje, 2011).

In the urban metabolism approach, the city is viewed as an organism, or rather as a complex ecosystem (C. Kennedy et al., 2007). In the light of these natural phenomena, "cities transform raw materials, fuel, and water into the built environment, human biomass and waste" (Decker, Elliott, Smith, Blake, & Rowland, 2000, p. 715). Urban metabolism studies the energy, water, nutrients, materials and wastes that enter and leave the city or that are stored here (C. Kennedy et al., 2007). However, in contrast to natural systems, that are described as relatively cyclical and efficient (Dunn & Steinemann, 1998) , urban systems are far from sustainable yet. Most resources are disposed once they are used; only a limited amount of materials is recovered for reuse or recycling. Therefore, the current consumption pattern, and thus the metabolism processes of most cities can be seen as linear (Girardet, 1992). In order to head towards sustainable cities, this linear type of metabolism has to be transformed into a circular, or sustainable, urban metabolism. Therefore, output streams have to be recycled to become input streams for the system again (Girardet, 2008). By doing so the consumption will be kept within the boundaries of the production and waste processing capacity of the city's hinterlands (C. Kennedy et al., 2007).

According to (Newman, 1999), the goal of sustainability in a city reaches further than the reduction in natural resources and the waste generation; he adds that cities simultaneously can improve "its liveability, so that it can better fit within the capacities of the local, regional, and global systems" (p. 220).

A difference can be made between product metabolism and waste metabolism. In contrast to the product metabolism that is based on raw materials, this study will mainly focus on the waste metabolism that is "the disposal and reuse of byproducts and wastes generated by the product metabolism" (Zhang, Zheng, Chen, Su, & Liu, 2014, p. 96). Therefore, the focus will mainly be on the output streams and the possibilities to transform these streams into input streams for the urban ecosystem.

As the introduction of this chapter indicates, urban metabolism forms the greater system in which symbiosis principles can be used to move towards a more circular metabolism in cities (Mulder, 2016a). Those concepts are explained next.

3.2 The Natural Phenomenenon 'Symbiosis'

3.2.1 Symbiosis
Symbiosis is a phenomenon in nature that was first described by plant pathologist Anton de Bary in the 19th century (1879). He defined symbiosis as the living together of different (interspecific) species, which refers back to the Greek term **'συμβιωσιζ'** . Many forms of symbiosis can be found in nature. The biochemical research field has studied symbiosis ranging from plants and algae to fungi's, bacteria and animals (Paracer & Ahmadjian, 2000).

Symbiosis has played an important role in the evolution since early history. It has the ability to create novelty, e.g. new metabolic capabilities (Douglas, 1994; Paracer & Ahmadjian, 2000). A central process in most of the cellular symbioses is endocytosis, that is described by "the uptake of extracellular material into a cell in a membrane bound vacuole" (Paracer & Ahmadjian, 2000, p.3). It is this endocytosis process that enabled eukaryotes, being cells having a membrane around their nucleus yet limited metabolic capabilities, to acquire new metabolic functions, such as photosynthesis and aerobic respiration, by forming a symbiosis with endosymbionts, performing the right biochemical processes (Douglas, 1994; Paracer & Ahmadjian, 2000). This gave rise to new cell organelles, such as mitochondria and chloroplasts. The extension of metabolic capabilities by symbiosis will be discussed more elaborately in subsection 3.2.3 'Extending metabolic capabilities.

Despite the fact that symbioses are acknowledged being important processes taking place in environments near us, there is no universal agreement on the definition of the term. Miller (1994) defines symbiosis as the exchange of materials, energy or information between at least two different species. In addition to the definition of De Bary, symbiosis can also be seen as an association between two or more organisms of a different specie who perform a permanent or long-lasting interaction (Paracer & Ahmadjian, 2000). However, research argues that also short-term interactions should be seen as symbiosis (Douglas, 1994). Moreover, whereas De Bary insinuates that also parasitism can be seen as a form of symbiosis, other researchers argue that symbiosis is only about interactions which lead to mutual benefits for the species (Douglas, 1994).

3.2.2 Interactions
According to Paracer & Ahmadjian (2000),"no organism is an island - each one has a relationship to other organisms, directly or indirectly" (p.3). Symbiosis can be seen as such a type of interaction between organisms in nature. Regarding the terminology used, in a symbiosis one specie adopts the role of the symbiont and the other of the host. Sometimes, when one talks about the two species in a symbiosis, they are both called symbionts. Often, the host is the largest organism (Douglas, 1994). According to Douglas (1994), symbionts can in most cases of symbiosis be found inside the host organism. She points out that symbioses can be intracellular or extracellular; the symbiont lives inside or outside the host's cells respectively, however the latter is most common. Moreover, in most cases of symbiosis, the host acquires new metabolic capabilities as it profits from the presence of the symbiont and their interaction (Douglas, 1994).

Paracer & Ahmadjian (2000) describe three types of symbiosis that exist:

1. *Mutualism*

This type describes the interaction between two or more different types of organism who mutually benefit from the symbiosis. The primary factor is nutrition. It is hard to assess to what extent the symbiont and host benefit (Bronstein, 1994b; Cushman & Beattie, 1991). Symbioses are namely characterised as being complex interactions (Bronstein, 1994a; Doebeli, M., & Knowlton, 1998). An example of equal benefit for both species cannot be found (Boucher, 1985; De Bary, 1879); the extent to which the species benefit rather differs.

2. *Parasitism*

Parasitism is described as the interaction between two species in a symbiosis of which one benefits at the expense of the other. In most cases of parasitism, the symbiont benefits in

terms of nutrition as it feeds itself with nutrients from the host. It can cause a disease inside the host or it can even lead to death. Due to the fact that symbiosis has been associated with mutualism, and so with benefits for both of the organisms, in the past, parasitism is often still rejected as a form of symbiosis. However, in many parasitic interactions parasites do not cause diseases and do not influence the host in an adverse manner.

3. *Commensalism*

In a commensal symbiosis one of the organisms benefits while the other gains neither harm nor benefit. The benefit for one of the symbionts is in most cases from a nutritional or protective nature. Specific types of commensalism are phoretic relationships, in which there is a benefit in terms of transport, and inquilinism, in which the two species share their dwelling space.

It has to be noted that each of the three forms of symbiosis are not static and that they can morph into another form due to environmental factors or internal influences (how the two symbionts develop) for example. Additionally, Paracer and Ahmadjian (2000) mention that for some symbionts goes that the interaction is obligatory; they cannot exist outside the symbiosis. Facultative symbionts on the other hand can also exist in free-living conditions.

3.2.3 Extending metabolic capabilities
As has already been stated in the first part of this section, symbiosis has the ability to extend an organism's capabilities. As has been written by Douglas (1994), "animals have restricted biosynthetic capabilities and, in particular, they are dependent on an exogenous supply of essential amino acids and vitamins" (p.30). Those organisms thus need nutrition from other organisms which can be obtained in a symbiosis. Additionally, symbionts can also help to recycle waste products produced by the host, which eventually can be taken up as 'high-value' nutrition by the host again (Douglas, 1994). An example is nitrogen recycling. This can also increase the overall efficiency of the use of nutrition (Douglas, 1994).

Most symbioses and acquired metabolic capabilities relate to nutrition (Douglas, 1994). One might think that only one of two organisms, called the 'recipient' (most likely the host), is fed by the so-called 'donor' organism (most likely the symbiont) during the symbiotic interaction. However, nutrition in symbioses is often bi-directional; usually the donor derives its nutrition from the recipient also (Douglas, 1994). The transfer of nutrition has been visualised in figure 3.1. According to Douglas (1994), nutrition can be derived from living cells of the partner (which takes place most frequently) or from dead material. A third option is when the partner is killed by which the nutrition becomes available. In case nutrition is derived from living cells, the amount of nutrition translocated (1), the type of compounds (2) and the way in which nutrients are released (3) are identified as important topics (Douglas, 1994).

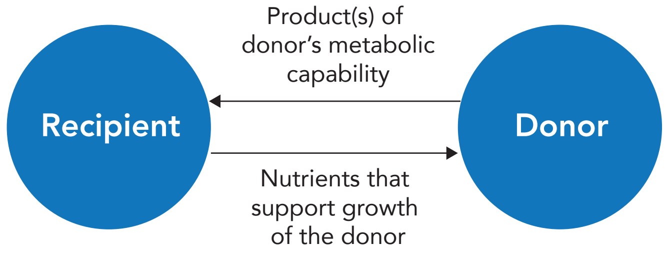


Figure 3.1, bidirectional nutrient transfer in symbiosis (adapted from Douglas (1994).

3.2.4 Formation
Douglas (1994) describes four topics which play a role in the formation of natural symbioses. The first topic stresses the identification of the source of the partner (1). Symbiosis are acquired by the host via the environment or via other hosts. In the light of the later, one can speak of vertical transmission when the symbiont is transferred from the parent host to its offspring directly. Secondly, the establishment of the symbiosis is mentioned (2). The

process of the actual establishment consists of several successive steps. Examples of steps are the first contact or the start of nutrition transfer. A third topic is the specificity of the symbiosis and reflects the range of organisms with which a symbiont can start a symbiosis (3). As stated in the book, "it can be viewed as the outcome of a trade-off, or comprise, between opposing selection pressures, one to broaden the range of acceptable partners and the other to become increasingly specialised (p.89-90). The final topic is about the recognition of the symbiosis (4). This represents the means that determine with which symbionts an interaction is started and with which symbionts is not. An example of such a mean are the mechanisms determining the symbiosis' specificity.

In the light of this chapter's first section, the concept symbiosis has been applied to many other fields than nature nowadays. The architect Kisho Kurokawa for example used symbiosis as a key value in his work (Kurokawa, 1994). The symbiotic mentality has also been adopted by the field of Industrial Ecology which led to the new concept of Industrial Symbiosis.

3.3 Industrial Symbiosis

3.3.1 The concept

Industrial symbiosis was once introduced by the field of industrial ecology and found its inspiration in the concept of symbiosis (Mulder, 2016b). It applies the symbiosis concept in industrial processes. In the light of urban metabolism, industrial symbiosis aims to connect industries to exchange (waste) resources that helps to close resource cycles and limits the use of raw materials. Therefore, within industrial ecology, industrial symbiosis is acting on the inter-firm level (Ehrenfeld & Chertow, 2002). Chertow (2000) describes industrial symbiosis as a strategy that "engages traditionally separate entities in a collective approach to competitive advantage involving physical exchange of materials, energy, water, and by-products" (p. 314). Moreover, Chertow stresses the importance of collaboration between parties and the geographic proximity that generates the possibilities for synergy. Although the concept of industrial symbiosis was introduced in the nineties, people are trading and exchanging resources since ancient times (Chertow, 2007).

When one speaks about industrial symbiosis, three types of exchange exist: by-product re-use among companies which substitutes their initial raw materials usage (1), utility or infrastructure sharing by which companies use and manage resources in a joint manner (2), and/or joint service provision via a shared system (3) (Chertow, 2007). From a natural symbiosis perspective, industrial symbioses aim to establish a mutualistic interactions; as formulated by Ehrenfeld and Chertow (2002), "it stresses collaboration, since, by working together, businesses strive for a collective benefit greater than the sum of individual benefits that could be achieved by acting alone" (p.335).

Chertow (2007) mentions several motivations for setting up an industrial symbiosis, either directly or indirectly as a result to meet other objectives one has. The most obvious ones are business-related, like the reduction in costs by resource sharing. Others are (critical) resource security or increased efficiency required because of regulatory or permitting pressure. Also, social or environmental objectives can be motivations. Apart from the objectives formed, the spontaneous co-location of business in industrial areas has often resulted in additional public and private benefits, like job increase, technological innovation and increased efficiency in infrastructure (Chertow, 2007; Marshall, 1890). Despite the fact that industrial symbioses have shown many benefits, not many of them have been realised; this is due to several barriers regarding business development, operations, finances or behaviour (Chertow, 2007).

In terms of network size, there is no agreement on a total amount of firms that need to be involved in order to speak of an industrial symbiosis (Chertow & Ehrenfeld, 2012). However, Chertow (2007) adopts the '3-2 heuristic' as a minimum criterion; here, an industrial symbiosis network has to consist of at least three entities exchanging at least two different types of resources (figure 3.2).

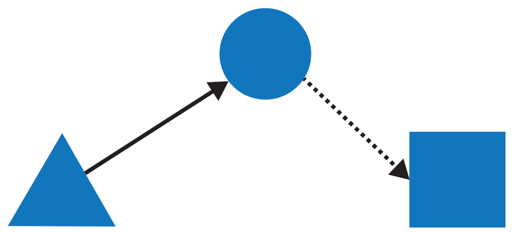


Figure 3.2, example of 3-2 symbiosis (adapted from Chertow (2007))

Examples of Industrial Symbiosis can be seen all over the world nowadays, of which a well-known example is Kalundborg in Denmark which enables more than 20 by-product exchanges (Chertow, 2007; Jacobsen, 2006; Van Berkel et al., 2009). Also in Japan many industrial symbiosis projects can be found (Van Berkel et al., 2009).

3.3.2 Material exchange types

As had been researched by Chertow (2000) and as has been described by Ehrenfeld and Chertow (2002), five material exchange types can be identified (figure 3.3). It has to be noted those do not all represent an industrial symbiotic network; those rather indicate how materials can be exchanged in a general sense.

1. Through waste exchanges: recovered or recycled resources (rather materials than water or energy) are donated or sold to other users by third parties. This exchange type is typically one-way and takes place rather once than regularly.
2. Within a facility, firm or organisation: in comparison to a regular industrial symbiosis, in this type of exchange resources are kept within the boundaries of one (larger) firm by which significant gains can be obtained.
3. Among firms co-located in a defined 'eco-industrial park': business which are located closely to each other (e.g. in an industrial park) can exchange resources, like materials, water and energy, but can also share information or services. The 'bounded' space is the core of the network; however, businesses located near can also participate.
4. Among local firms that are not co-located: this type can be related to the 'uncovered' industrial parks (see previous subsection), in which business are not placed together with premeditation, but in which businesses had been closely located already which can set up exchanges for their resources.
5. Among firms organised 'virtually' across a broader region: this type reflects exchanges that are dependent on virtual connections, which gives the possibility to connect to a more regional economic community, by which also the number of potential exchanges as well as the variety of businesses might be increased.

According to Chertow (2000), type 3, 4 and 5 can directly be related to an industrial symbiosis. The first one is least close to the definition of industrial symbiosis and rather relates back to the "traditional aspects of the material flow landscape" (p.322).

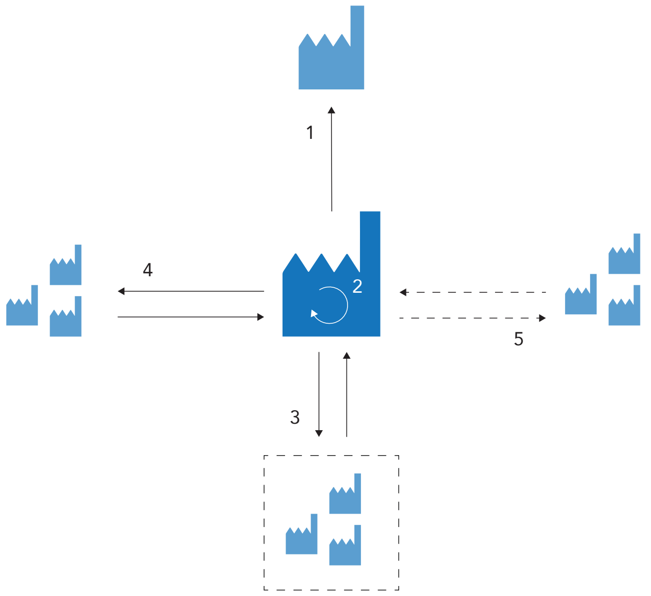


Figure 3.3, five types of material exchange (according to Chertow (2000), own illustration)[1]

3.3.3 Process

<u>*Establishment of industrial symbiosis*</u>
Based on a research by Chertow (2007), industrial symbioses can arise in two ways. One group of industrial symbioses is planned. Those industrial symbioses are established by identifying firms from different sectors and co-locating these to enable them to share resources. The development can be directed by a group of delegated stakeholders including a governmental party. A second group of industrial symbioses arises due to self-organisation. Important to note is that, in the beginning, the businesses are often not aware of the fact that they establish an industrial symbiosis. Private sector companies have established relationships to achieve listed aims, like cost reduction, by exchanging resources. Those symbioses can also be seen as being 'uncovered' over time, often catalysed by a third party. Subsequently, further development can be coordinated. It has been argued that those self-organised symbioses has been more sustainable and has led to greater sustainable industrial development than the first type (Chertow, 2007).

<u>*Frameworks, phases & stakeholders*</u>
While investigating the processes that lead to an industrial symbiosis, two recently developed frameworks were found. The first one describes the emergence process of an industrial symbiosis whereas the other describes a method for designing an industrial symbiosis. This difference suggests that the former framework is applicable to both the 'planning' as well as 'self-organisation' type described above. The latter only focusses on the 'planning' type of industrial symbioses (Baldassarre et al., 2019). Both frameworks are discussed next.

PROCESS

Framework for industrial symbiosis emergence process (Mortensen & Kørnøv, 2018)
The first framework is created by Mortensen & Kørnøv (2018) and includes a pre-emergence, emergence and post-emergence phase (figure 3.4).

The first phase in the framework is the pre-emergence phase. It represents current conditions and antecedents that are present as well as the undeveloped potentials for new or improved businesses.

It is followed by the emergence phase, which is divided into three steps. The order of those steps might seem to be chronically ordered yet is not restricted to this order.

1 See for credits for some of the icons in the figure chapter 'References'.

- *Awareness and interest in industrial symbiosis*

When one acquires knowledge or sees potentials in terms of environmental or economic benefits, this can lead to awareness creation and interest generation in new or improved businesses. Potentially supporting partners might be known or unknown. Awareness and interest are kept at an internal level, that is to say the individuals or collective who know about the idea. No action is taken yet. The building (Hewes & Lyons, 2008) and the mobilization (Boons & Spekkink, 2012) of social relationships is of crucial importance for the establishment of an industrial symbiosis networks. Also, developing trust and a supportive context is essential (Costa & Ferrão, 2010).

- *Reaching out and exploration of connections*

In the next step, in which one reaches out and connections are explored, the idea is shared with others and is moved to the external level. New connections and interactions are established and the network is extended.

- *Organizing*

After those connections are established and business ideas are shaped, one can start creating a business model. This does not include formal arrangements, such as contracts, yet. Those are namely made in the post-emergence phase, which also compasses the physical implementation and the start as well as the development of the network.

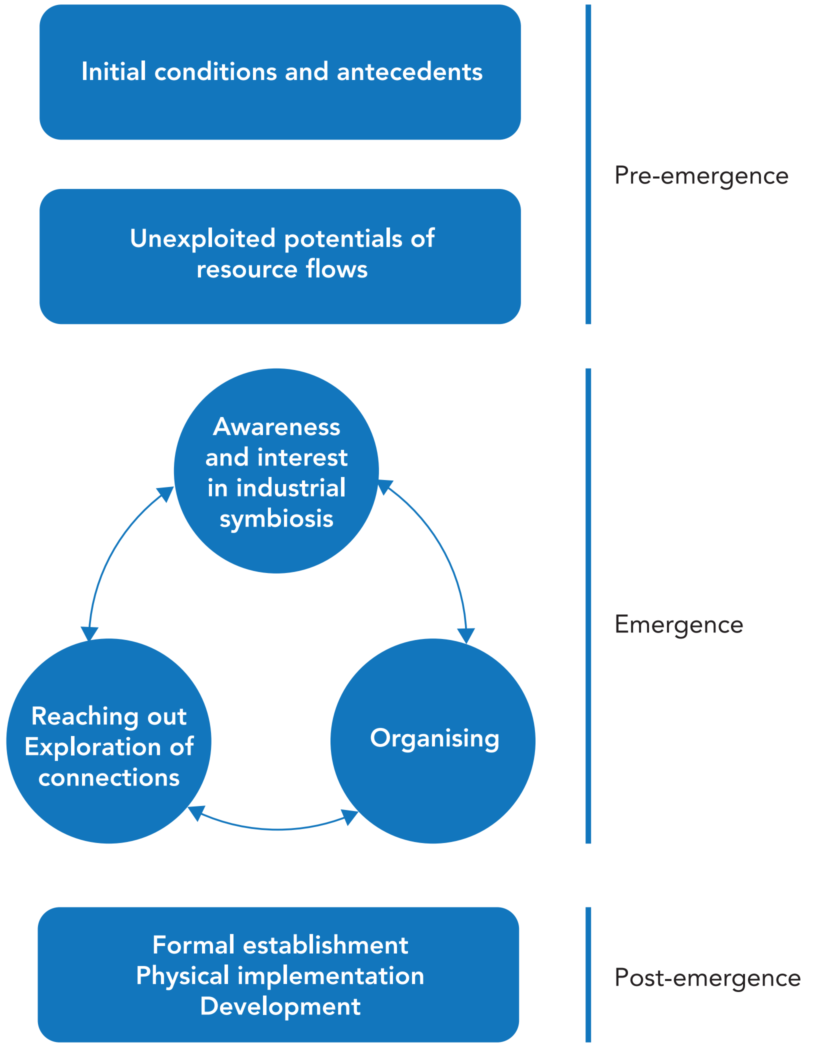


Figure 3.4, conceptual framework for industrial symbiosis emergence process (adapted from Mortensen and Kørnøv (2018))

STAKE-HOLDERS

Stakeholders
Actors who are involved in the process of the establishment of an industrial symbiosis (as described by Mortensen and Kørnøv (2018) and the roles they adopt are presented in table 3.1.

Actors	Role
Research and education institutes	Are seen as key player for the participatory and collaborative process in industrial symbiosis (Behera, Kim, Lee, Suh, & Park, 2012). Can contribute to/ play role of facilitator/ coordinator (Costa & Ferrão, 2010). They deliver the information needed in such a process and support knowledge sharing within the network (Panyathanakun, Tantayanon, Tingsabhat, & Charmondusit, 2013).
Public bodies	Can support companies, give access to specialised knowledge, encourage engagement and promote the symbiotic process (Valentine, 2016). Public bodies can generate trust among participants (L. Baas, 2011) and stimulate co-creation (Velenturf, 2016). In the organizing phase, the party can offer licenses and permits (Velenturf, 2016) or financial support (L. Baas, 2011). National, regional and local public bodies can be involved (Mortensen & Kørnøv, 2018). Local public parties can adopt an intermediary role between the national government and businesses because of their familiarity with the context (Costa & Ferrão, 2010).
Businesses	Play a role in the actual implementation of industrial symbiosis (L. Baas, 2011) and are therefore mainly involved in the reaching out and organising step (Mortensen & Kørnøv, 2018). Often, one (large) company is seen as a major player offering opportunities for exchange because of its resource flows. By raising awareness about their activities, other companies can become inspired to initiate symbiotic relations (Mortensen & Kørnøv, 2018). They can also act as a funding party (Spekkink, 2013).
Associations	This is a group of representatives of a particular group of stakeholders that let their interests be heard (Panyathanakun et al., 2013). They are involved from the moment of reaching out (Mortensen & Kørnøv, 2018). Can be part of coordination body (L. Baas, 2011; Velenturf, 2016). They can act as a mediator enhancing positive interactions (Beers, Bossilkov, Corder, & Berkel, 2007).
Consultancy companies	In the organising step, this party can take over the role of the research and education parties. They can create new business models (Mortensen & Kørnøv, 2018)

Table 3.1, actors and their roles in the establishment of an industrial symbiosis

PROCESS

Framework for industrial symbiosis design process (Baldassarre et al., 2019)
From a strategic design perspective, Baldassarre et al. (2019) proposes a framework for the design of new industrial symbiosis networks (figure 3.5). This thus relates to the 'planning' type that has been described by Chertow (2007). The framework describes three phases which are succeeding each other, however the starting point is not defined; industrial symbiosis projects are often based on previous collaborations and those can be a starting point for a new cycle. In the step on the top, a strategic shared vision is created among the stakeholders by which several tools, such as a stakeholder analysis, can be used. A subsequent step is the creation of a business model for the industrial symbiosis network. Again, several tools, e.g. for value mapping, can be used to set up the business model.

This step is seen as an iterative process. Afterwards, an impact assessment is done, i.e. the sustainability impact of the industrial symbiosis. This assessment is based on criteria that are formulated in the strategic vision and which relate to environmental, societal and economic aspects. In order to do so, life cycle assessment tools can be used.

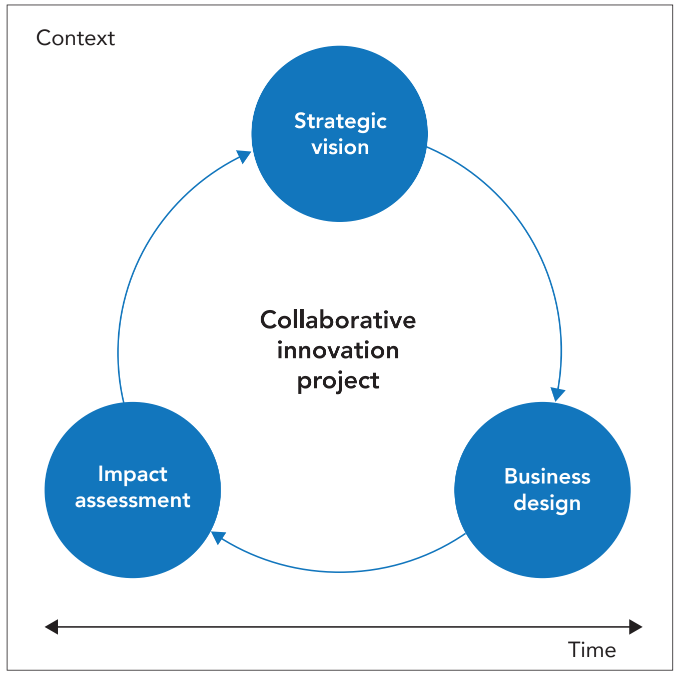


Figure 3.5, framework for industrial design process (adapted from Baldassarre et al. (2019))

3.4 Urban Symbiosis

3.4.1 The concept
Urban symbiosis stems from industrial symbiosis (Mulder, 2016b; Vernay & Mulder, 2016). As defined by Van Berkel, Fujita, Hashimoto, & Geng (2009), urban symbiosis is "the use of by-products (wastes) from cities (or urban areas) as alternative raw materials or energy sources in industrial operations" (p.1545). The concept was found in Japan during the realisation of an eco-town (Lenhart et al., 2015; Mulder, 2016b). In an urban symbiosis, connections are made between a variety of actors for resource exchange that will lead to closing resource cycles at the city level and subsequently to a reduction in the use of raw materials in urban areas.

Over the years, urban systems have often be created by 'profit driven entrepreneurs' who developed those systems as single units (Mulder & TU Delft, 2017). Because private and public interests started to interweave, many of those systems have come under control of public parties throughout the years. Some of the systems have become private property again (Mulder & TU Delft, 2017). Related to the diversity of systems in the city, urban symbiosis aims to bring forward innovations by connecting existing urban systems rather than bringing new innovations and products to the playing field (Mulder, 2016b). Vernay & Mulder (2016) state that "the emphasis is not on a 'novelty conquering the world', but on a rearrangement of actors in a specific local context" (p. 182). Therefore, the crossing of boundaries is required (Vernay & Mulder, 2016).

Geographic proximity that was mentioned as a key factor for industrial symbiosis by Chertow (2000) appears to be a key factor for urban symbiosis as well. Geng et al. (2010) argue that urban symbiosis is able to bring environmental and economic gains due to the transfer of resources between closely located urban and industrial areas. Another advantage of close proximity is that, in terms of social relationships, it can raise trust among stakeholders (Chertow, 2000; Ohnishi, Fujita, Chen, & Fujii, 2012). Additionally, Baas and Boons (in Lenhart et al., 2015) argue that regional learning on how to create a symbiotic local network can take place among adjacent stakeholders. Next to geographic

proximity, local partnerships and policy interventions are found to be important aspects for the analysis of urban symbioses (Lenhart et al., 2015; Ohnishi et al., 2012).
Regarding urban symbioses' contribution to greener cities, the study by Geng et al. (2010) shows that by applying urban symbiosis CO2 emissions can be reduced. Furthermore, the study by Geng et al. also concludes that "urban symbiosis presents a new model for more sustainable urban economic and industrial development at a regional level" (p.1000). Nevertheless, due to several barriers, as will be discussed in paragraph 3.4.3 'Barriers', no clear strategies on how to create urban symbiosis innovations exist (Pandis Iveroth, Vernay, Mulder, & Brandt, 2013).

Industrial symbiosis vs. urban symbiosis
The main difference between industrial and urban symbiosis is the focus on a distinctive social system. Whereas in the case of industrial symbiosis the focus is more on the industrial and technical systems, urban symbiosis focusses itself on the urban systems (Lenhart et al., 2015). This includes political and social aspects and the strategy includes more social actors. Lenhart et al. (2015) argue that governmental authorities, particularly local ones, play a prevalent role here. Furthermore, in contrast to industrial symbiosis, the implementation of urban symbiosis generally involves a more varied group of actors, buildings, infrastructures and functions (Lenhart et al., 2015). Regarding their context difference, urban symbiosis has to deal with additional challenges from social and governmental earth (Lenhart et al., 2015).

In a figure developed by Van Berkel et al. (2009) (figure 3.6) this difference can also be observed. The horizontal axis represents the societal benefits, ranging from amenity (common good of citizens) on the left to productivity (economic benefits) on the right. The vertical axis indicates the implementation of urban symbiosis by different actors being the private sector (top) or civil society (bottom). Here, local government is not included since they are always involved as a main facilitator in the process (Van Berkel et al., 2009). Within this quadrant, industrial symbiosis mainly brings economic benefits for the private sector that ideally also serves the wider society. On the other hand, urban symbiosis focusses on the common goods of citizens which concerns e.g. their quality of life and the environment.

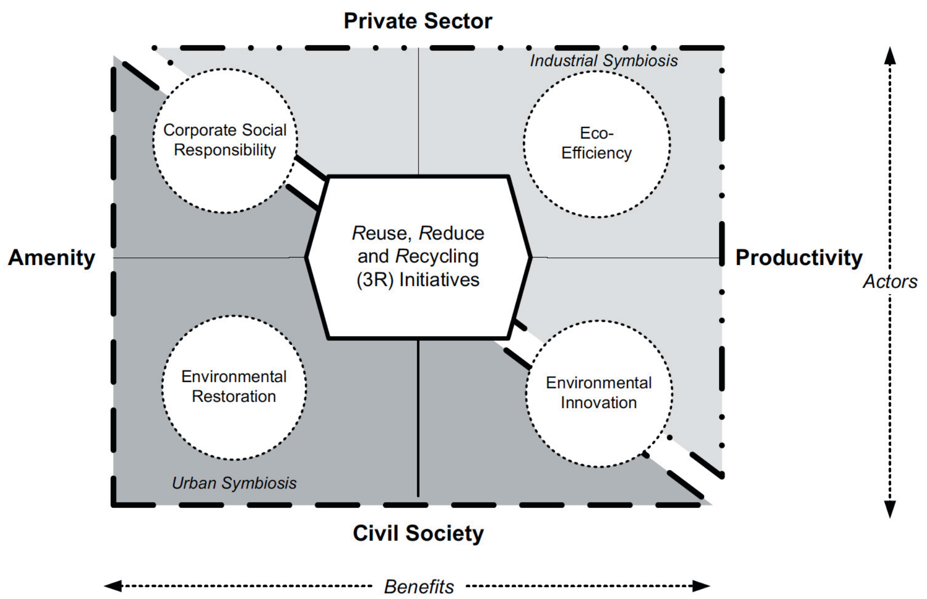


Figure 3.6, the distinctive contribution of Industrial and Urban Symbiosis to sustainable industrial development (Van Berkel et al., 2009).

3.4.2 Barriers
Although urban symbiosis has been acknowledged as a method that can increase the sustainability performance of a city, one can question why the method has not been applied very frequently yet (Mulder & TU Delft, 2017). Several barriers have been indicated

in research.

- Technological barriers: the study by Mulder (2016b) indicates that output streams of one company might not match the demanded input streams of another company or those might not fit in terms of timing. The study furthermore adds that additional distribution systems, storage and transport that might be needed can be realised, however often at substantial costs. In the same line of thought, storage and transport can require much space and the quality of the resources exchanged might be affected (Mulder, 2016b). Those can all be seen as barriers from a technological nature.
- Institutional barriers: companies that possess an infrastructural system are often keen on their autonomies (Mulder, 2016b). In the light of urban symbiosis, they therefore only want to adopt the approach if it does not affect them in their autonomy (Mulder, 2016b). However, urban symbiosis is often about building long-term relationships (e.g. by means of a contract) and symbiosis' actors become interdependent (Mulder, 2016b; Mulder & TU Delft, 2017; Vernay & Mulder, 2016). The infringement on a company's autonomy might therefore be seen as a barrier.
- Barriers based on technology history: urban infrastructures have often been built due to long term investments (Mulder, 2016b). Because of this, one can now speak of a lock-in situation in which changes to existing system are not easily realised or adopted (Mulder, 2016b). It might be that the current system cannot be changed into another system as it simply does not offer the opportunities to do so (Mulder, 2016b). When adding customised interventions to this system, the lock-in situation might even be enhanced further (Frantzeskaki & Loorbach, 2010). Next to this, often an extensive amount of knowledge on the conventional system has been generated; when developing a new system, one has to develop know-how from the ground up and the unknown might generate risks (Mulder, 2016b).
- Policy barriers: when one wants to the integrate systems, which is the aim of urban symbiosis, this does often not comply with the conventional policy framework (Hemmes, 2009). Mirata (2004) indicates that regulations can be seen as a complicating factor in the process.
- Interest & profit barriers: since a (large) network of stakeholders is involved in an urban symbiosis, the symbiosis needs to be profitable ("good" (p.5), in terms of economics, but also in terms of the environment) for each of the stakeholders (Mulder & TU Delft, 2017). This can be related back to the literature on natural symbiosis which states that the partners involved in a mutualistic symbiosis need to benefit both (Paracer & Ahmadjian, 2000). Making the symbiosis beneficial and interesting for each of the stakeholders can be seen as a challenge. Another barrier that has been acknowledged is the fact that urban symbiosis is often not core business for all of the involved stakeholders (Mulder & TU Delft, 2017). Furthermore, actors might be unwilling to be involved, which might lead to an "unproductive bargaining game" (Mulder & TU Delft, 2017, p. 5). The complex process of connecting the interests of the stakeholders in the symbiosis is seen as the main barrier for the implementation of the urban symbiosis strategy (Vernay & Mulder, 2016).

PROCESS

3.4.3 Process: strategies for the establishment of an Urban Symbiosis
Next to the barriers that have been indicated for the implementation of urban symbiosis, Mulder (2016b) also indicates several strategies that can overcome those barriers and that can be of help in the establishment of an urban symbiosis.

- Visioning: instead of developing innovations for locked-in urban systems, one has to start visioning based on the system change one wants to bring forward and the needs one wants to fulfil (Mulder, 2016b). By involving a wide variety of stakeholders, a future vision can be developed (Mulder, 2016b). This vision can be seen as a guiding document, which can subsequently be translated into concrete steps by performing backcasting (Holmberg & Robert, 2000).
- Technological change strategies: among a variety of technological implementations that are named as strategies by the study of Mulder (2016b), network management is seen as a mean by which the group of actors who determines the direction of the development can be changed or by which a variety of stakeholders can be brought

together to enhance learning from each other (Parandian, 2012). Another strategy can be to rather look at the system as a whole and evaluate on system-wide consequences, instead of focussing on single interventions at specific spots in the system (Mulder, 2016b).

- Institutional change strategies: in relation to the institutional barriers, a third party is mentioned as a player who could adopt a mediating role between stakeholders in a symbiosis who have different interests (Mulder, 2016b; Vernay & Mulder, 2016); according to Mulder (2016b), such a situation is also often occurring at the level of the city. Important is that the mediator adopts a neutral position and aims to achieve the symbiosis' benefits in particular (Mulder, 2016b). The role of third parties is further explained in the next paragraph about stakeholders in an urban symbiosis and their roles.
- Un-lock-in strategies: Mulder (2016b) presents several types of protection that need to help protecting new systems against conventional ones that have proven to be successful, something which the new system has not been able to do yet. Examples of those protection forms are trust, financial interests or social interests. The latter refers for example to governmental organisations who see a potential in the application of urban symbiosis in terms of environmental or safety gains (Mulder, 2016b).

STAKE-HOLDERS

3.4.4 Stakeholders & roles

System integration, and in this study urban symbiosis in particular, can be related to the actor network theory (ANT) (Vernay, 2013). This theory describes that each innovation is based on a network of heterogenous actors that share interests (Walsham & Sahay, 1999). Referring back to the biological symbiosis, Paracer & Ahmadjian (2000) describe that "no organism is an island – each one has a relationship to other organisms, directly or indirectly" (p.3). Applying this in an urban symbiosis setting, each active actor in the symbiosis is related to one another in the network. However, before such an urban symbiosis can be established, interests need to be aligned. By local engagement stakeholders can be connected and information and resources will become available to them (Lenhart et al., 2015; Ohnishi et al., 2012). For the local engagement, professional and personal relationships, shared interests and ownership are of help (Lenhart et al., 2015; Ohnishi et al., 2012). Open communication between the actors, both vertical and horizontal, is essential to enhance trust, transparency and learning (Lenhart et al., 2015).

A strategy to realise an urban symbiosis and to align interests, as has also been pointed out in the previous paragraph, is the creation of a shared vision among all involved actors (Mulder, 2016b). However, the matching of interests can be seen as a complex business (Vernay & Mulder, 2016). According to Vernay and Mulder (2016b), the integration of systems is about "being able to create relations between actors and manage their expectations and often conflicting interests" (p. 187).

Therefore, often a so-called 'translator-spokesman' is involved as a third party who can ease the creation of connections between actors and who can enrol other parties in the network (Callon, 1986; Vernay, 2013). Important for urban symbiosis is namely the connection across organisations and working fields (Mulder & TU Delft, 2017). Next to the connecting role of a translator spokesman, this party has also be able to maintain the network once it has been established (Vernay, 2013). Though, during the performance of his tasks, a translator-spokesman might face barriers of autonomy or self-interest of actors. This can also be linked back to the voluntaristic nature of ANT (Mulder & TU Delft, 2017).

The particular name assigned to the role of a translator spokesman is varying in research. Other names are for example 'system integrator' or 'intermediary organisation' (Vernay & Mulder, 2016) and 'resource exchange manager' or 'middleman' (Lenhart et al., 2015). In the further course of this report, particularly the terms 'mediator' (as has been referred to in the previous paragraph) and 'third party' are adopted.

Public and private parties adopt different roles in an urban symbiosis. Looking at the role of the government as a public party, nationally it can offer support in a financial and legal terms, whereas locally it can adopt a coordinating and promoting role in the network (Lenhart et al., 2015). Furthermore, due to its accountability to its citizens and businesses, they have a duty to enhance trust and provide transparent information (Lenhart et al., 2015).

Private actors are seen as implementers (Lenhart et al., 2015). The study by Lenhart et al. found that private actors need to be involved from a very early stage in the process, i.e. the design phase, to increase engagement and to prevent the feeling of a lack of ownership, which subsequently can lead to defects in the implementation and acceptance of the urban symbiosis' interventions.

Furthermore, citizens are indicated as being important actors in symbiosis as they are the end users, however, they might not be involved to a level that is actually required (Lenhart et al., 2015)

Although the role of a mediator can be assigned to both public and private parties, this might not always be the best option at hand due to incompatible interests (Vernay & Mulder, 2016). According to Vernay and Mulder (2016b), public parties possess several urban (infrastructural) systems and are accountable for the interests of citizens as well as for regulation. Therefore, they are found to be too much involved to become a trustworthy mediator (Vernay & Mulder, 2016). Similarly, private parties might experience difficulties in organising public activities (Vernay & Mulder, 2016). Mulder (2016b) names citizen's organisations and NGOs as actors who might be able to adopt the role of a mediator.

3.4.5 Best-practices

Among others, two examples can be given an urban symbiosis that have been realised recently. To begin, the first established urban symbiosis will be discussed: Kawasaki (Japan). This symbiosis is particularly focussed on the export of municipal solid waste management to local industries (Geng et al., 2010); a rare example, since most of the urban symbioses are limited to the exchange of either water or energy flows or combination of those. In a study on this urban symbiosis by Geng et al., (2010), an interesting point is made about the materials and their life cycles. An urban symbiosis comprises life cycles of multiple products, including links between their processes. Also, as has been mentioned earlier, the study concludes that urban symbiosis has the potential to reduce CO_2 emissions, however the amount of reduction partly depends on the material that is substituted; the embodied CO_2 of the original material and its treatment process determine whether it is valuable for the material to be substituted by a 'waste' material (Geng et al., 2010). Furthermore, Geng et al. state that for symbioses like these investments will be required, which lead to an increase in costs on the short term. Nevertheless, environmental benefits can be gained which can indirectly lead to financial benefits on the long term.

A second example that can be given is a Dutch urban symbiosis established in the city of Rotterdam. Here, by-products in the form of water and energy flows are used to feed several urban functions (Lenhart et al., 2015). According to Mulder (2016b), the water system is an interesting system due the ability of water streams to be transformed into other resources which opens up opportunities for symbiotic connections with other types of systems. An example is the residue from waste water treatment plants that can be used for agriculture. One might also argue this for energy flows, which can be transformed into heat or movement for example. Besides, one can question whether this also holds true for materials.

3.5 Comparison of symbioses

In order to gain an overview of the different symbioses presented and to use those to compare them with the results from the interviews and the focus group later on, table 3.2 summarises and compares the three different types of symbioses presented in this chapter based on the resources that are exchanged, important aspects in the symbiosis' establishment process and the stakeholders who are involved.

	Natural symbiosis	Industrial symbiosis	Urban symbiosis
Resources that are exchanged	Material, energy and information; often nutrition; in case of commensalism symbionts can share dwelling space and transport or can offer protection	Materials, energy, water, and by-products	By-products (wastes), e.g. water, energy and materials
Important aspects in the process of the symbiosis' establishment	Identification of the source of the partner, establishment of the symbiosis, specificity of the symbiosis, recognition of the symbiosis	Uncovering potentials, awareness and interest in industrial symbiosis, reaching out and exploration of connections, organizing strategic vision, business design, formal establishment and physical implementation, development, impact assessment	*(Strategies to overcome barriers)* Visioning, network management, system evaluation, third party involvement, protection (by generating trust, financial interests or social interests)
Stakeholders	Symbionts (host & symbiont)	Public bodies, businesses, research and education institutes, associations and consultancy companies	Public parties, private parties, mediator/ third party (like citizen's organisations or NGOs), citizens

Table 3.2, comparison of natural, industrial and urban symbioses

3.6 Study's Use of Theories & Metrics

In this study the concept of urban symbiosis is adopted as a framework in order to explore and evaluate whether outcoming construction materials can be reused on other building projects in Amsterdam. In contrast to the definition by Van Berkel et al. (2009), the term 'waste' will be used rather than 'by-product' since the study focusses specifically on materials that once have been used turning up as waste streams while being valuable as resources. Instead of industrial applications, this study rather looks for local application opportunities in the building sector, i.e. other construction projects. The adopted approach for the reallocation of resources from waste will be done in the same line of thought as Lansink's ladder, following the order of reduction, reuse and recycling of resources (Parto et al., 2007). The study will specifically focus on the reuse of 'components' (see chapter 1, 'Introduction').

Furthermore, related to the theory on natural symbioses, the study will focus on the mutualistic type of exchanges between companies, that is to say exchanges of which all companies benefit. This can be motivated by the fact that parties who do not have interest or do not benefit from the interaction might recall themselves on their autonomy or freedom. This has been indicated by literature (as has been presented above) as a serious barrier.

Due to the nature of the sub questions and the overall aim of this study, the research will frequently address the implications for the process, materials (or resources) and stakeholders in the symbiosis of construction materials. Those three aspects also form the core structure in the above presented literature findings for natural, industrial and urban symbioses as well as throughout the whole report. In the discussion (chapter 9), results of the study will be compared to the literature findings on the presented types of symbioses.

4

CONSTRUCTION SECTOR

The construction sector forms the context of this study. This chapter provides and overview of the current performance of the construction sector, particularly in the context of the Netherlands and Amsterdam. In section 4.1 a general introduction will be given about common characteristics of the sector and the difference between linear and circular building. In section 4.2 the Dutch construction sector is discussed. It presents several facts and figures on its performance and its vision for the future. Afterwards, the conventional Dutch construction process is introduced, that will be of help in the study later on to understand the case study's process and evaluate it within the larger framework. Section 4.3 will take a closer look at the construction activities in the city of Amsterdam. Again, its performance is studied, including a review of the stakeholders. Finally, the city's vision regarding construction activities in the future is presented, which provides an important context for the evaluation of the outcomes of this study.

PROCESS

4.1 Linear vs. circular construction

In general, the construction sector can be identified by several characteristics. First, it has a relative traditional character (Van Herk, Timmers, & Zevenbergen, 2007). Khasreen, Banfill, & Menzies (2009) state that buildings face complicated production processes and have a long life span, in comparison to other products. They also stress that the sector knows only little standardization.

Currently, most of the construction processes have a linear character (Jonkers, 2018). As figure 4.1 visualises, raw materials are extracted, which are turned into (half-) fabricates. Subsequently, those (half-)fabricates are used for the construction of the building. When constructed, the use phase of the building starts. At the end of its lifetime, or earlier when decided to, the building is demolished and materials are disposed. Also during renovation projects materials can be extracted and replaced by others.

Comparing this to a circular construction cycle (figure 4.2), no materials are disposed any more. During demolition of the building, or rather disassembly, materials are extracted which can be used as input for the production of new (half-)fabricates, which can subsequently be applied in a new building (Jonkers, 2018). According to Nelissen et al., (2018), circular building can be defined as "the development, use and reuse of buildings, areas and infrastructure, without depleting natural resources, polluting the living environment and affecting ecosystems" (p. 10).

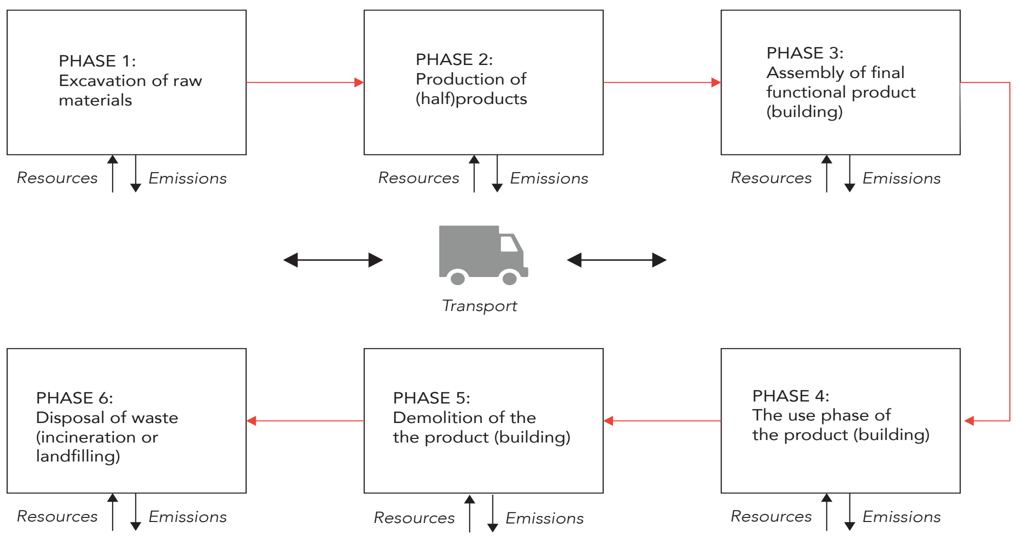


Figure 4.1, linear construction cycle (adapted from Jonkers (2018))[1]

1 See for credits for the icon in the figure chapter 'References'.

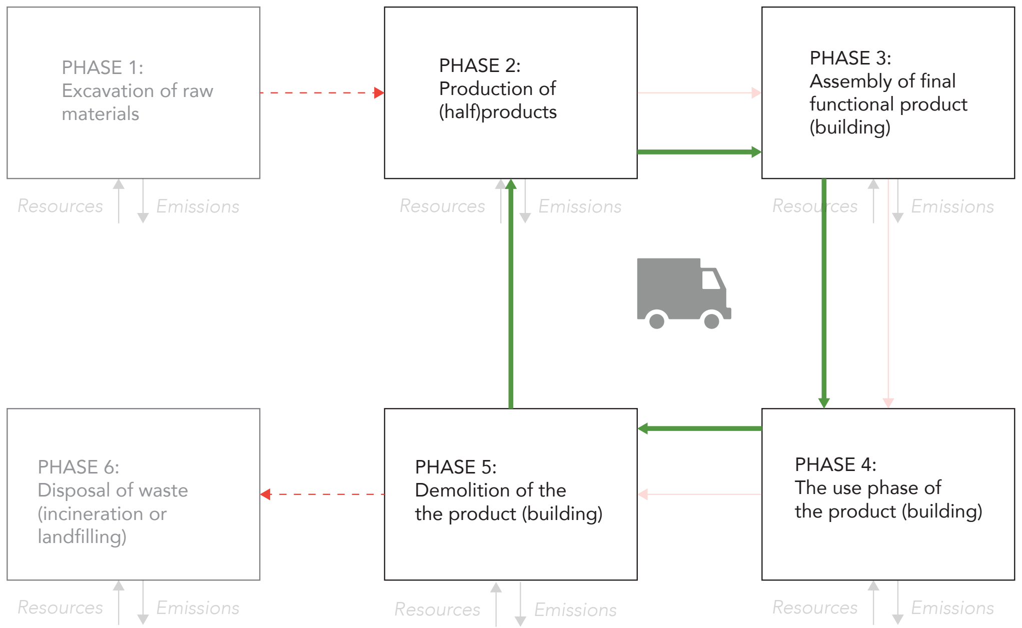


Figure 4.2, circular construction cycle (adapted from Jonkers (2018))[1]

An example of interventions that are introduced in the construction sector in order to promote its circular usage of building materials is a 'material passport'. A material passport is a document in which is stated what materials are applied in a building and how these are processed (Nelissen et al., 2018). This type of documentation increases transparency and can help to identify resources and to search for repurposes in the demolishing phase (Circle Economy et al., 2015). The Dutch government also acknowledges the value of these passports and currently discovers the course for implementation (Nelissen et al., 2018).

4.2 Dutch construction sector

4.2.1 Current performance and future vision

Figure 4.3 gives and overview of the new construction and demolition activities in the Netherlands over the past 7 years. It shows completely newly constructed buildings, buildings that are added to the stock due to other reasons (for example because of a change in utilisation function or renovation), demolition projects and buildings that are withdrawn from the stock due to other reasons (for example because of merging or a change in utilisation function) (CBS, 2019). As an example, in 2018 approximately 76.000 new-construction buildings were built in the Netherlands, both including houses as well as non-residential functions (CBS, 2019). In the same year, 12.500 buildings were demolished (CBS, 2019).

After a downtrend the number of buildings that are added to the Dutch building stock over the last five years has been relatively stable; the number of newly constructed buildings has become higher than the amount of buildings that are added to stock because of other reasons. The total number of buildings that have been withdrawn from stock is smaller than the amount of buildings added. From those stats, one can conclude that the building stock has increased.

In terms of environmental impact, the construction sector can be seen as the largest contributor to greenhouse gas emissions (Raynsford, 1999). In the Netherlands, the sector It accounts for 50% of the raw materials that are used. Construction and demolition waste has a share of 40% of the total amount of the nation's waste (The Ministry of Infrastructure and the Environment & The Ministry of Economic Affairs, 2016). Apart from the raw materials and the waste, the sector also has a large share in energy (40%) and water (30%)

1 See for credits for the icon in the figure chapter 'References'.

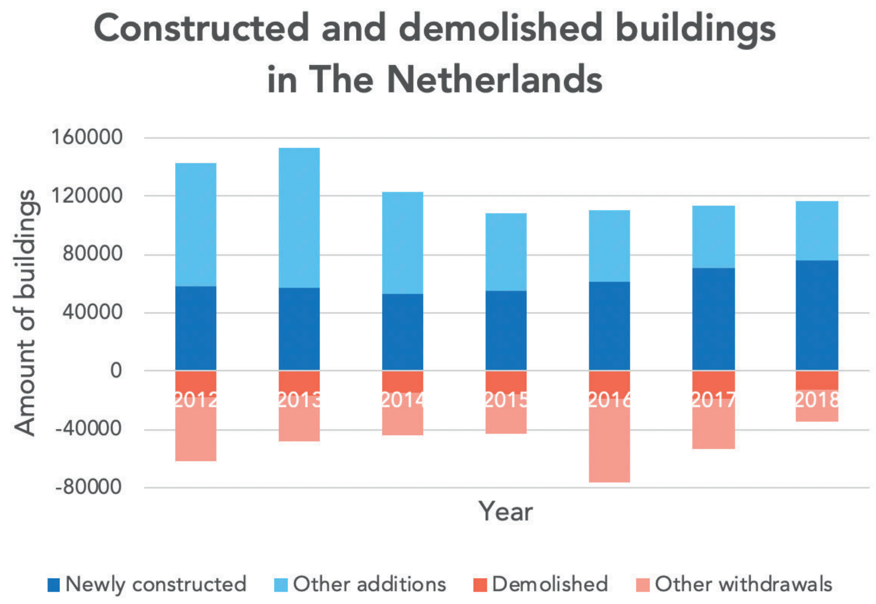


Figure 4.3, constructed and demolished buildings in The Netherlands from 2012 till 2018 (based on CBS, 2019)

consumption, resulting in a major contribution to the CO2 emissions (35%).

The Ministry of Infrastructure and the Environment & The Ministry of Economic Affairs (2016) state that more than 95% of the construction waste is currently reused. However, important to note here is that the largest part is not reused at the same quality level. Only 3% is reused in commercial and non-residential buildings; 85% is degraded and applied on the soil and civil engineering sector (The Ministry of Infrastructure and the Environment & The Ministry of Economic Affairs, 2016).

Comparing the sector's current performance with the sector-wide goals set by the Dutch government aiming for a raw material reduction of 50% in 2030 and full circularity in 2050, there is a lot of room for improvement. Therefore, a Dutch government formulated the following vision: "By 2050, the construction industry will be organised in such a way, with respect to the design, development, operation, management, and disassembly of buildings, as to ensure the sustainable construction, use, reuse, maintenance, and dismantling of these objects. … The aim is for the built-up environment to be energy-neutral by 2050, in keeping with the European agreements." (The Ministry of Infrastructure and the Environment & The Ministry of Economic Affairs, 2016, p. 59). The sector has to go through the transition of linear to circular building.

In order to achieve the goals set for 2050, several challenges can be identified. First of all, the presented increase in the number of buildings that have been built over the last years versus the vision on the decrease of raw materials usage can be seen as a main challenge. Furthermore, it has to be noted that the construction sector can be characterised as being very traditional; the circular economy has not yet been generally accepted by the major part of its actors (The Ministry of Infrastructure and the Environment & The Ministry of Economic Affairs, 2016). But besides those challenges, also a lot of opportunities, both social and economic, can be indicated: increase in efficiency by scaling up circular activities, creation of financial incentives, employment increase and knowledge development among others (Nelissen et al., 2018).

Nelissen et al. (2018) stress that only by engaging all parties that are involved, a circular economy, and thus a circular construction sector, can be established; cooperation is thus key.

PROCESS

4.2.2 Conventional construction process in the Netherlands

Process
The conventional Dutch construction process is described by the Dutch (pre)standard NVN 2574 (NNI, 1993). Tijhuis (1996) describes the four phases in the process: the planning, design, development and realisation phase (figure 4.X). As this model particularly focusses on the phases needed for the construction of a building, it excludes the use and demolishing phase. However, others stress that also the maintenance phase is part of the construction process (Maas and De Bondt, in Tijhuis, 1996).

In the planning phase, first the initiative of building is taken based on the housing needs that increase (Tijhuis, 1996). Afterwards, these are assessed on their economic, juridical, technical and urban development feasibility. Moreover, a location is assigned for the to-be-built construction. The phase ends with a clear definition of the project in a program of requirements. This reports the requirements, desires and expectations among other aspects.

The design phase knows a gradual process from fairly course to a very detailed outcome (Tijhuis, 1996). In the structure design step, the internal and external structure is designed. This is related to the function, structure, form, building mass and the urban planning. Also, a first estimate of the costs, which is based on groups of construction elements, and the planning is made.

In the next step, a preliminary design is presented. It envisions the location, the main structure, the construction and form. The cost estimate is further elaborated based on the elements and also investment costs as well as exploitation costs and yields are made transparent. The planning is updated.

By laying down the internal and external structure, the final design is presented. It includes very detailed information on the location, form, dimensions and materials. A final cost estimation is made based on the more detailly defined parts. The planning can again be updated.

Before the actual building activities start, specifications and costs should be further elaborated (Tijhuis, 1996). This is done in the development phase and includes the creation of the bill of quantities. In this contract pricing is based on the required materials, work and equipment. Also, the budget for the investment costs and the exploitation costs and yields is adjusted. A detailed planning is made.

In terms of pricing, a contract sum is defined. Subsequently the procurement process starts. Different forms of procurement processes exit, among which are open tendering, restricted tendering or single-source procurement. After a contractor is assigned, agreements are written down in execution contracts.

The construction process ends with the realisation phase. The assigned contractor and other parties are responsible for the technical elaboration of the plans and first need to prepare their work profoundly (Tijhuis, 1996). They have to make detailed execution drawings. Moreover, they have to make planning with respect to time materials, costs, equipment, labour and construction side facilities, which mainly refers to the aspects of 'time', 'quality' and 'costs'.

Subsequently, the building is realised. In this process, building activities should meet all agreements that are made in the previous phases of the construction process. This step can be identified by three main collections: building parts, work types and their activities.

In the final step, when the construction has been built, the building is formally transferred to the client. Remaining work is finished.

Afterwards, the use phase as well as the management phase of the building starts (Tijhuis, 1996). During this phase, renovations, rebuilding or other adaptations can be done. At the end of the building's life cycle, the construction is demolished; the construction process can start over again.

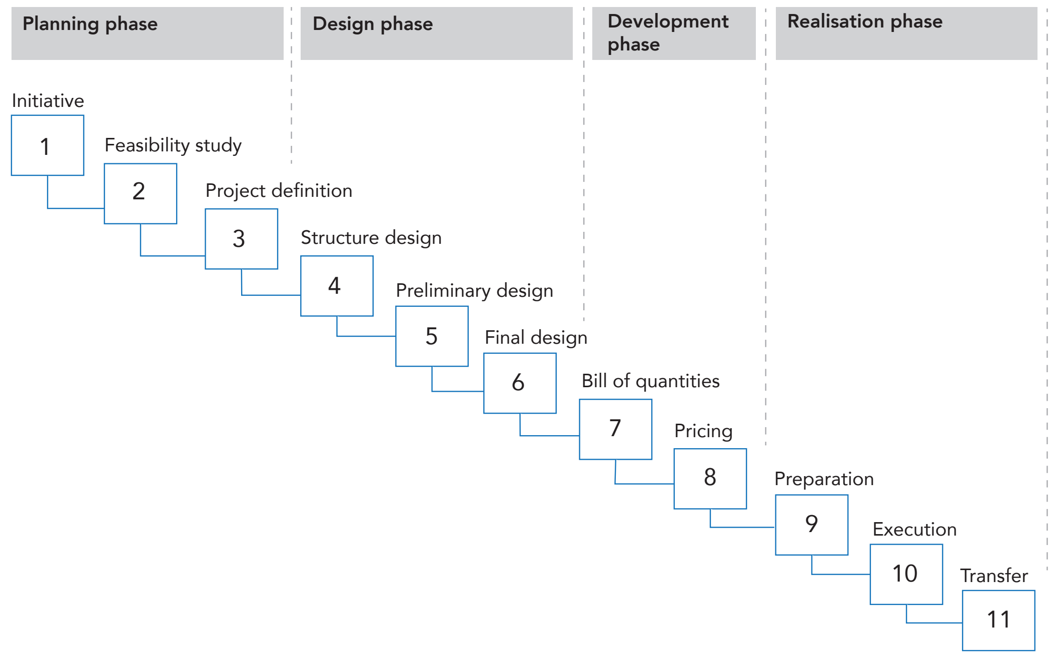


Figure 4.4, Dutch construction process according to the Dutch (pre)standard NVN 2574 (NNI, 1993) (adapted from Tijhuis, Maas & Spekkink (in Tijhuis, 1994)).

Figure 4.4 gives an overview of the construction process and its phases as has been described above. Tijhuis (1996) mentions that, although the phases and steps are visualised in chronological order here, projects phases might run parallel when the project is split up in several parts of work. He gives the example of the foundation being realised, while the inner walls are being designed.

STAKE-HOLDERS

Stakeholders
According to Clough, Sears, Sears, Segner and Rounds (2015) several stakeholder in the construction process can be distinguished. Those stakeholders are named and their roles are further explained below.

Owner
- Takes the initiative of building
- Pays for the project's design and construction
- Can be public or private. Private owners make use of private money and either become the end-users of the building themselves or sell it when it is finished. Public owners have governmental roots. The projects they do are funded by public money and serve public needs.
- Outsource work to an architect or contractor, however some aim to take actively part in it and adopt the role of a designer or construction manager partly.
- Has a contract with design firm

The architect (or engineer)
- Designs the project
- Can be in different positions:
  - Architect is a private and independent design-firm, who has a contract with the owner (traditional agreement)
  - Architect is a functional part of the owner's organization (in-house)
  - Architect is in close connection with the construction contractor and they deliver their services in a design-built arrangement
  - Architect who is in a permanent relationship with a firm and delivers design for them ('corporate partnerships')

(Engineering) consultant
- Can deliver architects specific knowledge about or a specific part for the design of the building
- Has often a contract with the primary designer and are also paid by them. However, he can also have a contract with the owner to provide him with specific knowledge.

Construction manager
- Is a third party who represents the interests of the owner and delivers services to the owner.
- Has a contract with the owner, delivers several services to the owner
- Can be a designs firm, contractor or construction manager
- Performs advising, coordinating, planning and management services

The prime (or main) contractor
- Often has a contract with the owner (not the case when the contracting method is either 'traditional organisation or 'turn-key').
- Brings together and manages all diverse elements and resources for the construction of the building at greatest time and cost efficiency.
- Is responsible for the management coordination of the whole construction process
- Often has contracts with subcontractors, who deliver specific parts of the construction work

The subcontractor
- Has a contract with prime contractor, though does not have a contractual relationship with the owner.
- Performs specific tasks or delivers specific portion of the work for the project. This is a very effective way in which a main contractor, employing only a limited number of full-time employees, can hire subcontractors to perform very specific tasks. This keeps sub-contractors very skilled and this is often also faster and cheaper. In private construction project, the prime contractor can decide how many subcontractors he hires. However, in some private project and often public projects, there is a maximum amount of work that is set by the owner that can be outsourced to subcontractors.

The sub-subcontractor
- Has a contact with the subcontractor
- Performs part of the work of the subcontractor. The amount of work that can be performed by sub-subcontractors can be limited by the owner or by the prime contractor in the contracts.

Vendor
- Delivers materials and products
- Does not provide services regarding the installation of materials and products
- Has a sales contract or purchase agreement with the prime contractor, subcontractor or sub-subcontractor

In addition to the stakeholders identified by Clough et al. (2015), Fewings (2013) mentions the role of a project manager.

Project manager
- Has leadership. Sometimes, leadership might change along the course of the project among different stakeholders (e.g. designer has the lead in the beginning phase, whereas the prime contractor has the lead in the construction phase). When a project manager is assigned, he has leadership of the construction team throughout the whole project.
- Is the single point of contact for the client.

Construction contracting methods

Although all construction projects differ, Al Hassan, Friedl, Reinarz, Rentenaar and Verkooijen (1999) introduce three main construction contracting methods in the Netherlands reflecting common organisational and procedural structures: (1) the traditional organisation, (2) the construction team and (3) the turnkey (figure 4.5). In those constructions, they make a difference between functional relations and contractual relationships.

1. Traditional organisation

The traditional organisation method is characterised by its simple process and its clear separation of phases and tasks. Per phase, tasks are put out to tender by the client, resulting in open competitive bidding. The client remains the responsible party throughout the whole project. A disadvantage of this type of contract is the shock-wise phasing. Moreover, also the relative long total lead time and the late involvement of the executive parties can be seen as pitfalls.

2. Construction team

In this type of contracting method, important stakeholders are involved in the construction project as soon as possible. They aim for an efficient and effective process in which they bring together common expertise and knowledge from early on which should lead to advantages such as faster processes and agreements and a reduction in problems in the project's final phases. Together the parties help design and realise the final construction. Nevertheless, the client of the project remains the responsible party and bears financial risks. Another advantage is the exclusion of a tender. However, responsibilities within the team are relatively complex and pricing is not based on competition.

3. Turnkey

The third contracting method is characterised by a client who, after having revealed his wishes, outsources his project to one of the stakeholders in the process. Often this is a project developer or a main contractor. The particular stakeholder takes care of the development of the project in its further course as well as of the other stakeholders who are involved. The party might even become responsible for the project. In fact, after the 'turnkey organiser' has been assigned, the rest of the process is rather traditionally organised (see contracting method 1). At the end, he delivers the building to the client. Outsourcing the construction management to one of the stakeholders who has experience and can bear the risk can be seen as a main advantage of this type of method.

4.3 Construction supply chain in Amsterdam

4.3.1 Current performance

Figure 4.6 gives and overview of the construction and demolition activities in the municipality of Amsterdam during the past 7 years. It makes use of the same construction and demolishing categories as has been used in the graph for the Netherlands shown in the previous section.

In this figure, the increase in building stock in Amsterdam can be clearly observed. The graph presents an overall increase in construction activities since 2012; only the year 2015 is an outlier. On the other hand, the number of buildings to which demolition work has been done is fluctuating, though within certain limits. 2018 represents a year in which an increase in construction projects goes along with a decrease in demolition activities.

Regarding the environmental impact, the construction chain is responsible for 40% of the total waste stream of Amsterdam (CBS, 2014). When buildings are constructed, 96% of the materials that are used orginates from primary raw materials whereas only 4% orginates from secondary raw materials (i.e. reused or recycled) (Eigen haard). According to

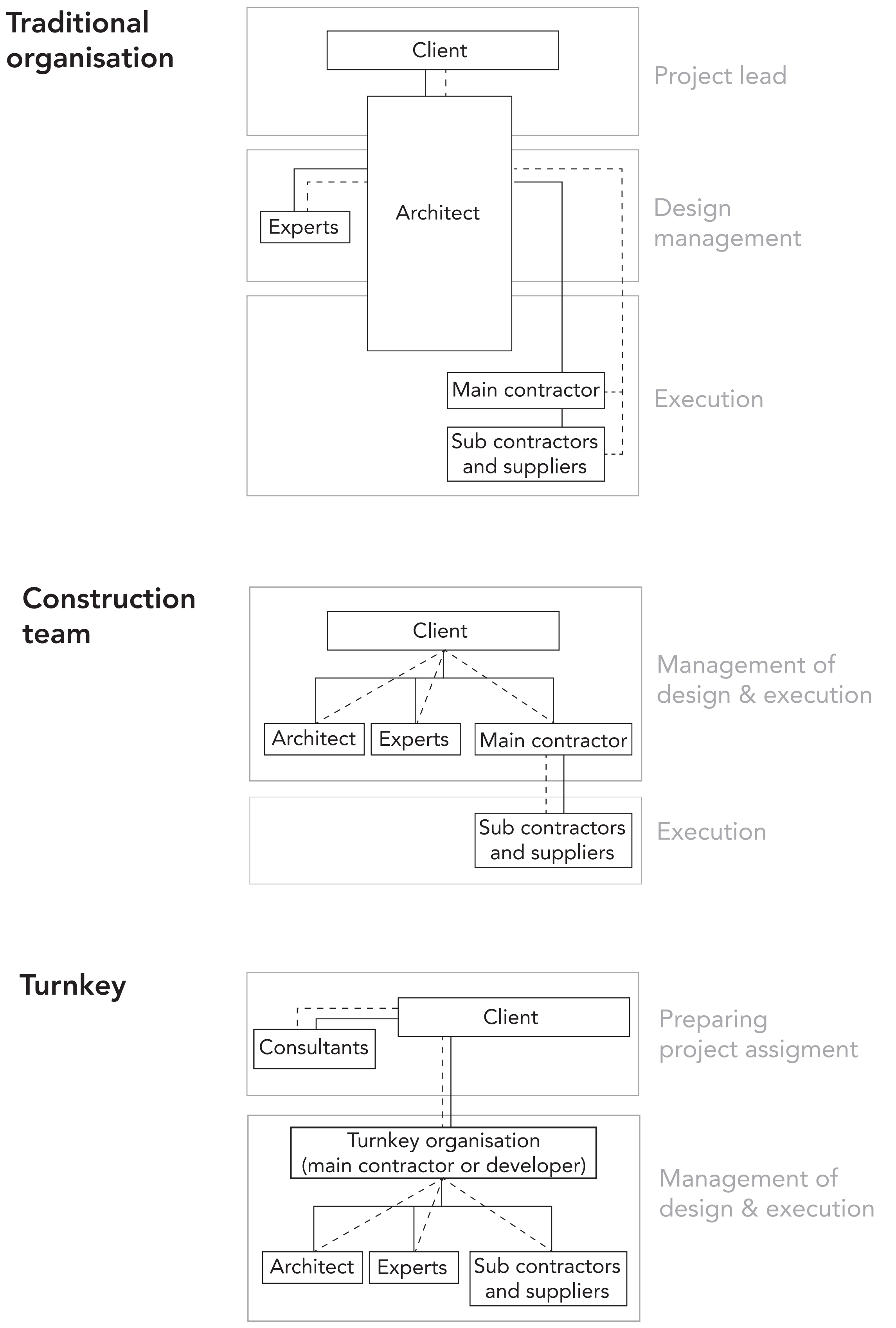


Figure 4.5, different types of contractual relationships: traditional organisation (top), construction team (center) and turnkey (bottom)(adapted from Al Hassan et al. (1999))

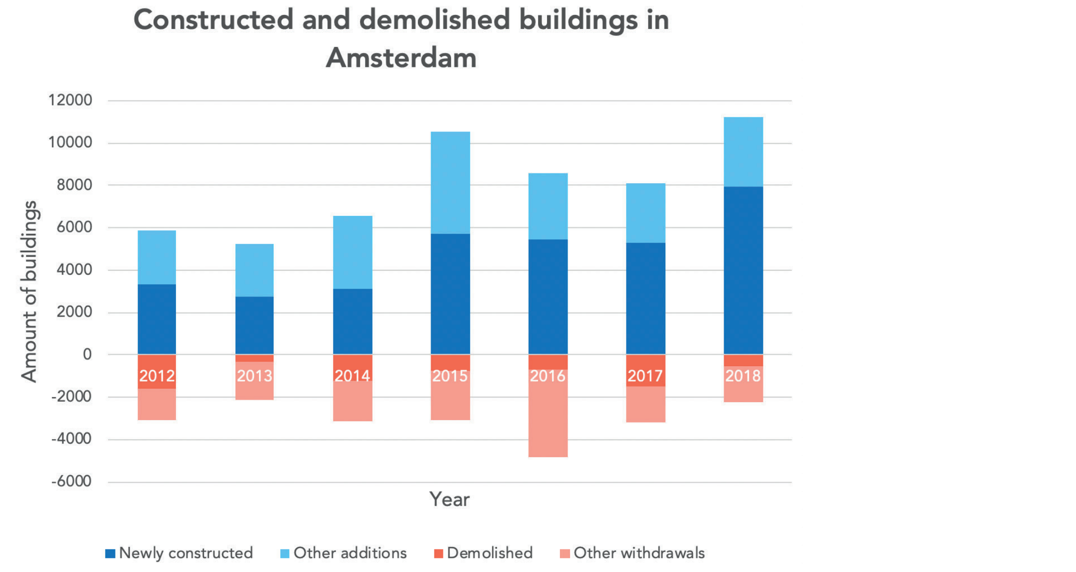


Figure 4.6, constructed and demolished buildings in Amsterdam from 2012 till 2018 (based on CBS, 2019)

Metabolic & DR2 New Economy (2018), the value that is released by outcoming materials in the metropolitan region of Amsterdam is 688 million euros yearly. However, half of this rate is lost due to material degradation.

STAKE-HOLDERS

<u>Stakeholders</u>

Circle Economy et al. (2015) made an overview of the stakeholders in the construction sector of Amsterdam (figure 4.7). A distinction is made between material suppliers, architectural and design firms, construction companies, real estate firms and waste processing companies. The size of the circles represents the importance of the particular stakeholder. As has been indicated by the dotted line, 'waste' products can be turned into secondary raw materials that can become input for other construction projects.

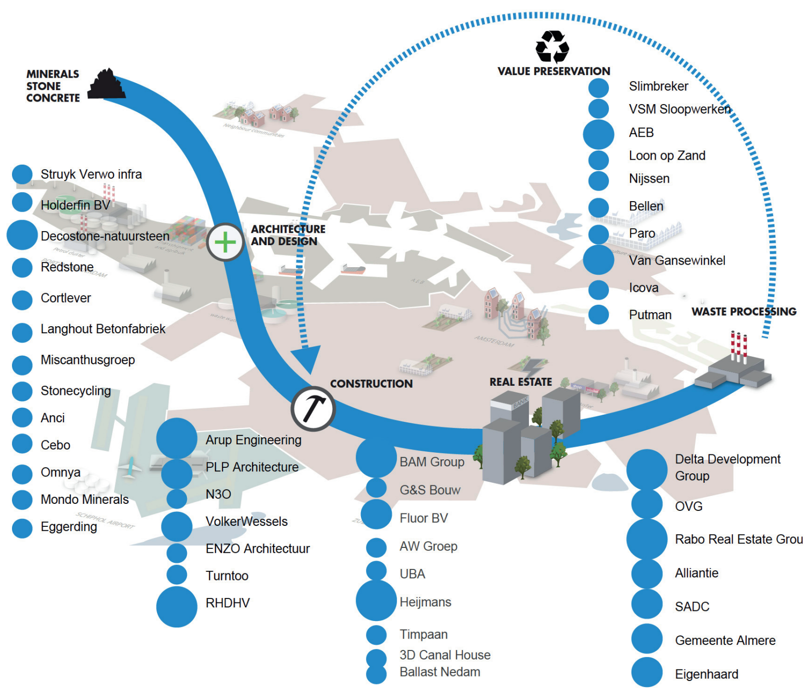


Figure 4.7, stakeholders in the Amsterdam construction sector (Circle Economy et al., 2015).

4.3.2 Future vision & strategies

Towards 2040, 70 thousand new homes will be built in Amsterdam (Circle Economy et al., 2015). Additionally, the city also has to meet the requirements set by the Dutch government regarding circularity. Those ambitions give rise to a lot of opportunities for Amsterdam, such as a 3% increase of productivity, resulting in economic growth and employment opportunities (Circle Economy et al., 2015). Furthermore, the reuse of materials can lead to the saving of 500 thousand tonnes of material, which is 1/3 of the city's yearly material import (Circle Economy et al., 2015). However, this does not go overnight. A vision for a circular construction chain in Amsterdam, as formulated by Circle Economy et al. (2015), states the following: "Construction and demolition of buildings in Amsterdam should be coordinated so that the construction materials from demolished buildings may be used again in new construction projects and renovation projects. That way, the use of new materials in new construction projects will be reduced to a minimum." (p. 17).

Circle Economy et al. (2015) name four strategies for the municipality of Amsterdam that should help in achieving the aims set. It stresses the following aspects:

- smart design (like modular design or the use of bio-based materials).
- dismantling and separation (to prevent contamination with other resources).
- high value recycling
- establishment of marketplaces and resource banks. After the separation and recycling of construction materials, there often raises a gap between the demand and supply of the resources recovered (Circle Economy et al., 2015). The establishment of a 'marketplace' can help to match supply and demand (Circle Economy et al., 2015; Metabolic & DR2 New Economy, 2018). Several of these initiatives exist, however they have not been applied to the scale of the city. Important is that, instead of developing separate systems running parallel to each other, an collective approach is adopted by which data can be connected (Metabolic & DR2 New Economy, 2018).

Partly, they have an influence on each other. Envisioned results of those strategies are visualised by a material flow model shown in figure 4.8.

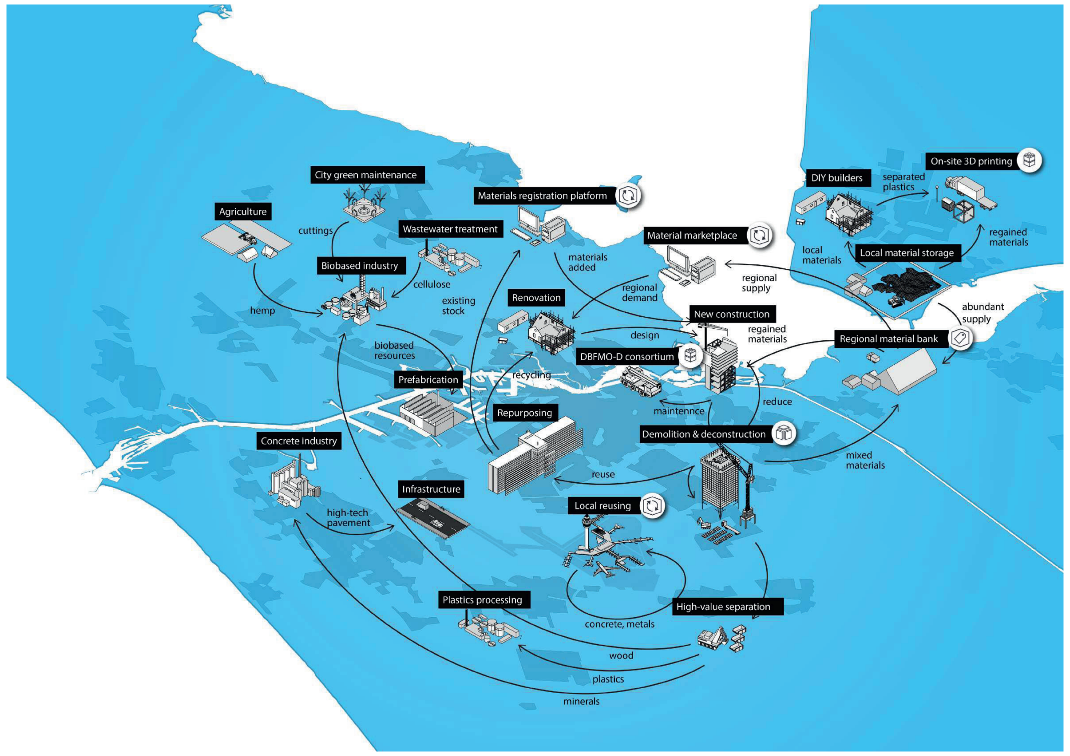


Figure 4.8, visualisation of Amsterdam's vision on its construction activities (Circle Economy et al., 2015).

Next to the strategies that Circle Economy et al. (2015) present, they also indicate several barriers. Those mainly come from laws & regulations, culture, market and technology. The largest barriers for the dismantling and separation as well as for the high reuse value are from regulatory or cultural nature. Furthermore, regarding separation at the source, other barriers might be the increase in labour costs and the restricted amount of time and space of storage areas (Metabolic & DR2 New Economy, 2018). For the realisation of a market place goes that the largest barriers are formed by the market (Circle Economy et al., 2015).

5

RESULTS I: BASELINE ASSESSMENT CASE STUDY

To be able to compare the situation in which urban symbiosis is applied to construction materials with the current situation later on in the course of this report, this chapter presents the outcomes of the case study's baseline assessment. Findings result from the interviews that are done. In section 5.1, its construction process and the involved stakeholders are reviewed. Section 5.2 provides an overview of interview findings in relation to material usage in the project. In this chapter also a prerequisite is derived from the findings that can be used for the development of a design. This one is stated in a yellow box. Important to note is that those prerequisites and design criteria are interpretations. An overview of all prerequisites and design criteria can be found in chapter 7 ('Interim Reflection: Deriving Design Criteria').

5.1 Construction process & stakeholders

Before one can create a strategy on how the conventional construction process can be reorganised, and more specifically the case study's process, the regular process and the involved stakeholders are reviewed.

5.1.1 Stakeholders

STAKE-HOLDERS

Based on the interviews with three stakeholders of the case study's project (architect, main contractor and project manager), a picture could be painted of the group of stakeholders who are involved in the construction process and of their roles.

Within the construction team, the housing corporation De Alliantie has initiated the renovation in 2015 (Project manager). More specifically, De Alliantie Amsterdam is the main client of the project. The project manager tells that he is the client's representative and works for their Development department. He develops the project and is responsible for the budget. The project manager has been involved since the investment agreement for the project was made. From this moment on also an area developer from the corporation has been involved. At the end of the project, the project manager will be involved for 4,5 years.

The residents have a contractual relationship with De Alliantie in the form of a lease agreement (Project manager). De Alliantie provides them with a house and accompanying services. The residents are not related to any of the other stakeholders named here.

The architectural firm has been involved since the beginning of the project in 2015 and works on behalf of the client under a contractual agreement (Architectural firm). In exchange for revenue (as is implied), they develop the design for the building and provide the client with advice on materials like other advisors can do (Architectural firm; Project manager). From the firm, two actors work on the project: the architect and the project coordinator. The architect designs the building and the project coordinator takes care of the process (Architectural firm). They optimised the design together with several advisors in the initiative phase. Among those advisors are a building physics consultant, a constructor (with whom they have a contractual relation (Project manager)), a material expert and the main contractor. Also a knowledge institute (TU Delft) might be involved in those activities. Normally, the architectural firm is not directly involved in the project's execution phase, however the architectural firm explains that in this project De Alliantie asked them to look after the quality during this part of the process. This is done by the project coordinator.

The client also has a contractual relation with the main contractor (Main contractor; Project manager). More specifically, this is a contractor's agreement describing the conditions under which the contractor works (Main contractor). The main contractor has been involved since the moment before the contractor's agreement had been made and is in the process responsible for the project from the start of the assignment till the after-care. The project manager tells that the main contractor has also been made responsible for the budget. Furthermore, the party is connected to a group of sub-contractors (in this project approximately 20-25) (Main contractor). 80% of the contractor's work is outsourced to them. With those sub-contractors the main contractor has separate contracts.

Both the main contractor and subcontractors buy their materials at material suppliers (Main contractor). However, their choice is restricted by the program of requirements that is imposed on them by the client (Architectural firm). Some material suppliers are also directly connected to the client by maintenance contracts as they deliver maintenance service for the building's materials in exchange for revenue (as is implied) (Project manager). For more information on the choice of materials, see this chapter's subsection 5.2.1 "Construction materials", paragraph "Choice of materials".

As the case study building has been renovated, at the start of the project also a demolition party was involved to take away part of the materials (Main contractor). According to the main contractor, they become the owner of the materials. From there on, some of the material streams can enter the market again as new resources.

Figure 5.1 provides an overview of the results presented above; the value flow model indicates the stakeholders who are involved in the case study and illustrates their relations. The grey icons represent the parties who are involved. They are connected by a type of value flow, indicated by the orange icons. Furthermore, major part of the stakeholders is connected by contractual relations to one another. Those are represented by the blue icons.

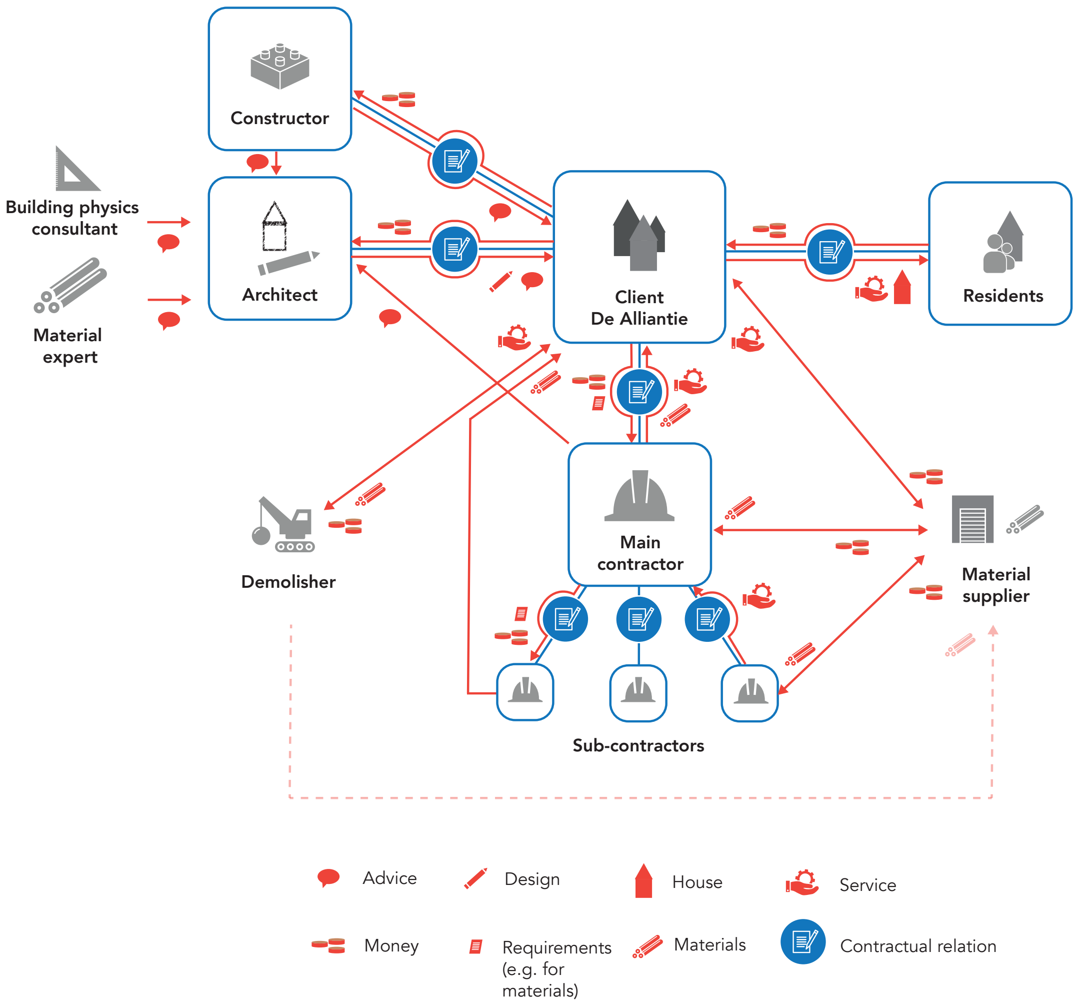


Figure 5.1, value flow model of state-of-the-art case study[1,2]

1 The revenue streams in the value flow model are not explicitly pointed out by the interviewees; however, it is implied that delivered work or services are in exchange for revenue.
2 See for credits for some of the icons in the figure chapter 'References'.

PROCESS

5.1.2 Process

Next to the value flow model including the stakeholders who are involved in the construction process, also an overview can be given of the case study's construction process based on the results presented in the previous section. This is presented in figure 5.2. The results are structured according to the conventional Dutch construction process as has been found in section 4.1.2. A division is made in terms of the stakeholders' degree of activity in the process phases: high level of involvement (performance of the stakeholder's main activity) and low level of involvement (advice). Furthermore, parts of the lines are solid whereas the others are dotted. The former indicates the involvement of the stakeholder in phases he is usually, in the conventional Dutch construction process, also involved in. The dotted parts in their turn indicate the involvement of the stakeholder in phases he is normally not performing any of his activities.

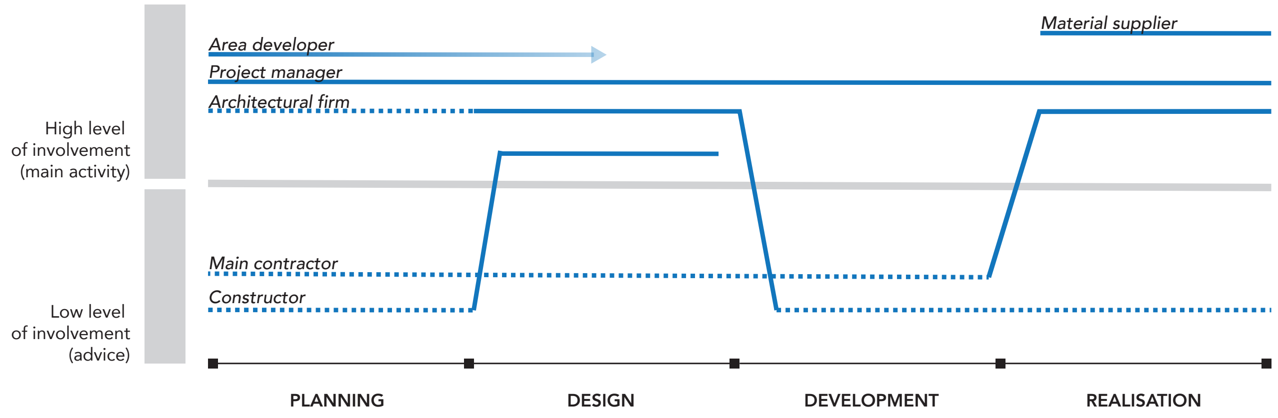


Figure 5.2, overview of the involved stakeholders throughout the case study's construction process

As can be seen in the figure and as also has been reported in the interviews with the stakeholders of the case study the construction process of Burg. Fockstraat building has been somewhat irregular in comparison to the conventional one presented in section 4.1.2. This is due to the fact that a similar project had been initiated by another housing corporation before. The architectural firm was also involved in this project and gathered a lot of experience (Architectural firm). Moreover, the project manager indicates that a lot of knowledge was generated. According to both interviewees, this made De Alliantie choose the same main contractor and architectural firm to work with in the Burg. Fockstraat project.

The architectural firm and the main contractor have been involved from the very beginning of the project. This is where the project differs since in regular processes those parties step in later on. Another difference is that the architectural firm will be involved till the end of the project. As most of the parties were already assigned, the project was not put out to tender during the development phase (Project manager); this is usually the moment a main contractor is assigned. Nevertheless, as can be seen in the figure, at certain moments in the process the parties are involved to a greater extent than at others.

MATERIALS

5.2 Construction materials

5.2.1 Ingoing (raw) materials

Information about the material and its characteristics

One of the aspects that was stressed during the interviews for raw materials was the availability of information on materials and the way this potentially contributes to the choice for sustainable materials.

According to the two interviewees of the architectural firm, for many more complex products it remains a discussion which material is most sustainable to use. In case of a window frame for example, material suppliers have different answers to the question whether the use

"It would be nice if everybody would be open and honest about this and if you could capture it measurably."

Architect of architectural firm

of wood, plastic or aluminium would be most sustainable. Moreover, the market and the suppliers tell them all kinds of stories about materials; those parties are prejudiced. This causes that the architect and the project coordinator do not know what information or supplier to believe. They stress that openness about materials' information is therefore essential but hard. Additionally, it would help if the information becomes measurable according to them.

Furthermore, the architectural firm stresses that parties have interests in different calculation models. As mentioned by the architectural designer, sustainability is very broad term. In order to state something about a material's sustainability performance, a wide variety of factors should therefore be taken into account according to him. It is implied that this might complicate the generation of a complete overview of a material's sustainability performance.

Prerequisite construction sector: Openness about a material's information

Choice of materials

Several parties are involved in the decision on the materials that will be used. First, the client De Alliantie formulates a program of requirements, a document which among others describes the required quality and characteristics for materials to be used in the to-be-constructed building (Architectural firm; Project manager). Some requirements can be very detailed and strict, like the use of specific products and brands, yet others only describe certain characteristics of the material which leaves room for choice (Main contractor). The project manager stresses that those requirements are mainly written down to ensure the materials are compatible with other materials and that they can easily be maintained. Related to the latter, the client makes sure that similar products are used in their buildings and only a restricted number of maintenance types and services has to be offered (Main contractor). The project manager explains that this practically means that all materials that might require maintenance in the future are prescribed.

According to the architectural firm, they thereafter make a proposal for the to-be-used materials by their design which is in line with the program of requirements. He can thereby provide an advice on the choice of materials so can other consultants who are involved (Project manager). As indicated by the main contractor, he and his subcontractors subsequently determine at which supplier the proposed materials are bought within the boundaries of requirements that have been set. Moreover, the contractor always needs to receive an approval for his final material choice from both the client and the architect (Architectural firm).

In general, various factors play a role in the choice for a material. The architectural firm mentions several ones: the technical characteristics of the material, the program of requirements for the building, costs, availability and planning. Next to those, the project manager stresses the importance of maintenance. Finally, for renovation also a required outlook, e.g. in case of a monument, can have an influence on the choice for a certain material over another (Architectural firm).

5.2.2 Outcoming ('waste') materials

"If something [a material] is extracted, this is because it is used up or broken in most cases."

Project coordinator of architectural firm

Quality

The interviewees were also asked about the quality of the materials that come out of a building. According to the architectural firm, materials are often taken out because they are broken or at the end of their lifetime, especially materials from buildings which are renovated. Furthermore, the architectural designer stresses that currently, a lot of buildings are built low-grade, which thus results in the fact that not many valuable materials can come out.

The actual value that is assigned to the extracted material is determined by the demolisher who becomes the owner of the materials (section 5.1.1) (Main contractor). The main contractor explains that the way in which the material is treated and separated afterwards

depends on whether the demolisher can make money with the material; disposal of some waste materials namely costs money whereas the disposal of others makes money. A higher quality of material generates an incentive for the demolisher to reuse it. The value of the outcoming material is thus determined by the owner of the material.

Management

The interviewees of the case study have also given insight in the management of the materials that come out of a building and their disposal. In terms of the order in which materials are extracted during the renovation project, the main contractor tells that the first materials that are taken out are the materials that are encountered at first. He indicates that also the turning elements (such as doors) and the metals are taken out soon. Furthermore, demolition is done per porch from top to bottom (Main contractor).

After extraction, the materials are separated. A separate collection of waste is currently required at the construction site; this is also seen as a first step towards more sustainable use of materials like recycling and reuse possibilities (Architectural firm). The main contractor explains that their managing board has the aim to limit the maximum amount of the mixed waste stream to 50% of the total amount of waste (currently this is 36%); the rest of the waste needs to be separated at the source, even when this is more expensive.

The debris is collected first (Main contractor). The main contractor explains that those streams can be reused as a resource for concrete by demolition or dumping companies. He strikes the modular characteristic of those materials, that is to say their ability to be broken apart or to be melted. After the debris a combined waste stream is collected (Main contractor). The latter one is also the one which is most expensive to process.

As becomes clear from the interviews, among some stakeholders there is not much awareness about the processing of the materials after those have left the construction side. For example, the two interviewees from the architectural firm indicate that the recycling of materials goes beyond them; they do not know where and how the waste is processed. However, they also think this is not their job. Only in case of restauration, and thus when materials are valuable, they say they are interested in the reuse of materials.

In the future, the architectural firm expects that it will become required for contractors or owners of components to report the process of how extracted components are processed. By this intervention, he thinks the entire material cycle will be under control.

5.2.3 Attitude towards materials' sustainability & sustainable technologies

According to the project manager, new technologies are developed that ease the separation of construction materials for reuse, however those have only rarely been applied yet. With regard to the same topic, the architectural firm tells about an ongoing discussion in which is questioned whether one should focus on the future disassembly of components when creating a new building or whether one can rely on new technologies that will be able to separate those materials in the future.

Additionally, it is questioned whether promising technologies should be distributed before the success of the concept has been proved (Project manager). For example, the performance of a particular technology at another scale level in another context than the original conditions in which it has been developed might differ (Project manager).

From those results can be concluded that, as the project manager states, the construction sector seems to have difficulties in defining what sustainability means in their sector and how this could be achieved.

6

RESULTS II: TOWARDS AN URBAN SYMBIOSIS

This sixth chapter presents the findings that are retrieved form the interviews regarding the reuse of materials, the application of an urban symbiosis to construction material flows and a design that might be of value during the symbiosis' establishment. In section 6.1 a difference is made between the reuse and the recycling of materials. Due to the main objective of this study, the study mainly focusses on the reuse of components (for further motivation see chapter 1 'Introduction', subsection 'Research questions'). Section 6.2 presents the outcomes of the interviews with respect to the reuse of components with respect to the process, materials and stakeholders and concludes with a recap of the challenges that came forward. In section 6.3 findings are stated which relate to the applicability of urban symbiosis to construction materials. Lastly, section 6.4 present findings with respect to a design that can be created to stimulate the establishment of an urban symbiosis and the creation of connections in a network.

Similar to the previous chapter, prerequisites and design criteria are derived from the findings introduced in this chapter for the development of a design. Those are presented in the yellow boxes. Important to note is that those prerequisites and design criteria are interpretations. An overview of all prerequisites and design criteria can be found in chapter 7 ('Interim Reflection: Deriving Design Criteria').

6.1 Reuse vs. recycling of materials

During the interviews a distinction has been made between the reuse of 'components' (building parts or elements, such as doors and windows (Icibaci, 2019)) and the reuse of resources. According to the ladder of Lansink (Parto et al., 2007), the former can be seen as a type of reuse whereas the latter is rather a form of recycling, by which the material is degraded to a certain level and is used for a new application. As stated in the introduction (chapter 1), this study has a particular focus on the reuse of components due to the aim of the study. During some of the interviews, difficulty has been experienced in keeping the subjects on track and letting them focus on the reuse of components rather than on resource reuse.

The architectural firm and contractor question the reuse of components. They believe in the reuse of resources in 'new' products rather than in the reuse of components. The reuse of resources currently happens a lot according to the contractor while the reuse of components is a challenge and takes place only rarely. Also, the project manager indicates that De Alliantie solely reuses components at a very small scale; one can almost speak of hobbyism. Moreover, the project planner thinks that it is easier to produce components based on the design requirements for the future building so resources are reused for the production of those components instead of reusing original components and adapting the building to their sizes.

The architectural firm and contractor both tell that only when the materials are authentic, e.g. in case of restauration, or are very valuable, this creates an incentive for them to reuse them.

Although the interviewees of the case study talked about the reuse of components slightly reservedly, they gave a few examples of reused components in their buildings. More specifically for the case study building, they have reused central heating boilers from an old school in the past. During the current renovation, they reuse 30 boilers that had recently been installed.

So, although some of the interviewees showed reservation regarding the construction material reuse, the further course of this chapter will solely focus on findings regarding the reuse of components being in line with the study's research questions and objectives.

6.2 Reuse of materials

This section shines a light on the reuse of construction materials with respect to the process, the materials and the stakeholders who are involved. Throughout the section, several challenges are raised, which are collectively presented in an overview in subsection 6.2.4.

6.2.1 Process

PROCESS

Four phases

Results regarding the reuse process and activities that come out of the interviews can be traced back to four main phases in the reuse process: harvest, design, processing and implementation. It has to be noted that the order of the first two phases can be alternated, dependent on the type of process.

Harvest

The architectural designer explains that in his work materials are harvested in two ways. In the first case, they search for products that can be harvested out of other products from projects that are demolished; those are also called 'donor projects'. In the other case they go to industry companies, large contractors and demolition companies to see what they take out. As can be observed, the process of matching supply and demand differs between the two. Whereas the latter makes use of the materials that have been extracted already and have ended up at larger companies, the former rather focusses on materials in a specific project that are or will be harvested.

The architectural designer also explains that current reuse activities mainly clean up 'leftovers' (assumed to be materials that have been taken out of a building already). Additionally, he explains that in the future, related to the theory of Thomas Rau, one has to already start looking for the reallocation of materials that are at that moment used for the construction of a new building. In this way, when that building is demolished after its lifetime, its materials have already been assigned potential reuse strategies.

Important for harvesting are continuous supplied flows of residual materials (Architectural designer). Furthermore, it is mentioned that extraction of materials can be a pretty specialised, which requires education (Architectural Designer).

Design

"It does not change the role [of the architect] so much, but it changes the design process."

Architectural designer

The architectural designer thinks that although the traditional role of the architect will not change that much, the design process will. The to-be-reused materials namely become the input for the design process (Architectural designer). In case of procurement of a to-be-reused from another building, next to specific dimension drawings, processing steps might be needed; the role of the architect might shift more towards the role of a main contractor or buyer (Architectural designer). Furthermore, designers are often kept in the dark because it is for a long period unclear which materials or components will become available; the uncertainty about supply is thus seen as a complicating factor here (Architectural designer). The earlier the supply is known, the easier it is for the designer to work with (Architectural designer).

This is also stressed by the designer of the case study's building, the architectural firm. He explains that as a designer he chooses materials he wants to be used in the building, however it can take one or two years before the building is constructed. For a design process, timing is therefore seen as a very important and complicating factor during the design phase.

Furthermore, according to the architectural designer one has to design smartly. He and his company accept for example that their houses will have other interiors such that they can buy smaller batches of to-be-reused materials as those are more often available. However, due to their differences, the challenge arises to store and process those components in diverse ways (Architectural designer).

Prerequisite construction sector: Following the previous prerequisite, stakeholders should start reusing a variety of batches of outcoming components for a single application in a new building. In this way, smaller batches of components can be processed.

Processing

As can be read in the next section about materials (6.2.2, paragraph 'Quality'), components that are extracted from a building and that one wants to reuse often need to be upgraded due to the fact that their quality has cascaded over their lifetime (Designer). Moreover, other reasons can be found for which processing steps are required, for example in relation to the building decree and fire safety standards that should be met (Architectural designer). Another example is given by the project manager; he argues that when the to-be-reused component does not fit the required dimensions, it would be better if it is redesigned by a manufacturer to make the component fit to the right sizes.

Those results thus support for a processing step in the process before the components will be applied in another application.

Design criterion: Give insight in processing possibilities to make from the extracted product the desired product. Make it also possible to make connections with those processing parties *(criterion B5).*

Implementation

After components have gone through the processing phase, they are ready to be implemented in the new building. Since the study focusses on the reuse process towards the implementation of the new components, no information was gathered for this specific phase.

Storage & transport

"It will almost never happen that it [the material] can go from spot A to spot B directly without in-between storage."

Designer

Next to the four general phases in the reuse process, two side activities can be identified: storage and transport. Those two activities often take place after harvesting, during the processing phase. It is most convenient if supply and demand are linked as directly as possible, though this is experienced to be difficult in practice (Architectural designer). Buffer space is often needed to bridge the time gap (Designer). Although the designer thinks that storage space is available, it results to be an expensive business (Architectural designer; Designer). When a storage facility is used in the process, more certainty can be offered that a product will be available (Architectural designer). Furthermore, materials will be located more centrally, however transport of materials is required (Architectural designer).

And this transport of materials turns out to be another expensive matter (Architectural designer). Furthermore, it differs for materials how far they can be transported because of a difference in embodied energy they comprise; in comparison to wood, steel can be transported over a longer distance due to the large amount of energy that was required for its production (Architectural designer).

Design criterion: Include transport possibilities. Make it also possible to make connections with those transport companies *(criterion C1).*
Design criterion: Include storage possibilities. Make it also possible to make connections with those storage parties *(criterion C2).*
Prerequisite construction sector: Link supply and demand as soon and directly as possible.

MATERIALS

6.2.2 Materials

“If you look at a project like this [case study], what materials come out that would be useful? Actually, I couldn’t imagine.”

Project coordinator of architectural firm

Quality
The quality of a material that one wants to reuse can be seen as an unsettled factor (Architectural designer). The architectural designer explains that it depends on the material’s status as well as on the degree to which the material was damaged during extraction. Whereas the architectural firm cannot imagine the reuse of any of the components from the case study’s building, the platform’s designer indicates that, in general, extracted materials can be reused, however that one can often speak of cascading, or a degraded quality, when those are used once again. One has to make sure that the problems that are caused by a building’s component are not replaced to another building when this component is reused there (Designer). An upgrade of the material is therefore often in place (Architectural designer). Also the architectural firm argues that there are often one or two processing steps needed before the material can be reused (or recycled). This might not be required if the material is reused for an application that asks for a lower material quality (Designer). Moreover, the contractor stresses that the reuse value of a component is determined by the type of application one wants to reuse this material for.

These results show that, although there are some doubts about the reuse of components due to their often-degraded quality, as has also been mentioned in section 6.2, other parties believe in the reuse of components either for the same application (after an upgrade or several processing steps) or for lower quality applications.

Material’s requirements
A challenge for the reuse of materials that is encountered by the contractor and the architectural designer is that to-be-reused products are often not in line with current requirements for materials and changes in the building decree. This would be less of a problem if the component would be modular and parts can be adapted or replaced (Main contractor).

Prerequisite construction sector: When possible (depending on the application), requirements for the use of a specific materials should be made more flexible in order to reuse a larger number of materials, differing in characteristics, instead of applying new ‘raw’ materials.

Modularity
According to the contractor, it is important that materials are modular to reuse them later on. An example of the case study building he has given was the fencing that was taken apart during the renovation and that was reconstructed afterwards. Due to the fact that the fencing was made of metal instead of wood, they were able to reuse. This thus implies that certain materials might be more appropriate for reuse purposes than others.

Demountable components also enable that their parts can easily be reused one by one. The architectural firm tells that in case products are going through a change over the years, e.g. because they become more efficient, initial parts can be deconstructed and can be processed and reused separately.

Furthermore, in relation to the discussion whether we can rely on future technologies that will separate materials (section 5.2.3), the architectural firm can imagine that we mainly focus on short lasting products and make those demountable instead of on materials that are there for the longer term.

Modularity of components thus seems to be an important factor that plays a role in a component’s reuse potential.

Prerequisite construction sector: For the reuse of the material it is favourable if the initial material is modular.

Repetition
From the interviews can be derived that also repetition seems to be of value in the reuse process. According to the designer, the more repetition is found in the materials that are used in and are extracted from a building, the more likely it is that materials can be extracted to their full extent and that they can be reused (personal communication, April 12, 2019). In this case the material types and characteristics are namely limited. Furthermore, the project manager thinks also the upgrading process can be done serialised, such as NewHoirzon is currently doing (personal communication, March 12). He expects that the supplying industry will become an important player in this process.

Design criterion: Focus on repetition. Require a minimal amount of similar products that can be supplied and can be bought. In this way, types of products and their characteristics are limited which makes it easier to process them serialised during the construction of the new building *(criteria A6 & B4).*

Standardisation
In case information about a material is not documented properly and people want to buy it, it can be costly and time consuming for the supplier to inform those demanders and let them check the material (Designer). A standardisation step is therefore desired; the specific set of information that is required to let someone decide whether or not he wants to purchase it can be made available (Designer). An increase in the amount of supply offered can contribute to this standardisation step (Architectural Designer).

Design criterion: Make use of standards in the data *(criterion A1).*
Prerequisite construction sector: Standardisation step within the building sector to make a specific set of information available for each material.

Costs
The extraction of components during the disassembly of a building is not seen as the hardest challenge and is technically possible; the main question is whether there is a market for the materials that come out (Main contractor).
The disposal of both separated and debris streams is too cheap (Designer). If the prices to dispose materials increase, the designer thinks it becomes more interesting for building owners to look for other ways to dispose materials, like reuse. This same story holds for new components; when new components would become very expensive, it might be more interesting to reuse other components (Main contractor). So, based on those results, for both the supply and the processing of the materials goes that a change in the current economic valuation of materials would be of help to successfully move towards a reuse culture.

Also costs for extraction play a role. In case the costs that are made to properly extract the material from the building do not outweigh the costs to dispose the material, one prefers to demolish and dispose it (designer).

“There are a lot of things [materials] that are economically just not worth recycling, so it becomes more expensive to reuse it.”

Architectural designer

In the end, one has to keep reflecting on whether it is worth it to reuse a material. According to architectural designer, the costly aspect of the reuse process still determines the process’ current feasibility and makes it difficult nowadays to convince clients to reuse materials. He thinks that this is not always unjustified and one should also resign himself to the fact that for some materials goes that it makes no sense to reuse them.

So, till the moment a change in the material valuation system is established, one has to think about which components are worth it to be reused.

Extending life time
Both the architectural firm and the main contractor of the case study stress that, in terms of sustainability, it is best to restore a building or to keep elements in place. Furthermore,

"Best reuse is to keep it [materials] in place."

Main contractor

leaving materials behind is seen as a functional way to reuse those materials for other purposes (Main contractor). For example, the main contractor explains that in the case study's building, the old roof coverage has become a layer of insulation when a new layer of roof coverage was applied on top of it during the renovation activities. However, the balance between the longer-term use (e.g. in case of renovation) and the maintenance costs is found to be hard (Project manager). As he explains, this is mainly determined by financial drivers.

Guarantees & certification

Guarantees and certificates turned out to be of great value for the reuse process. Being important incentives, they can contribute to the increase of the reuse of materials (Architectural designer). However, those can often not be provided for to-be-reused materials. Most of those materials only have certificates dating from when they were placed in the initial building (Designer). Consequently, those are not up-to-date any more. Because of this reason, not many of the contractors or installation companies decide to make use of reused materials as they have to provide guarantee for a certain amount of time (as is stated by their guarantee structures) (Main contractor). Otherwise, this can yield them large amounts of unforeseen costs.

Prerequisite construction sector: Another guarantee structure for to-be-reused materials should be developed in order to ease and increase the reuse of components.

Attitude towards reused materials

Also the attitude towards reused materials turns out to play a role in the acceptance and adoption of the reuse process. From the interviews it results that people have a different approach towards reused materials. According to the main contractor, tenants generally expect that new materials are used in their new home. Apparently, this is also culturally dependent; the project manager tells that Moroccan and Turkish tenants see new materials in their home as a high-class status. On the contrary, he notes that native and young people often think older materials are charming. Here, the narrative aspect plays a role. When a building is rebuilt and materials from the initial building are reused for other applications in the new construction, this can also create a certain 'connection' (Project manager). This observation can be turned to good account for the reuse of materials (Architectural designer).

Furthermore, the project manager thinks the reuse of materials is still at a high level of idealism. The society is used to throw materials away (Project manager). According to the architectural designer, a culture needs to be established which values the reuse of materials and which has to replace the more traditional culture. This can for example be done by a new generation embracing this change for the longer term (Project manager).

It is thus important to think about the customer's experience with respect to the materials to be reused (Main contractor). This depends on the acceptance of the age and quality of the material (Main contractor). The architectural designer thinks that even changing the naming of 'waste' into 'building materials that have fulfilled a function in a project' might contribute.

Prerequisite society: Change in attitude towards reused material.

STAKE-HOLDERS

6.2.3 Stakeholders

During the interviews, the interviewees were asked which stakeholders they think are key players in the process of reusing materials and who should take the lead in this. Based on the answers that were given, the following table can be constructed.

Most important (+)/ leader (L)
** not completely clear*

	Interviewees				
	Architectural firm	**Main contractor**	**Project manager**	**Architectural designer**	**Designer**
Reuse & recycle (-reuse; - recycle; - both)	Client	Client/ owner (+)	Suppliers* (+)		
	Suppliers (+, L)	Contractor	Government (+, L*)		
	Architects	Demolition company	(Client)*		
Reuse only			Supplier	Waste processing company	Owner/ client (L)
				Client (financing)	3rd party
				Contractor (+, L*)	
				Demolition company	
				Architect	
				Consulting parties	
				3rd party (L)	

Table 6.1, overview of stakeholders in either the reuse and recycle process or only in the reuse process of construction materials as indicated by the interviewees.

As can be seen in table 6.1, a distinction is made between 'reuse & recycle' and 'reuse only'. This distinction was made due to the fact that in some the interviews both the reuse and recycle processes and their stakeholders were addressed by the interviewee alternately. This category therefore stresses key stakeholders in either the reuse or recycle process or in both. Since the study focusses on the reuse of components rather than on the recycling of resources (see section 6.2 for motivation), only the key players important in the reuse process are taken into account in the further course of this section.

Table 6.2 provides an overview of the key players identified for the reuse process in such a way that the answers can easily be compared.

Concluding from table 6.2, the client or the owner of the building is by most of the interviewees seen as a key player in the reuse process. The main contractor and the designer even think this party is most important or can have a leading role respectively. According to the main contractor, the client has to accept the quality of the to-be-reused material. As stated by the designer, the owner of the building has to be willing to reuse materials. He explains that it is likely the owner wants to reuse materials if this is attractive in terms of social responsibility or finances or because of other motivations. This goes for both supply and demand. The designer also notes that currently the reuse process is too much unknown to building owners.

In the light of the finances that have been mentioned, the architectural firm strikes that the client needs to be willing to pay for those reused and sustainable materials. In his turn, the architectural designer argues that if the client is willing to pay more for reused materials, this creates an incentive for main contractors to sell their valuable extracted

	Interviewees				
Indicated stakeholders in reuse process	**Architectural firm**	**Main contractor**	**Project manager**	**Architectural designer**	**Designer**
Client/ owner		+			L
3rd parties				L	
Demolition company					
Supplier					
Government			(+, L*)*		
Waste processing company					
Contractor				+, L*	
Architect					
Consulting parties					

Table 6.2, overview of stakeholders in the construction material reuse process as indicated by the interviewees

materials, which leads to a greater amount of supply offered.

Striking is the fact that the project manager, being the representative of the client and owner of the case study, does not recognise himself as a key player. He furthermore explains that pricing plays a major role when he tries the convince De Alliantie to use a more sustainable material; this might only be successful if the total costs of ownership will become lower and costs will thus be recovered.

Additionally, the architectural designer and the platform's designer both see third parties as important key players in the reuse process; the latter even thinks third parties can adopt a leading role here. Several examples are given. The architectural designer strikes that most logically the main contractor might be the party who takes the lead in the search for reused materials; however, since there is no financial incentive yet, this is currently not happening. He thinks that there can almost be a separate role or platform for this. When talking about a potential platform for a housing corporation, he can imagine that the corporation does not want to link their supply and demand themselves, but that another company takes on this task at a larger scale. The designer stresses that such a potential third party who is going to connect supply streams, like Harvestmap, should have a limited profit motive.

Since the demolition party receives the outgoing materials and becomes the owner, the main contractor thinks there is also a role for this party in the reuse process. Also the architectural designer thinks this stakeholders can play a role here.

Furthermore, there are a few key players named by single interviewees. The project manager acknowledges material suppliers and the government as important key players. Related to the former, he thinks a mindset change is needed in the whole supplying industry. This mainly strikes the pricing of materials; he argues that technically it is possible, however as long as the prices for new materials (including ones produced abroad) are lower than the ones for reused components, he expects this transition will not take place. Regarding the role of the government, he thinks that change can be brought about if they are able to let reused material concur with new materials by regulations pricewise.
Both key players are thus expected to be important to bring financial changes about that could contribute to the reuse of materials.
The architectural designer further thinks that waste processing companies, contractors, the

architect and consulting parties play an important role in the reuse of materials. About the first one he says that they also start to see it is time for change; they will become a material bank. Furthermore, he thinks the contractor is a very important party since he has to be willing to implement reused materials. Normally, it is easiest for him to work with materials he can just buy in stores. In contrast to the regular process, the reuse process is more complex process and it requires more energy and time.

Moreover, the architect is acknowledged as a key player. The architectural firm of the case study explains that since they make an important choice for the to-be-used materials, they can be more conscious in those decisions. Furthermore, he explains that they can also convince clients to use a certain material or product. However, he mainly argues those sayings for the recycling of materials rather than for the reuse of components.

To conclude, the architectural firm thinks for harvesting in general it is important that connections between stakeholders are short enough.

Prerequisite policy: Government has to let reused materials concur with new materials in terms of pricing.

6.2.4 Recap of challenges

This subsection presents several challenges that are raised in this section. It concerns challenges regarding process complexity, costs, material quality and requirements and other aspects. When comparing those challenges with the barriers that have been defined for urban symbiosis (subsection 3.4.3, 'Barriers'), similarities can be found. Many of the challenges stated in this subsection comply with the (historical) technological, policy and interest & profit barriers. The institutional barriers named in the urban symbiosis subsection do not seem to play a role here.

Process complexity
In general, the reuse of materials requires extra work, energy and steps. It is all customization, which makes the process very complex.

Costs
The reuse of materials is (still) costly due to:
- Proper extraction and application of the material somewhere else. Dismantling requires extra energy. It is also often the question whether the costs to extract the material weigh out the costs to dispose it. It is currently too costly for most parties to reuse materials as the current way of using and disposing materials is too cheap.
- Transport
- Storage
- Post-processing that might be required
- Designing that costs extra time

Also, the reusability of the material is an important factor as well as the question whether this is financially attractive. This can all differ per building and per material.

Material quality and requirements
- The degraded quality of the material remains a challenge for the implementation. Products that one wants to reuse are often not in line with current requirements for materials and changes in the building decree.
- If contractors and installers are not able to provide warranty for the material (and thus the material does not have guarantee or is not certificated), the material will not be used by them.

Other
- Information needs to be quantifiable.
- People have to be educated due to activities, such as disassembly, that can be very specialised.

PROCESS

6.3 The reuse of building materials in an urban symbiotic system

In some the interviews there has been reflected upon whether the reuse of construction materials can be seen as an urban symbiosis. This section presents the outcomes of this.

6.3.1 The reuse of building materials: a type of urban symbiosis?

"Symbiosis is nothing more than an interaction between actors."

Architectural designer

First of all, the architectural designer states that the core of the symbiosis concept is about the interaction between stakeholders. In the same line of thought, the main contractor states that in the reuse process of construction materials it as about bringing people together and matching supply and demand.

"I don't see it as a symbiosis actually. I have more the idea that it is about energetic circular flows."

Architectural designer

However, the architectural designer does not see the reuse of components as a symbiosis but rather as energetic circular flows. He makes a comparison with a reversed food pyramid. A standard food pyramid starts at the bottom with a large number of small organisms which are in their turn eaten by larger organisms (producers) in the direction towards the top (figure 6.1). When turning this pyramid around, the architectural designers suggests it represents materials used in larger, more complex projects at the top that flow towards smaller projects. Furthermore, he argues that when a flow is not used by an organism, so in this case a project, it will be passed on to a next one. In the end of the process, the flow is reduced to basic resources. This food pyramid way-of- thinking also includes the end of life of an organism, or in this case the end of life of a material, which is not a direct interaction (like symbiosis) in his eyes. He thus thinks the food pyramid is a more logic metaphor to be used here.

In contrast to a reversed version, this process might also work like an actual food pyramid since residual waste streams can also be combined. However, this causes a lot of practical problems and extra work, as stakeholders have to deal with different kinds of materials.

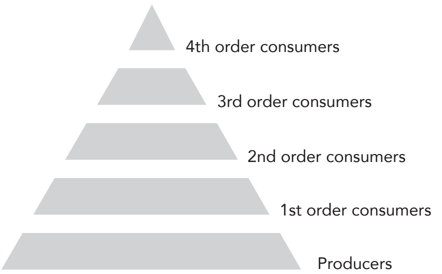


Figure 6.1, example of a food piramid

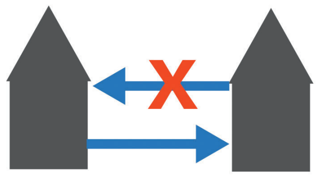


Figure 6.2, visualisation of exchange of resources between two projects; however, the transfer is rather one way.

6.3.2 'Exchange process'

A symbiosis can take place between a variety of building projects, also between a pair of projects. During the interviews, the word 'exchange' was therefore sometimes used.

"I think that exchange one on one is unrealistic and not needed."

Architectural designer

However, resulting from most of the interviews, an exchange between two projects one-on-one is not assumed to be realistic (Architectural designer & Designer); only the architectural firm thinks this type of exchange might happen once in a while. As the current process of reusing of materials is experienced to be already quite complex, an exchange of materials between projects one-on-one would be even harder, especially on large scale (Architectural designer). Furthermore, the architectural designer thinks that, although it would be the most efficient way, there are other efficient transfer processes that can be designed, including short storage periods that might lead to an increase in material choices (Architectural designer). Additionally, the dimension dependency is called as a complicated factor (Designer).

Therefore, it can be concluded that the use of the word 'exchange' is out of place here.

6.4 Design for the establishment of an Urban Symbiosis

In order to develop design criteria for a design that can aid in the development of a potential urban symbiosis of building materials, this section describes results from the interviews that reveal insights in what interface or platform would be appropriate, which process it should adopt and who are its future users. A distinction is made between suggestions for a platform and best-practices of a similar platform, Harvestmap (Harvestmap, n.d.).
Harvestmap is a business-to-business platform that has been developed for the building sector to make an inventory of materials that come out of buildings (Designer). It provides an overview of the materials that are offered as supply by a variety of stakeholders on a map. The service plays an intermediary role; it forms the link between supply and demand (Designer). The designer of the platform explains that in the future the platform can develop an overview of the total supply and demand; however, currently, it is unknown to a large extent who are the suppliers and demanders of to-be-reused materials and where they are located. Aim of the platform is to let every stakeholder in the chain profit while offering a material that is competing on the regular market.

As can be derived from the interview with the architectural designer, Harvestmap is, together with New Horizon, the only larger platform that has the aim to improve the communication between stakeholders in the reuse process (personal communication, March 15, 2019). It is therefore interesting for this study to investigate what interventions they make use of in order to improve this communication.

Prerequisite construction sector: Every stakeholder in the chain should profit.

PROCESS

6.4.1 Process

Three variants

The designer explains that there are three ways in which the process of Harvestmap can take place:

1. The material is scouted by Harvestmap. Consequently, they determine the material's measures and value and offer this as an intermediary party. In this case, they are also actively searching for buyers.
2. The material is offered by its owner. An example is a building owner who is going to demolish the building. This can also be a collector of materials.
3. The material is scouted by an external scout who acts as an intermediary party. In case the scout is a larger company possessing its own platform, this can also be linked to the Harvestmap platform. In this way, the latter is used as a 'front door' which gives insight in the total supply of the market. Users are in this case redirected to other websites where they can buy the material.

Currently, the first type of process in which the platform plays a major role is taking place most frequently (Designer). In the latter two cases, Harvestmap is not involved; the platform only acts here as a mean, or "serving hatch" as the designer calls it, by which the material is passed on to a next user. In terms of outcome, it should not differ a lot which of the three processes is at hand (Designer).

Supply

After the supply has been scouted by one of the stakeholders named above, it will be offered via the Harvestmap platform. The supply is offered partly publicly and partly privately (Designer). The private part is behind an account. In this way, individual companies or groups of stakeholders can make use of the platform, without sharing their supply with the rest of the platform's users. When certain supply streams are not used within the company, those can be made available for the public part of the platform.

In terms of timing, the platform requires a minimum period of a few weeks between indication and extraction of materials (Designer). The clearer the moment is that a material will become available, the larger the chance that a successful match will be made (Designer). One of the challenges that Harvestmap experiences is keeping the platform's offer up to date. The designer thinks it is hard to remove supply from the platform that cannot be offered any more; only when the initial owner indicates an expiry period, this can be properly regulated. And as a platform, they do not want to adopt an authoritarian role here.

As regards the amounts of supply, the designer points out that it is not realistic that a whole building will be offered by the platform; next to the fact that a building's offer is simply too large, building owners think it is too much work to put all single elements on the platform.

"What I am afraid of is that an enormous fragmentation in supply is going to arise. And I hope that it is possible to link all this kind of parties via one front door"

Designer

Furthermore, an important statement is made about a major consequence of the growing interest in the reuse of materials for supply. Since the term 'harvesting' has gained more attention, the designer is afraid that supply will become fragmented. A decrease in effectiveness of reuse is lurking if different parties are not connected via one 'front door' (Designer).

Design criterion: Give insight in materials that will come out of the building as soon as possible (at the moment it is clear a building will be renovated/ demolished) so supply and demand can be matched as soon as possible *(criteria B2).*
Design criterion: Present supply from all building projects in Amsterdam to prevent fragmentation *(criterion B1).*

Demand
Regarding the course of the process, the main contractor thinks it often starts with a question or a demand. When the designer was asked in the interview about a demand function on the platform, he indicates that some risks come along when implementing this. It was decided by Harvestmap not to include a demand function since requests might be fugitive; someone can easily post a request yet might forget about it soon (Designer).

Whereas the demand function is thus seen as a useful function in the work field, its realisation and processing into a platform function seems to be challenging and, above all, can be questioned.

Conversations & agreements
Communication between the supplying and demanding parties on the Harvestmap platform can be directly or indirectly (Designer). In case of direct communication, the suppling and demanding party are in direct contact with each other. In case of indirect communication, Harvestmap acts as an intermediary (Designer). Although an extra link is needed here, the advantage is that there is only one contact person (Designer).

In terms of agreements that are made between the suppling and demanding party, the designer explains that an invoice and quotation are often sufficient. Furthermore, if guarantees and certificates for the extracted material are available those can be transferred (Designer); however, based on results mentioned in subsection 6.2.2 this only happens rarely.

Design criterion: For the purchase agreement, an invoice and quotation should be made. If certificates and guarantees for the material are available, these can also be attached *(criteria B6).*

6.4.2 Interface

Data
Based on the interview data, important material characteristics are identified that are of relevance to be presented on the platform. Among those are dimensions and quality

DESIGN

(Architectural firm; Main contractor). The former is identified as the most important one; the latter is hard to be determined (Designer). Moreover, age, time and availability are defined as key information to be known (Architectural firm). Also, the type of material is acknowledged to be of relevance (Main contractor). In general, one can say that the more information is known, the better (Designer). However, the more detailed information is required, the harder it becomes to name all those required characteristics for materials (Designer).
The designer can imagine that the information that is of influence on the material choice is presented publicly, while other information, such as contact information, is kept private.

In order to enable a user to make its ways though the large amount of supply offered, it is advised to structure materials according to their data by applying a classification structure e.g. according to materials' qualities (Project manager).

Design criterion: Provide a set of standard information of each material publicly; information on how to get the material should be private *(criteria A2).*
Design criterion: Provide at least the following information for each material: dimensions, age, moment of availability, quality, type of material, amount *(criterion A3).*

Map function
Harvestmap makes use of a map function. Whereas usually the price is decisive, the visualisation of the location makes people aware of the local supply and makes them start looking for local materials according to the designer. In this way, materials are moved as little as possible, which reduces the amount of transport (Designer). Nevertheless, the factors of time and price are seen as more important than the location (Designer).

Design criterion: Introduce a map function to make people aware of local materials *(criteria A4).*

Connection to other systems
Looking from a wider perspective, a connection between Harvestmap and other systems in the future is conceivable. Based on current developments such as the ones Madaster and BIM are going through, the designer can imagine that there will become a direct link between Harvestmap and BIM. As by BIM one can look into the future supply of materials, the connection between the two systems will make it possible to adapt future building projects to this supply (Designer).

Design criterion: Offer the possibility to connect directly to BIM / Madaster *(criteria B3).*

6.4.3 Users

Harvestmap has a wide variety of users. A distinction can be made between supplying and demanding stakeholders. An example of a supplying company are demolition companies who know exactly which materials are coming out of buildings (Designer). Another example are large institutional parties who work on a great amount of rebuilding cases (Designer).

STAKE-HOLDERS

In terms of demand, requests are most often coming from architects and designers (Designer). Examples are the architectural firm Superuse Studios, which is linked to the platform, as well as other building projects who work with the platform. When the material has been chosen, it is the main contractor or another building party who buys the materials via the platform (Designer).

Another type of user are externals scouts (Designer). They can make an inventory of materials that are interesting for reuse in a building that will be demolished at short notice. In the meantime, before demolition, the scout can try to sell the materials by use of the platform. When sold, those can be taken out properly. Also building owners are named as users of the platform (Designer).

6.4.4 Scale

When discussing upon the scale at which to-be-reused materials can be transferred and at which an assisting design can be applied, both arguments can be given for the reuse at small and large scale.

The project manager expects that the application of an assisting tool would become harder if the scale becomes bigger. For example, he thinks the scale at which De Alliantie is working (100-500 houses per project) is too large. Furthermore, it has to be noted that there is not an infinite flow of high quality to-be-reused supply and therefore the architectural designer states that a tool or design is not endlessly scalable.

On the other hand, the architectural designer argues that when for example small projects are demolished, the supply streams become very specific. In contrast, larger projects offer supply with a greater similarity in material characteristics and are therefore more suitable (Architectural designer). According to the architectural designer the tools, such as Harvestmap and New Horizon, are there, however the supply of materials is not yet large enough to let them become regularly used solutions.

Lastly, cities are identified as being important for the reuse of materials, due to its local character which offers the potential to reduce traffic flows (Designer).

7

INTERIM REFLECTION: DERIVING DESIGN CRITERIA

According the 'Research through design' approach that is adopted in this study (see chapter 2, 'Methodology'), the interviews are followed by the creation of design criteria, and so an interim interpretation of results, before those criteria are evaluated in a focus group. This chapter is the interim interpretation of the results of the interviews and sets up those design criteria for the platform (section 7.2). Also some prerequisites (e.g. for the construction sector) have been be derived from the interviews.

However, before those criteria could be created, an outline of the general construction material reuse process has to be sketched, which forms the actual context in which the platform will be used. The latter will therefore be addressed first (section 7.1).

PROCESS

7.1 Course of the reuse process

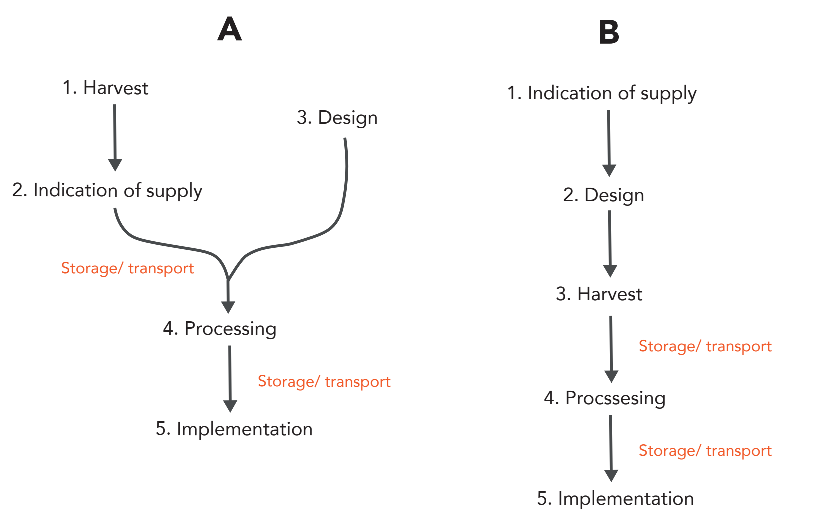


Figure 7.1a-b, the two reuse processes of construction materials

Mainly based on the outcomes of the interview with the architectural designer, four phases of the reuse process of building materials were defined: harvest, design, processing and implementation ('Process', 6.2.1). Besides those four, two side activities were defined, being storage and transport. Though, when reflecting on the platform's process described by the designer, one important step seems to be missing among the four earlier defined phases: the scouting and subsequently indication of supply ('Process', 6.4.1) This hence seems to be a fifth phase in the reuse process.

When putting those five phases in order, two different types of processes seems to be definable. It is the moment of harvest in comparison to the moment of supply indication that causes the main difference between the two. Based on the results described for the Harvest phase, a distinction can be made between materials that are already harvested at the moment of indication (A) and materials that are not yet harvested yet will be taken out of a building in the (near) future and are potentially assigned a reuse strategy already (B). In case of process A, the harvesting first takes place after which supply is indicated for sale (figure 7.1a). The design of the new application runs parallel. For process B goes that the supply is indicated before the materials are harvested (figure 7.1b). In this particular case, the design is based on the offered supply and therefore is made after the indication step.

Reflecting on the occurrence of those two processes in current times, it might be suggested that process A is taking place more often, whereas process B is rather future oriented. This assumption is based on the fact that, in the light of process A, the architectural designer says one is currently cleaning up leftovers, but that in the future, with respect to process B, one has to start looking for the reallocation of materials that will become available in the future. The latter is supported by the designer who thinks that by connecting for example their platform Harvestmap to the software of BIM future supply can be indicated and subsequently prospective projects can be adapted to this.

Since in both processes the storage and transport activities take place before and after the processing of the component, those are included in the processing phase for the further course of the study.

DESIGN

PROCESS

7.2 Design criteria & prerequisites

Design criteria for a platform can mainly derived from general mentions during the interviews yet also from answers to specific questions about this topic (7.2.1). Furthermore, based on current challenges that came forward out of the interviews, several prerequisites are derived that need to be realised in order for the platform to live up to its full potential (7.2.2).

7.2.1 Design criteria for platform

This subsection presents the derived design criteria for a platform. Those criteria are presented per phase of the reuse process. Furthermore, each of the criteria is categorised according to the following categories: data (D), process-related (P), supply & demand (S&D), agreements (A) and optional criteria (O).

Phase 1: Indication of supply

A1. Make use of standards in the data (D).
A2. Provide a set of standard information of each material publicly; information on how to get the material should be private (D).
A3. Provide at least the following information for each material: dimensions, age, moment of availability, quality, type of material, amount (D).
A4. Introduce a map function to make people aware of local materials (D).
A5. Make use of a classification for products (D).
A6. Focus on repetition. Require a minimal amount of material that needs to be offered. In this way, types of products are limited which makes it easier to process them (S&D).

Phase 2: Design

B1. Present supply from all building projects in Amsterdam to prevent fragmentation (S&D).
B2. Give insight in materials that will come out of the building as soon as possible (at the moment it is clear a building will be renovated/ demolished) so supply and demand can be matched as soon as possible (S&D).
B3. Offer the possibility to connect directly to BIM / Madaster (O).
B4. Focus on repetition. Require a minimal amount of material that needs to be taken off. In this way, types of products are limited which makes it easier to process them (S&D).
B5. Give insight in processing possibilities to make from the extracted product the desired product. Make it also possible to make connections with those processing parties (P).
B6. For the purchase agreement, an invoice and quotation should be made. If certificates and guarantees for the material are available, these can also be attached (A).

Phase 4: Processing

C1. Include transport possibilities. Make it also possible to make connections with those transport companies (P).
C2. Include storage possibilities. Make it also possible to make connections with those storage parties (P).

7.2.2 Prerequisites

A group of prerequisites can be derived based on current challenges in the reuse process. In order for a platform to work properly, those preconditions have to be realised first. Prerequisites for the reuse process, the construction sector and society can be defined.

Prerequisites for the reuse process

- Every stakeholder in the chain should profit.
- Link supply and demand as soon and directly as possible.

Prerequisites for the construction sector

Data

- Openness about a material's information
- Standardisation step within the building sector to make a specific set of information available for each material.

Material quality and requirements

- Another guarantee structure for to-be-reused materials should be developed in order to ease and increase the reuse of components.
- When possible (depending on the application), requirements for the use of a specific materials should be made more flexible in order to reuse a larger number of materials, differing in characteristics, instead of applying new 'raw' materials.
- Following the previous prerequisite, stakeholders should start reusing a variety of batches of outcoming components for a single application in a new building. In this way, smaller batches of components can be processed.

Material characteristics

- For the reuse of the material it is favourable if the initial material is modular

Policy

- Government has to let reused materials concur with new materials in terms of pricing.

Prerequisites for society

Attitude

- Change in attitude towards reused materials.

8

RESULTS III: EVALUATION

As can be read in the methodology chapter (paragraph 2.3.2, 'Qualitative analyses'), two goals had been formulated for the focus group:
1. *Co-creating a communication structure between stakeholders (based on research sub question 3)*
2. *Evaluating the design criteria which came forward out of the interviews and applying those for a platform (based on main research question)*

The focus group consisted of a short discussion on a platform for De Alliantie as housing corporation as well as of a more in-depth discussion on a potential platform for the city of Amsterdam (subsection 2.3.2 'Qualitative analyses', paragraph 'Focus group'). For the latter case, there has been made use of a scenario (about the reuse of two hundred doors, see appendix D) which went through all phases of the reuse process. For each phase, the participants could indicate specific tasks for the platform as well as stakeholders that might be involved as potential users.

In this section, a distinction is made between the evaluation results addressing the platform's scale and implications for the reuse process and materials on the one hand (section 8.1) and an evaluation of the platform itself and the design criteria that were formulated in chapter 7 on the other (section 8.2).

8.1 Evaluation of scale, process and materials

This section particularly reports the results of the reflection on the scale of the platform. Furthermore, also general thoughts were shared by the participants on the reuse process and the to-be-reused materials, which are reported later on in this section.

8.1.1 Scale

As the focus group started with the discussion on the establishment of a platform for De Alliantie as a corporation, the participants were asked to reflect on this particular scale of the application.

Concluding from the results, two perspectives are weighted here. The CE manager on the one hand imagines that De Alliantie does not need other parties as the corporation has very large streams of materials and thus a large volume themselves. He thinks that this supply might be large enough to draw off materials for reuse. Though, this opinion is not shared by all of the participants. The architect stresses that one will not find materials for e.g. this case study's 112 houses within the group of more than 1000 houses that are renovated by the corporation a year. Additionally, he mentions that the designer's choice for materials is restricted in this case.

The other perspective, as also mentioned by the CE manager, reflects that cooperation with other national and regional parties or colleague corporations might be better instead of the establishment of their own platform. Nevertheless, such a cooperation platform is identified as being very complex (Project manager (F)).

Weighing those perspectives among the participants, it can be concluded that especially the CE strategic consultant and the architect have the feeling that the platform needs to be applied at a larger scale than corporation level.

It furthermore resulted that the type of the to-be-reused components matters for the scale on which those are passed on; for some components a larger scale would be more appropriate whereas for others a smaller scale would satisfy. Citing the architect, **"the more complex the components are, the larger the scale should be to put it well in place".** Additionally, the construction sector's high degree of customisation in comparison to for example the car industry is seen as a complicating factor here (Project coordinator). This namely causes that very specific and customised components are required; however, those are harder to be found within the supply of to-be-reused materials and this subsequently might have an influence on the scale one has to search for those components. Only for a particular group of components, like boilers, toilets bowls and washbasins, this does not hold true (Project coordinator). Furthermore, it is stressed that a sufficient amount of choice in components has to be guaranteed (Architect).

It is therefore suggested to evaluate components on a component level in order to make a difference between components that can be passed on internally (in a company or corporation), such as the more generic ones, and components for which the larger scale is needed (CE manager). For the former goes that the risk of missing out the material at the moment of application in the construction process is smaller (CE manager).

Subsequently, a few consequences were derived which occur when the platform is scaled up. A larger scale would first of all result in a quicker lead time on the platform (CE strategic consultant). Moreover, by scaling up the amount of supply that is offered, the number of choices is increased (Architect). On the other hand, the CE manager mentions that the larger scale, the more bureaucratic the process will become. When the scale stays small, e.g. when materials are passed on internally, the material remains property of the same party. Property rights become more complex if the scale is enlarged and a system is established in which components are passed on to other companies.

During the second half of the focus group, the discussion focussed on the platform for Amsterdam (figure 8.1), for which the scenario of the two projects in Amsterdam was input for the debate. In this discussion, it had been stressed that one cannot think in connecting flows between those two projects (Architect). According to the architect this causes many obstacles and since projects take years it is not possible to align those exactly; the time path is very fragile. Therefore, the group sees the buffering of the materials at a storage location as inevitable. Although a depot for monumental materials has recently been closed due to financial reasons, the CE manager thinks that the municipality of Amsterdam might be open to set up such a storage location.

The challenge of timing was also mentioned in the discussion on the platform for the corporation. There is a time difference between building projects and those also have to deal with overrun (CE strategic consultant). Therefore, storage is required, which consequently increases the costs (CE strategic consultant).

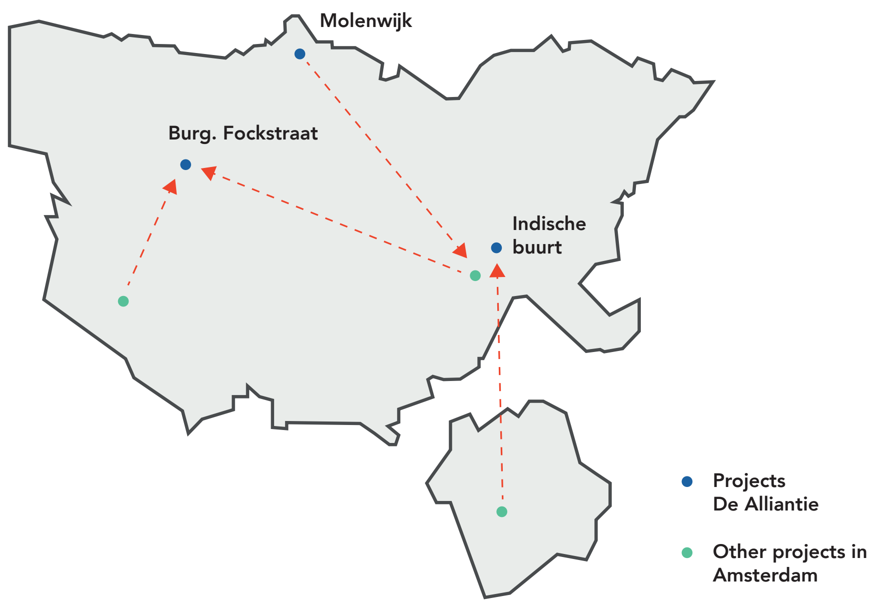


Figure 8.1, example of an urban symbiosis for construction materials in Amsterdam (related to the scenario that was discussed during the focus group).

"You see now that everybody is making their own system, ..., but you should actually do this nationally or so."

CE manager

MATERIALS

PROCESS

An overarching platform

Looking specifically at the platform application, it was mentioned that several parties are currently developing their own systems (CE manager). The CE manager argues that one platform should be established which covers it all and hence connects all parties. An example is given of a demolition company which developed a platform for reuse and subsequently asked several housing corporations and developers to join (CE strategic consultant).

8.1.2 Reuse process & materials

During the discussion, also thoughts were mentioned regarding the reuse process and to-be-reused materials in general. Those can be categorised according to the following topics: design, transport & storage, components and pricing.

Design (phase 2)

It is mentioned by the project coordinator that, while designing, the designer does not know what to-be-reused materials will be available at that time that the construction is being built. In case he bases his design on the materials that are available at that moment, materials need to be stored for a long period. In this way, the designer is taking an option on the material (CE manager).

Furthermore, the way in which a to-be-reused material is purchased differs from the conventional purchasing manners. In a usual design process the contractor is not on board yet during the design phase (Architect). Since it is the contractor who decides where the materials will be bought in the end (as has also been described in the paragraph "the choice of materials" in section 5.2.1), the exact component and the firm it will be bought at is therefore unknown to the architect at the moment he is finishing his design (Architect). However, in case of the reuse process in which the architect opts for a to-be-reused material early in the process, this material needs to be determined already very early and the material has to be earmarked (Architect). This is seen as a complicated factor. A large volume is needed and the certainty has to be offered that one will find the components (in this case doors) with the right quality in e.g. two years (Architect). Regarding the changing roles of the architect and contractor in terms of purchasing materials, the main contractor (F) suggests that a requirement for the procurement of a contractor can be set up; when making an offer as a future contractor, this party has to agree on buying the specific doors that have been chosen by the architect already.

Transport & storage (part of Processing phase)

As has been reported in the section about scale (8.1), participants think that the storage of components in the transfer of components to another building is inevitable. However, it also results from the discussion that one has to make sure storage is limited as much as possible. Storage is expensive, but it has also negative effects on the environment due to transport as well as on the material itself (CE manager). The CE manager therefore points out that when one is able to solve the component storage problem in the right way, a potential revenue model will be born. A requirement here is the large volume, i.e. a certain number of components, that is needed for this (CE manager).

Components

As it turns out, the reuse of materials might also imply that other materials have to be added to compensate the degraded performance of the reused material (e.g. in case of insulation) (Project manager (F)). Because of the application of those extra materials, one can question whether in the end the reuse of a material is rewarding in terms of financial perspective (Project manager (F)). The reuse of materials can also influence the choice of materials in others parts of the building. To illustrate this, the project manager (F) gives the example of a set of tubes for which partly other materials had to be used because of the reuse of some boilers that stated other requirements for those tubes than the group of brand-new boilers that were installed.

Pricing
Nowadays, you see that companies offer reused materials for the same price as similar 'new' materials as they suggest those have a similar quality. However, this is found strange by the CE manager; he thinks reused materials should actually be cheaper. The main contractor (F) and project coordinator agree on this.

Furthermore, based on an example given by the CE strategic consultant, a demolition company can make special arrangements for corporations who deliver materials and want to buy those back by only requesting money for the processing and storage costs of the material.

Finally, it was stressed by the main contractor (F) that the reuse of elements is rather out of environmental ambitions than out of economic ones. This might change if it would happen more often (Main contractor (F)).

8.2 Evaluation of platform

This section reports the results of the evaluation of a platform and the design criteria that had been formulated for such a platform in chapter 7. Input for the discussion was the scenario about the platform for Amsterdam as a city (appendix D). The first part of this section reports the envisioned general tasks and characteristics of the platform per phase in the reuse process as well as the stakeholders who might be users of the platform according to the participants; the second part reports the evaluation of the platform's design criteria.

8.2.1 Platform & users

PROCESS

STAKE-HOLDERS

DESIGN

Phase 1: Indication of supply
Overall, the system needs to give insight in what is extracted somewhere and where else this can be applied (CE manager). It has to offer total transparency, something which is currently missing (CE manager). Examples of overarching platforms from other sectors are given, like from the tourism sector, which offer this kind of transparency directly (CE manager). This should also be realised for the construction reuse platforms (CE manager). Furthermore, the platform needs to make a distinction between generic and specific components (CE manager).

In the light of the difference between generic and specific components that are offered, the project coordinator advises to also build in a risk indicator to report the likeliness of the availability of the material at the moment that it is needed. For some components (e.g. very specific ones) the risk of unavailability might namely be larger than for other materials (Project coordinator).

Additionally, the CE strategic consultant thinks that the platform, next to its indication function, can offer another function. In order to ease the sale of components he thinks the platform can deliver a function which upgrades components' qualities (in this case the two hundred doors). In this way, also the information about the components will become clearer (CE strategic consultant). The platform needs to get a task on itself (CE strategic consultant).

The demolisher is indicated as a stakeholder who plays a role when the two hundred doors are offered (CE manager). Furthermore, a third party is identified who should organise this process logistically (Project manager (F)). The CE manager additionally mentions an interface. A building owner was suggested as a potential user by the researcher, however none of the participants commented on this.

Data
Data is seen as a valuable mean that has not been used to its full potential in the building sector yet (CE manager). It is believed that data could be of help in the complex process as it can make it more efficient (CE manager). However, also some challenges have been addressed. Proper data capture of buildings has been done since recent times (Architect). In this light, data is only captured (e.g. by BIM) for buildings that have recently been dealt with (e.g. new construction or renovation) (Architect & Project coordinator). Furthermore, data can only be used if the data is well-captured at its origin, like in new construction project (Architect). In the light of renovation projects, an important statement about reality data versus virtual data is made. According to the architect, none of the components is the same. He stresses that there is too much uncertainty in the digitization of those renovation projects and it is also an illusion that data can be captured precisely; this might only be the case if components are disassembled and one can really see the component. Therefore, reality is often still more important to them than virtual models they are making of those existing buildings. For new construction, the architect advises to capture everything from now on. It will take another few decennia (40 years) before most of the building data will be available (Architect).

Phase 2: Design
The supply on the platform and the design process seem to be closely related. The CE manager explains that two options can be at hand. One option is that the supply is mapped after which a new design is made, customised to the offered materials or components (CE manager). In this way, the regular design process is turned around (CE manager). This type of process is identified as very specific. A second option is that rather generic components are offered by the platform, like locks and toilet bowls (CE manager). When the platform offers very specific materials, it seems to be true that the conventional design process needs to be turned around, whereas when the platform offers more generic materials, this does not have to be the case.

Looking at the stakeholders who might make use of the platform in this phase, the main contractor (F) agrees on the architect as a party looking around for materials on the platform. Furthermore, the main contractor (F) is the party who buys materials and hence also plays a role in this phase (Project coordinator). Finally, it is suggested that also actors from the private individuals' market could look around on the platform (Main contractor (F)). It is namely assumed that this particular market acts differently from the business-oriented market and is easier on this (Project manager (F)). The CE manager and the main contractor even think they could also offer materials on the platform.

Phase 3: Harvest
Demolishers and disassembly companies are identified as the companies who harvest materials (Main contractor (F)). Those parties thus might become users of the platform in this phase of the process.

"Circular Economy is also about process innovation and organising parties differently, in this story you could also ask the question whether you need a demolisher."
CE manager

During the discussion, the participants also shed a light on the future role of this party. Because of the circular economy, processes will be innovated and parties will be reorganised (CE manager). When the current construction process will be organised differently, the role the demolition party can be questioned in this new process (CE manager). The project coordinator thinks that one cannot do without a demolisher completely. Furthermore, he stresses that disassembly is characterised as being very specialised work. This is supported by the CE manager and the main contractor (F). The latter namely also explains that demolition companies often work differently in comparison to for example installers of components who sometimes go into the building before the demolition company starts and carefully take out their components first.

The CE strategic consultant and the project manager (F) think demolition parties might become disassembling parties in the future. However, the CE manager explains that disassembly is often labour only. Normally, demolition companies make a living by the materials they extract (CE manager). They actually earn twice; when they dispose materials and when sell those again. When they only have to perform the disassembly activities, and so the labour, their revenue model is taken away (CE manager). When their business is taken away, they start to practice protectionism (CE manager).

Phase 4: Processing
For this phase, only the storage and transport activities have been discussed. The CE manager thinks transparency on the platform has to lead to a limited amount of storage and transport which will help in the transition towards the desired revenue model.

The participants of the focus group indicate that it is the demolition company who transports materials from the construction site (currently being waste materials that are transported to other companies). Therefore, this party might become a user in this phase.

Phase 5: Implementation
Since the study focusses on the reuse process towards the implementation of the new components, no statements on the implementation phase were made during the focus group discussion.

Recap: Overview of users
Figure 8.2 gives an overview of the above-named stakeholders as potential users of the platform. Those are structured according to different phases along the reuse process line created in section 7.2.

In the figure can be seen that among others the demolition company is a frequently involved party in several phases of the process and might be seen as an important future user of the platform. Furthermore, the architect and the main contractor are indicated as important stakeholders and might become potential users, especially in the design phase of the process.

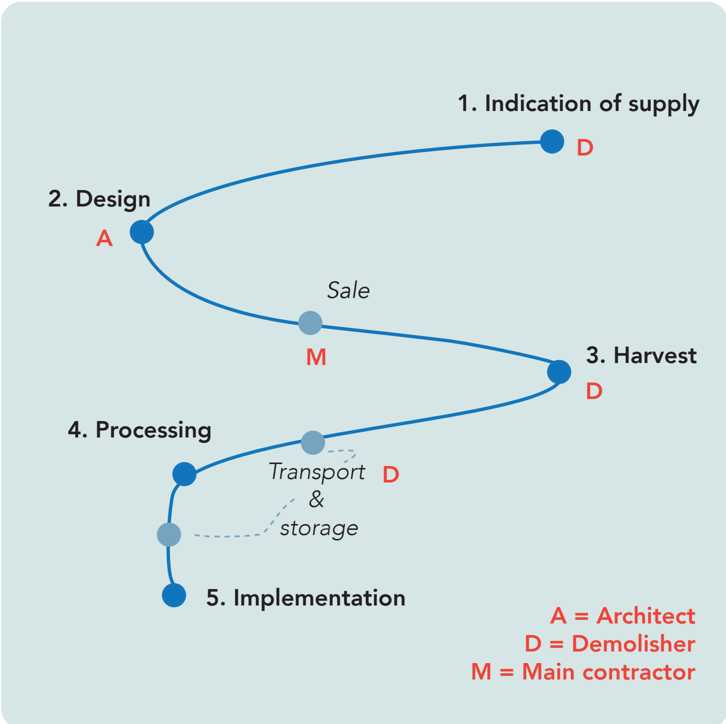


Figure 8.2, overview of the stakeholders who are involved in the several phases of the reuse process

PROCESS

DESIGN

8.2.2 Design criteria
The design criteria for a platform that have been set up in chapter 7 have been evaluated during the focus group. Since those criteria have been assigned to a specific phase in the reuse process before (see section 7.1.1), this section will follow that structure.

Phase 1: Indication of supply
Table 8.1 shows the evaluation results of the platform's design criteria set up for the supply indication phase in the process. As can be observed, this set of criteria is mainly received positively. Especially the first three criteria as well as the fifth one got lots of agreement.

Looking at criterion A1, it is assumed that by underlining the word 'standards' the CE manager thinks the standards that are used for the data are important. The same goes for the word 'publicly' under criterion A2 that might imply that public availability of standard information is thought to be important by the CE manager. He also mentions Madaster here. In the discussion, he stressed that the platform has to be aligned with the

Criteria	Architect	Project coordinator	Main contractor	Project manager	Manager CE	Strategic consultant CE
A1. Make use of standards in the data					*('standards' underlined)*	
A2. Provide a set of standard information of each material publicly; information in how to get the material should be private.					Madaster *('publicly' underlined)*	
A3. Provide at least the following information for each material: dimensions, age, moment of availability, quality, type of material, amount.	Quality test, make transparent				As least as possible	Keep it simple > offer a number of doors with their dimensions *('age', 'moment of availability' and 'quality' are crossed out)*
A4. Introduce a map function to make people aware of local materials.		Is a next step, ideal situation	Goes via depot in-between		Yes	
A5. Make use of classification for products.		Make use of existing classifications	Apply the new BIM classification		BIM *('classification' underlined)*	
A6. Focus on repetition. Require a minimal number of similar products that can be supplied. In this way, types of products are limited which makes it easier to process them.		You will continue to have major differences anyway				
General notes						

Table 8.1 evaluation of design criteria platform for supply indication phase

Agree *Disagree* *Unknown*

developments of Madaster instead of developing its own system.

In case of criterion A3, two participants indicate that the information available for each material should be kept simple and limited (CE manager & CE strategic consultant); the CE manager for example crossed out the 'age', 'moment of availability and 'quality'. Furthermore, the architect stresses the importance of transparency of the information and also suggests a quality test.

For criterion A4 about the map function a clear distinction can be made between the opinions of three case study participants (architect, project coordinator and main contractor (F)) and the CE manager; the former say not to agree on the criterion or indicate that this is rather a next step whereas the CE manager thinks this is important since it meets the circular principles by keeping the circle as small as possible as was stressed verbally during the focus group. Additionally, it is mentioned by the main contractor (F) that materials go via a depot in-between.

The classification criterion (A5) was received positively by everyone (it is assumed the CE manager agrees as he underlined 'classification' and made suggestions). An important suggestion that was made is that it would be of use if the platform is in line with existing classifications, like the BIM classification.

Criterion A6 was received positively by the major part of the participants; only the project coordinator disagrees. Despite the fact a minimal number of similar products is required by the platform, he argues that major differences in the supply of components

remain to exist. The opinion of the CE manager is unknown here. Additionally, the CE manager strikes that the 'amount' of interface should be as little as possible. Furthermore, he thinks the platform has to be connected to existing systems and it has to be prevented that other systems are standing in between.

Criteria	Architect	Project coordinator	Main contractor	Project manager	Manager CE	Strategic consultant CE
B1. Present supply from all building projects in Amsterdam to prevent fragmentation.	System	Central	*('all' underlined)*			
B2. Give insight in materials that will come out of the building as soon as possible (at the moment it is clear a building will be renovated/ demolished) so supply and demand can be matched as soon as possible.	Time is a problem, stock gives time space	Make it central, factor of time is a problem				
B3. Offer the possibility to connect directly to BIM / Madaster.					V *('Madaster' underlined)*	
B4. Focus on repetition. Require a minimal amount of material that needs to be taken off. In this way, types of products are limited which makes it easier to process them.	Demand + supply…					Rather a minimum number
B5. Give insight in processing possibilities to make from the extracted product the desired product. Make it also possible to make connections with those processing parties.		Complex…	Hard to determine			
B6. For the purchase agreement, an invoice and quotation should be made. If certificates and guarantees for the material are available, these can also be attached.		Certification/ guarantee will be excluded from original delivery			Gladly	
General notes					Transparency	

Table 8.2, evaluation of design criteria platform for the design phase

Agree *Disagree* *Unknown*

Phase 2: Design

In table 8.2, the evaluation results of the criteria for the design phase are presented. Evaluating the first criterion on the presentation of the total supply of Amsterdam (B1), a major agreement can be observed. The architect and the project coordinator mention the key words 'system' and 'central', which support the collective approach of the criterion. However, the main contractor (F) does not agree on the criterion; he underlined 'all' which is assumed to reflect that he thinks it is not possible or relevant to show all supply of the city.

Also on the second criterion, which states that the platform should early give insight in available materials to match demand and supply as soon as possible (B2), a major agreement can be noticed. The project coordinator adds that the platform should make it central, but that the time factor can be a problem. This is also mentioned by the architect who therefore does not agree on the criterion. The latter two comments hence stress that timing can be seen a complicating factor in the general reuse process instead of just for the platform.

Criterion A3 is received positively. At least five out of the six participants think the connection with other systems like BIM and Madaster can be of value. The CE manager underlined Madaster which is assumed to be done to emphasise it.

On the contrary, the fourth criterion on the minimal amount of materials that need to be taken off (B4) was received less positively. Only the main contractor (F) and the project manager (F) agree here. The other four participants do not think this design criterion for the platform is appropriate. The CE strategic consultant thinks that rather a minimum number of materials needs to be taken off here instead of a minimal amount. This participant also stresses that there is a risk that a batch of certain size is bought according to this criterion, but subsequently part of it will be thrown away by the buyer since he does not need all components. Moreover, the CE manager thinks this criterion makes it unnecessarily more complicated and is therefore not needed, however that there might be a role for big data here.

In the light of the fifth criterion (B5), half of the participants thinks that when the platform gives insight in components' processing possibilities this might be of value; the other half disagrees on this. Although the project coordinator agrees on the criterion, he thinks this is complex. The main contractor (F) seems to support this mentioning by stating that such processing possibilities are hard to determine; he therefore disagrees with the criterion. Furthermore, the main contractor (F) mentions that it is the task of the designer to see what can be done with the component and this is therefore not a task the platform has to perform. The platform might even limit the designer in his work (Main contractor (F)). The CE manager agrees on this.

Finally, on criterion A6, that addresses the agreements that need to be made between the supplier and buyer, the major part agrees that an invoice and quotation should be made and that certificates and guarantees can be provided when those are available. The remark of the project coordinator is assumed to imply that certificates and guarantees are only given by the original supplier and therefore it is not possible to provide certification for to-be-reused materials. This might also explain why he partly agrees and partly disagrees. Also, the CE strategic consultant disagrees on this criterion.

During the evaluation of the criteria for the design phase it was mentioned by the project manager (F) that, in an ideal world, one can actually only but agree on all the criteria on paper, however that we do not live in such an ideal world. From this statement can be derived that he thinks the design criteria that are stated are valuable, however that one has to look carefully whether and how they are applicable in current conditions.
Furthermore, a general note on transparency was made by the CE manager which is assumed to express the importance of transparency on the platform.

Criteria	Architect	Project coordinator	Main contractor	Project manager	Manager CE	Strategic consultant CE
C1. Include transport possibilities. Make it also possible to make connections with those transport companies.					As little transport as possible	Leave this to the platform
C2. Include storage possibilities. Make it also possible to make connections with those storage parties.	Central + scale increase				Prevent storage	Leave this to the platform
General notes					Electric, boat, bike	

Table 8.3, evaluation of design criteria platform for processing phase

Agree *Disagree* *Unknown*

Phase 4: Processing

Table 8.3 presents the evaluation of the criteria set up for the processing phase. Those address the transport and storage of components. The first criterion (C1) is about the transport and states that the platform should include all transport possibilities and it should enable users to connect with those parties. Half of the participants agrees on this criterion whereas the other half does not. The argumentation of the CE manager who disagrees is mainly based on the fact that transport should be kept limited in the reuse process in general (CE manager). Based on the table X, the note that was made by the CE strategic consultant seems to be in contrast with his disagreement; he namely thinks that the platform can indeed play a role in arranging transport.

In terms of criterion C2, which stresses the storage of components, four of the six participants agree that the platform has to give in sight in storage possibilities and that users can make connections with those parties via the platform. The CE manager and the CE strategic consultant do not agree. Similar to criterion C1, the note that was made by the CE manager rather strikes the reuse process in general as it says that storage should be prevented. The note by the CE strategic consultant seems to be in contrast again with his disagreement on the criterion for the same reason as had been mentioned under criterion C1.

General key words that were written down by the CE manager are 'electric', 'boat' and 'bike'. Those are assumed to relate to transport possibilities mentioned under criterion C.

8.3 Summary of findings

From the discussion on the scale at which a symbiosis can best be established can be concluded that this highly dependent on the type of component one wants to transfer; complex components require a larger scale to be effectively transferred whether the more standardized components offer potential to be transferred at a more local scale. Factors such as lead time, amount of choice and level of bureaucracy will be influenced by the scale at which materials are transferred. Secondly, it is important that one universal platform is established to prevent fragmentation. Furthermore, several stakeholders are named who might make use of the platform in each particular phase. The demolisher is expected to be the most important user. Additionally, such a platform might be of use for a main contractor and architect. A third party was thought to be a good organiser who could manage this process logistically. With respect to the reuse process, timing remains a problem; storage therefore seems to be an inevitable step.

When evaluating the design criteria for the platform that have been formulated in chapter 7, uniformity in data appears to be crucial to let it be compatible with existing classifications, standards and other systems, like BIM. Furthermore, the data has to be kept transparent and simple. The criteria on repetition requirements are not evaluated very positively. Finally, because of the futuristic character of the criteria, one has to reflect upon whether and how those design criteria are applicable in current conditions.

9

DISCUSSION

In this section the study's findings are discussed within a wider scope, both in terms of literature as well as the construction sector. Section 9.1 does this by linking the study's results to existing literature. In section 9.2, the study's methodology will be evaluated. Lastly, in section 9.3, the urban symbiosis' stakeholder network for construction materials is established after which it is connected to a design of a platform in order to define how communications in the network can be facilitated. The interactions taking place between the network and the platform are presented in a framework.

9.1 Reflection on findings in relation to existing literature

This section discusses the findings of this study in relation to existing literature on the topic. First, the assumption that is adopted in this study states that the urban symbiosis approach is applicable to construction materials. Based on the results, arguments can be given that imply the validation of this assumption whereas other argue why the assumption can be rejected.

One of the arguments that supports a successful application of urban symbiosis to construction materials is the fact that extracted materials can be transferred to other building projects where they can be reused. This is one of the principles of the urban symbiosis concept. Furthermore, during the symbiosis' implementation, a varied group of stakeholders, buildings, infrastructures and functions are involved (Lenhart et al., 2015). Regarding the stakeholders, this does not only include actors from the private sector, such as the construction firms, but it also concerns public actors such as governmental organisations. The involvement of the social system is another characteristic of urban symbiosis that is named in research (Lenhart et al., 2015). Moreover, in the same line of thought as the urban symbiosis' aim, two existing, initially separated, system are connected (Mulder, 2016b): the construction (or supply) system and the waste system. Additionally, materials will be exchanged between a variety of buildings, which can be seen as different species due to the high level of customization in the sector. Finally, in terms of geographic proximity, which is mentioned as an important symbiotic characteristic (Chertow, 2000, 2007), buildings lend themselves perfectly for a symbiotic system due to their large numbers in a relatively small area, resulting in a great number of opportunities.

However, arguments can be given that might imply the rejection of the hypothesis and particularly stress the duration as well as the type of flows that are transferred. As stressed by O'brien, Fischer and Jucker (1995), the building industry is known for its constantly changing coalitions of stakeholders in projects. Since most symbioses, natural as well as in industrial and urban ones (Chertow, 2000; Mulder, 2016b; Mulder & TU Delft, 2017; Paracer & Ahmadjian, 2000) are based on long-term relationships, the duration factor does not seem to comply with the usual symbioses' durations. Applying the urban symbiosis strategy for construction flows might lead to the necessity to frequently form symbiotic networks, something which is already seen as a time consuming and major challenge for the establishment of symbioses in general (Chertow, 2000; Vernay & Mulder, 2016). Furthermore, literature states that urban symbiosis focusses on the urban system, including public actors (Lenhart et al., 2015). In the study, the government is the only public party who has been identified as one of the stakeholders in the symbiosis' network. Due to the limited number of public stakeholders involved, one can question whether this can be seen as an urban symbiosis. The large variety in supplied material streams (due to the variety in extracted construction materials) can be seen as an additional challenge to establish an urban symbiosis for construction materials when comparing this to for example 'standard' water and energy waste streams. However, when construction companies become able to organise themselves in more constant coalitions which enables them to establish long-lasting relationships and networks, these two challenges might be tackled; as an example, main contractors can become standard 'clients' of demolition companies who can provide them with materials on a more frequent basis.

Assuming that the construction sector will become a varied long-lasting network as mentioned previously, it can be assumed that the urban symbiosis approach can successfully be applied to construction materials. The discussion above can be seen as a valuable addition to research because of its critical view on the application of urban symbiosis to materials, and more specifically construction materials, which is only minimally addressed in existing literature.

Moreover, the study sheds a light on the hypothesis that a third party might be valuable in the organisation of an urban symbiosis as is formulated in the studies by Mulder (2016b), Mulder and TU Delft (2017) and Vernay and Mulder (2016). Results from the interviews as well as from the focus group support this hypothesis. Circle Economy et al. (2015) state that the municipality of Amsterdam can facilitate the exchange of construction materials and advise them to take the initiative to set up an online market place. However, this study concludes that the government might not be the most ideal party to take up this role. Potentially incompatible interests as well as the municipality's accountability for citizens' interests and regulations are named as barriers to become a trustworthy mediator (Vernay & Mulder, 2016). It is advised to let an independent party evaluate whether these potential barriers might occur in the case of construction materials and whether a change in the particular action point proposed by the Circle economy et al. would be advisable.

The study furthermore generates insights with regard to the implications of the symbiosis' 'urban' aspect, i.e. the scale of the city, for building materials. Ohnishi et al. (2012) state that the most efficient geographic boundaries at which materials are reused can differ per material. The material's value determines the distance for which it can be transported; materials with high market value can be travelled over a longer distance than materials with a lower market value which can better be reused at a regional scale (Chen, Fujita, Ohnishi, Fujii, & Geng, 2012). The study of Lenhart et al. (2015) supports the use of such flexible geographic boundaries. It suggests that larger streams, such as industrial waste heat, are likely to be reused at a larger scale, like the city, whereas the reuse of smaller streams, like heat from offices, might be more appropriate at a smaller scale, like the neighbourhood. This study adds to the above-named literature that the desirable scale at which resources are transferred, in this case construction materials, also depends on the complexity and type of resource (or component) that is exchanged. In a way, it is contradictory to the finding by the study of Lenhart et al. , as specific components, often in small amounts, are preferred to be exchanged on a larger scale whereas standard components, frequently in large amounts, can be exchanged at a smaller scale. The disparity might be explained by the difference between and variety in resources; in comparison to (construction) materials which often comprise a much more varied composition, energy, and partly also water, can be seen as relatively uniform streams.

PROCESS

When comparing the reuse processes that are derived in this study to existing literature about the Dutch reuse processes for construction materials, both similarities and differences can be found. Icibaci (2019) recently published a research to gain an understanding of the current reuse practices of building products in the Netherlands and future possibilities. It states that the current Dutch reuse processes include the following phases: deconstructing (harvesting), collecting (transporting), sorting, processing and retail. The order in which the phases take place is not explicitly clarified and is therefore assumed to be similar to the phase order that is stated here. In comparison to the findings of this study, it additionally names the sorting and retail phase. Phases that result from this study but that are not named by Icibaci are the indication of supply, design, storage and the implementation. The difference in phases might be linked to the fact that this study focusses on the reuse process in relation to the establishment of a design or platform. This might declare the indication phase. Additionally, whereas Icibaci seems to focus solely on the supply side, i.e. the process from harvesting to retail, this study also includes phases from a demand nature, such as the design and implementation phases. For the same reason it is assumed that the study of Icibaci does not name the storage phase. However, this phase is thought to be of great importance as results from this study. This is also stressed by Circle Economy et al. (2015).

STAKE-HOLDERS

Regarding the stakeholders who are involved in the Dutch reuse processes, several parties are named (Icibaci, 2019): demolition companies, building strippers and building owners and retailers. The table below gives an overview of their role during the process phases that are mentioned by Icibaci (2019). In this table, they are also compared to the stakeholders involved in the process as derived from this study.

		Involved stakeholders according to this study	*Involved stakeholders according to Icibaci (2019) (four possibilities)*			
Phases in reuse process according to this study	*Phases in reuse process according to Icibaci (2019)*		1	2	3 (building stripper contacted by demolition company/ developer/ building owner)	4
Indication of supply		D				
Design		A, M, O				
Harvesting	**Harvesting**	D	D	D	S	?
Transport/ storage	**Transport**	D (transport)	?	?	?	?
	Sorting		?	?	?	?
Processing	**Processing**	?	D	R	S	?
	Retail		D	R	S	O
Implementation		?				

Table 9.1, comparison of the stakeholders in the reuse process according this study and Icibaci (2019) (D= demolition company, R = retailer, S = building stripper, O = building owner, M = Main contractor, A = Architect)

In accordance with this study, Icibaci identifies the demolition company as an important stakeholder in several phases of the reuse process. The building stripper can be compared to the disassembly firm that is identified by this study, being a more specialised company who can carefully take out to-be-reused materials. In this study, the role of the retailer is fulfilled by the platform, that connects a demanding party to a supplying party. Finally, in both studies the building owner is identified as a party who can, apart from the demolition or disassembly companies, initiate retail of the products himself, especially in small-scale projects (Icibaci, 2019).

DESIGN

Lastly, next to the validation of the design criteria by the stakeholders, the criteria can also be evaluated by comparing them to previous findings in literature. Though not specifically mentioned for a platform, Addis (2012) indicates several key aspects that play an important role in the decision on whether one wants to buy to-be-reused materials. Information that is similar to the requirements stated by the design criteria stress the material's performance and quality, guarantees, certification, costs, precise wording and the procedure for purchasing. Furthermore, Circle Economy et al. (2015) recognise the use of a map function as a valuable addition to encourage retailers to take initiative to reuse waste streams of local companies.
The study by Addis additionally mentions the installation procedure, insurance and product liability, the material's durability and the assessment of the environmental benefits as other important aspects for the decision on to-be-reused materials. Especially the last two can be seen as valuable additions to the findings of this research. Therefore, an indicator on the environmental benefit can be seen as a valuable addition to the platform.

9.2 Reflection on methodology and its limitations

This section discusses the methodology that has been adopted in this research and reflects on its limitations and how this might have influenced the outcomes.

As an overall framework, the RtD approach has been adopted. This framework on the one hand has enabled the study to address research aspects regarding symbiosis and on the other hand design interests. In contrast to the method's descriptions in literature (chapter 2), this study has gone through an additional, but small decoupling and interweaving step. It has to be noted that the decoupling of the two types of interests was not as strong as in the actual and final decoupling phase. After the interweaving (that has been done in the interviews), an interim interpretation of results was done for both the research and design interests. After the interpretation, they have been brought together and have been discussed during the focus group. Although one might think that the results had to be decoupled and coupled first before interweaving them again, it is assumed that it was not required to couple the interests again as the interweaving took place within the same contextual setting, aiming for the same research objective in the same study. The validation and elaboration of the results in an extra loop (in this case the focus group) can be seen as a valuable step, not only in this research, but also for the RtD methodology as a whole; it enables the researcher to more deeply explore the individual interests yet also the way in which they are interacting. It furthermore fits the identity of design processes which are known for their iterative character.

Another limitation of this study that can be identified is the lack of a side project with which the case study could (theoretically) have exchanged or transferred materials. Due to the bilateral nature of the symbiosis subject, the approach of the study might therefore be seen as somewhat unilateral. Since the focus group's participants were from the same project or company, the scenario discussed there might mainly have been evaluated from one perspective, namely the demand side that the participants were asked to take. However, one can argue that the single case study method that has been adopted in this research has enables the study to focus on the particular case without broadening too much and letting the results be influenced by other cases.

Furthermore, a relatively small group of interviewees was spoken to. This might have resulted in the fact that in the study's sample representatives of important actor groups are missing. Examples are a waste company and a governmental party. Additionally, only one person from each group has been interviewed (except from the architects). Especially for the design it would have been of value if more platform or tool designer were interviewed to derive their best-practices. Now, the design might be based on the experiences of one tool too much. These two limitations named can be seen as the limitations which have had most impact on the study's results.

Additionally, it also has to be mentioned that no distinction has been made between the answers of the architect and the project coordinator that were given during the interview with the architectural firm. Although this might have influenced the results since it has not reported their individual visions, it is believed that the effects are limited as the two often agreed upon each other and no clear disagreements between the two could be derived.

Lastly, for the directed qualitative content analysis that has been used for the analysis of the results, predefined topics from the topic list were used. In this way the researcher might have started the analysis with a slight bias which might have resulted in a selective selection of answers (Hsieh & Shannon, 2005). In order to reduce this effect, relevant information in the summaries has first been highlighted without the use of the topics. Afterwards, the marked parts have been classified according to either existing or new topics.

9.3 Reflection on the urban symbiosis' stakeholder network & design

9.3.1 Reflection on stakeholder network

PROCESS

Since the reuse of materials in an urban symbiosis has implications for the construction process, this also has an effect on the network in which the stakeholders are organised. This subsection presents a new stakeholder structure and the accompanying value flows that are transferred between them. It comprises the introduction of new parties, but also the reorganisation and redefinition of existing parties.

STAKE-HOLDERS

Figure 9.1 presents the new network in which the stakeholders are organised in case of the establishment of an urban symbiosis for construction materials. It is built on the conventional case study's network as is presented in chapter 5 and it is further adapted

based on the findings from the interviews and the focus group. Whereas the conventional network complies with a linear construction process, this network fits a circular construction process instead, for which the derived reuse process B (with a focus on the future) has been of main influence. It has to be noted that this represents the ideal scenario in which the construction supply chain is completely circular; however, it can be argued that this will not (yet) be achieved in the coming years.

The shift from linearity to circularity can be best observed right in the centre of the visual. Instead of one building that will be built or needs to be renovated (figure: lower building) (as is illustrated in the conventional network), it also includes one or more buildings that provide the supply of materials for this new building (figure: upper buildings). Together, those buildings form the urban mine, representing all the buildings in the city that comprise a large amount of materials which will once become available, e.g. during demolition or renovation.

The supply of materials for the newly to-be-constructed or to-be-renovated building is thus coming from those buildings in the urban mine. First, during the demolition or renovation of (part of) a building, materials will be disassembled and extracted by a disassembly company. This is limited to a service delivered by the disassembly company to the initial building owner; the former receives the materials, but does not become their owner. It is the main contractor of the new building who buys the materials from the client or owner of the building in the urban mine from which materials are extracted. In the next step, materials might need to be transported and temporarily stored before processing can take place. When processed into the right component that complies with the requirements for the new building, the material most likely needs to be transport and stored once again. Afterwards, the materials will end up at the main contractor or sub-contractors who, in line with the conventional network, implement them in the building. It is assumed that the main contractor or subcontractors of the new project are responsible for the payment of the storage, transport and processing of the to-be-reused materials. This is due to the fact that they are also responsible for the procurement of the materials and are therefore expected to take up the managing role from the moment they buy the material from the urban mine till the moment they apply it.

The changes in the network named above mainly comply the service side in the figure. Regarding the demand side, an additional transfer can be observed between the architect and the urban mine. Since the supply will not originate from the primary mine any more, but rather from the urban mine, the architect has to base his design on the extracted materials from the urban mine. The arrow between the urban mine and the architect suggests an information flow that tells the architect which materials are or will become available.

In an ideal scenario in which the construction process is completely circular, the supply side will disappear. However, it is highly unlikely that the process will become completely circular. Therefore, and also in the light of the process towards it, the supply side will remain to exist and offers supply where needed. The interaction between the stakeholders from the supply side with the rest of the network presented can therefore also be observed in the visual.

Within the light of redefining the roles of certain actors, the demolition company might transform into a disassembly company, as has also been discussed during the focus group. Furthermore, the material supplier might become a processing company; in that case, this party will process to-be-reused materials into useful components, just as it does with resources from the primary mine and secondary mine in his current job.

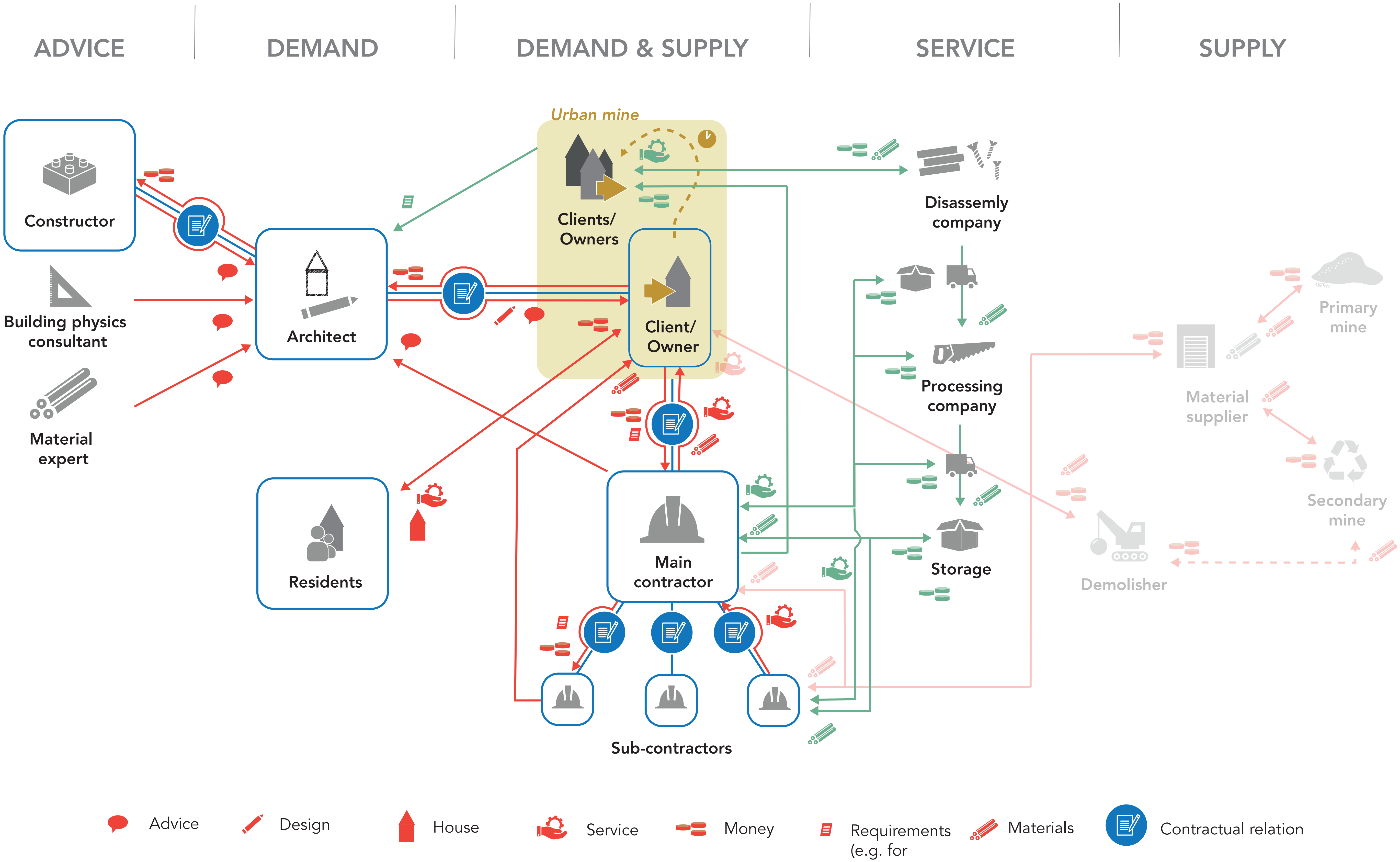


Figure 9.1, urban symbiosis' stakeholder network for the reuse of construction materials[1]

1 See for credits for some of the icons in the figure chapter 'References'.

9.3.2 Reflection on design

Now a new stakeholder network is derived for the urban symbiosis of construction materials, the connection can be made between this network and the proposed platform, its phases and the stakeholders who are involved (as presented in figure 8.2, chapter 8). Figure 9.2 visualises a framework that shows how the platform and the symbiosis' network are interacting. It shows how the platform takes an overarching position by which it can start and facilitate some of the conversations in the network that is presented above. The platform is characterised by the five phases and the sale, storage and transport activities in the reuse process. This paragraph presents the reuse process of construction materials in a symbiosis' setting, by which is made use of the platform.

First, the supply is indicated by the building owner or the demolition company; although the demolition company has a key role in this phase according to the participants of the focus group, the initial indication is assumed to come from the owner as he or she announces that his building will be renovated or demolished and materials will come out. As Icibaci (2019) indicates, the owner might contact a building stripping company (comparable to a demolition company or disassembly company in this case) to harvest and in that case such a party becomes important early in the process. Materials that will be extracted are offered by the platform (represented by the upward connection between the owner of the initial building and the first phase the platform addresses).

In the design phase, the architect starts looking for materials on the platform to be reused in his designs. In accordance with the owner of the building and the program of requirements that is made, a potential to-be-reused material can be recommended to the main contractor. The main contractor subsequently is the party who can buy the material from the initial owner via the platform. Afterwards, the process follows the harvest, transport & storage and processing steps to end at the implementation of the to-be-reused material. As visualised, the platform plays a major role in the first part of the process, in the connection of supply and demand in the urban mine. The final three steps are often already organised; the platform might only give insight or facilitate in those final steps. However, as evaluated by the focus group, there is a potential for the platform to arrange storage, transport and processing facilities through the platform. As discussed in the previous subsection, it is assumed that the arrangement of those services is done by the main contractor. It is implied that the main contractor starts making those arrangements from the moment he buys the material.

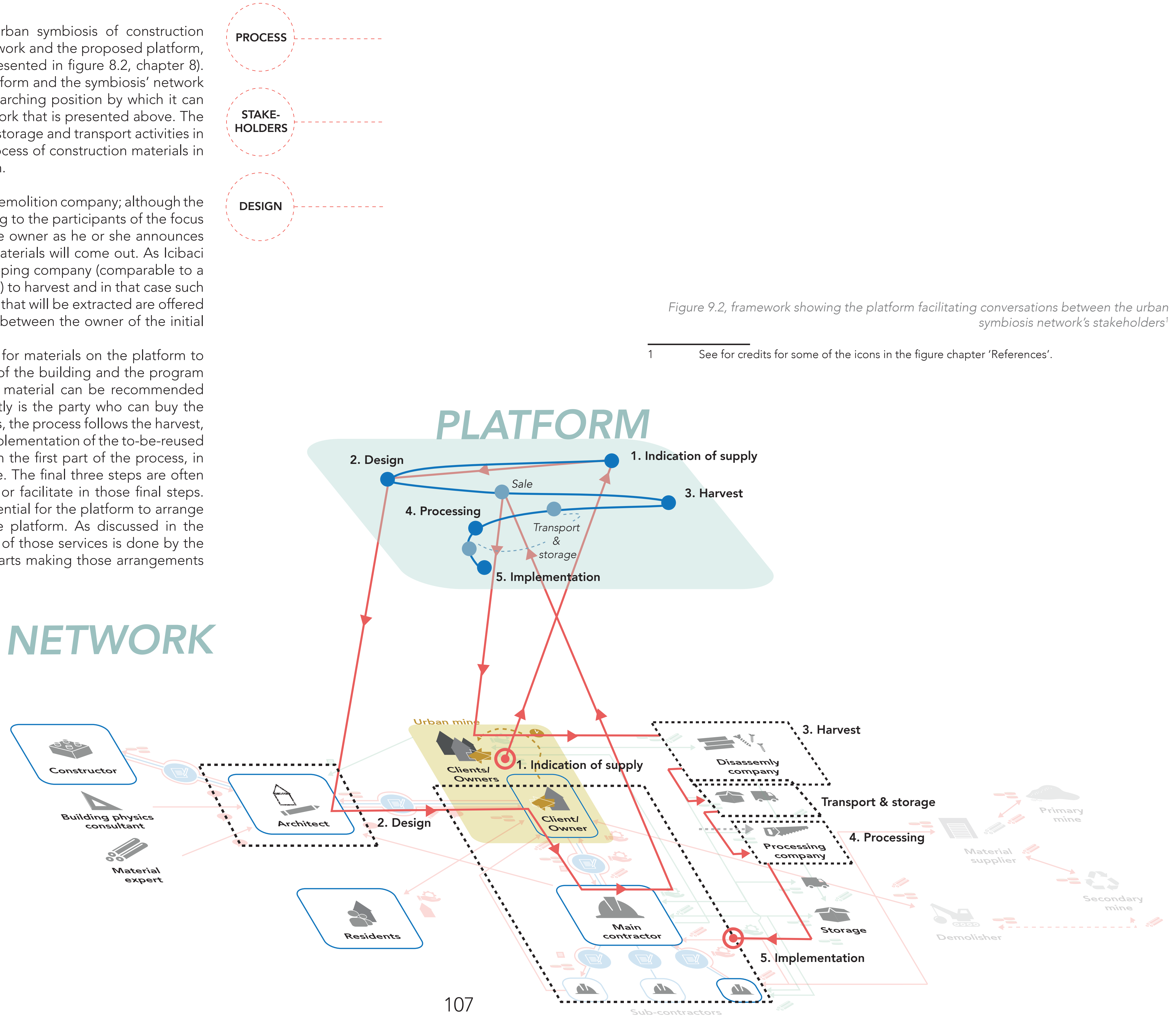


Figure 9.2, framework showing the platform facilitating conversations between the urban symbiosis network's stakeholders[1]

1 See for credits for some of the icons in the figure chapter 'References'.

10

CONCLUSION

Nowadays, the construction sector is seen as one of the most polluting sectors globally; both the demand for raw materials as well as the generation of waste put large burdens on our environment. Throughout the years, several principles from nature have functioned as inspiration source in order to understand and transform environmentally harmful systems into efficient and sustainable ones. One of those examples is urban symbiosis.

This study researches the application of the urban symbiosis strategy to the Amsterdam's construction material flows. Within the urban symbiosis framework, it explores which designs can be created that facilitate conversations between symbioses' stakeholders in order to valorise those construction flows.

In order to reach the aim of the study, the 'Research through Design' approach has been adopted that enables to research both the symbiosis and systematic as well as the design interests. A renovation project in Amsterdam has been used as a case study. Literature research, interviews and a focus group have further been used as data collecting methods.

Literature research revealed the state-of-the-art of urban symbiosis. To help decrease the environmental impact systems have, the overall aim of the approach is to integrate those systems by aligning stakeholders' interests rather than building new ones. However, the alignment of interests can currently be seen as a major challenge for the approach. Urban symbiosis is furthermore characterised by its focus on the urban system, including not only technical, but also political and social aspects, in which it differs from the more technical industrial symbiosis. Although the symbiosis strategy has frequently been applied for water and energy resources, limited research is performed on its application to materials.

Based on a comparison of characteristics, it can be concluded that urban symbiosis has the potential to be successfully applied to construction materials. However, several challenges are found for its establishment which stress the complexity of the process, costs and the to-be-reused material's quality and requirements. Therefore, the study has set up several prerequisites. The construction sector, the government and the society as a whole can be seen as parties who play in role in the realisation of those prerequisites. Additionally, further research is required on the actual environmental benefits of the symbiosis strategy applied to materials in the construction sector.

The study furthermore explores the creation of a design that can start and facilitate conversations between stakeholders in the symbiosis network for building materials. In order for this design to respond to the process running, the reuse process of construction materials has been derived first. Five phases can be identified: indication of supply, harvest, design, processing and implementation. Side activities, such as the sale, storage, transport of materials, are also part of the process. The order of the phases is dependent on the type of project; the moment of harvesting emerges as decisive.

Constructing the symbiosis network requires the rearrangement of stakeholders and a redefinition of stakeholders' roles in comparison to the conventional system. Stakeholders who are thought to be part of the network are the client or owner of the building, demolition company, suppliers, government, waste processing company, contractor, architect and consulting parties. Furthermore, third parties are seen as a potential mediator.

The study presents a future value flow model of the symbiosis' network clarifying the particular relationships the stakeholders will form. In general, the model becomes more cyclic in comparison to a traditional model; whereas on the demand side not many changes can be observed, the supply side goes through a transition. The urban mine can be found in the centre and offers the supply of materials for construction projects. The initial supply side, including the prime and secondary mine, is therefore eliminated. Parties offering a service, like disassembly companies, become increasingly important in closing the cycle. On the demand side, a major change in the building's design process is taking place since the architect has to base his design on the materials that become available from the urban mine.

Connecting this network structure with the reuse process, its phases and stakeholders, a design for a platform is proposed that is able to facilitate the conversations between

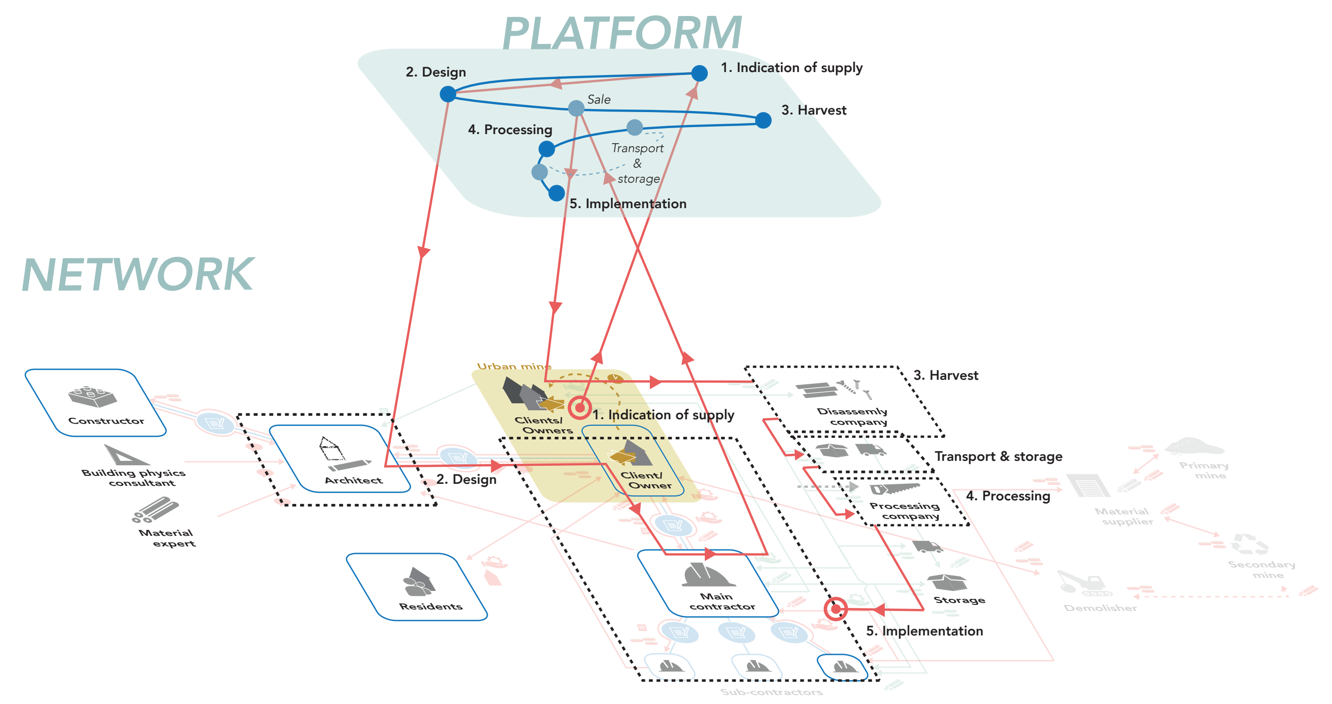


Figure 10.1, framework showing the platform facilitating conversations between the urban symbiosis network's stakeholders[1]

particular stakeholders during the process. A framework has been created that shows the interactions between the platform and the symbiosis network that take place (figure 10.1). The platform can be seen as a conversation starter that connects symbioses' stakeholders; more specifically it connects the supply of the urban mine with demand in the urban mine. The platform's main activities are therefore in the first two phases of the reuse process, being the indication of supply and the design phase. After sale, the platform can play a facilitating role in further arrangements like processing, transport and storage during the other phases of the reuse process. The platform is based on several design criteria that mainly stress the importance of uniformity with respect to classifications and standards, compatibility with other systems, like BIM, and the transparency and simplicity of the data.

Relating to the main research question of this study, it can be concluded that such a platform is an example of a design that can be created to facilitate conversations between symbioses' stakeholders while also valorising Amsterdam's construction waste flows.

The scale at which such an innovation is applied in order to achieve a high level of efficiency is crucial, though not set. Whereas the urban symbiosis strategy might suggest the scale of the city, in this case Amsterdam, the optimal scale appears to be rather dependent on the materials' characteristics. If favourable, it is therefore advised to look for collaborations at other levels to which the same symbiosis principle could be applied. At the same time, a universal system is key to prevent the fragmentation of supply.

So, this study concludes that the urban symbiosis strategy can be seen as an inspiration for the valorisation of construction materials in cities. In a similar way, the design that is proposed by this study has the potential to inspire and help construction stakeholders in their complex network to reuse materials and increase the sustainable performance of their sector.

10.1 Future research

This section proposes recommendations for future research in relation to the study's findings. Most importantly, future work has to investigate what the actual environmental benefit would be when urban symbiosis is applied to construction materials in comparison

1 See for credits for some of the icons in the figure chapter 'References'.

to the current situation. Although its potential has been indicated, the actual environmental benefit yet needs to be defined quantitatively. Geng et al. (2010) present a method which assesses the CO_2 emissions of several scenarios for the urban symbiosis of municipal solid waste materials in comparison to the current situation. This is seen as an appropriate method to be applied to a symbiosis of construction materials too. For the baseline assessment on the current construction performance, a connection can be made with the REPAiR project (REPAiR, 2019), that possesses local data on construction waste flows and their processing methods. Data on ingoing material flows have to be acquired from the material suppliers as data on these flows are often not available in BIM models or at main contractors.

Furthermore, in line with the sector's current developments, future research might investigate which role material passports play in an urban symbiosis of construction materials.

Additionally, more in-depth research is required with respect to the scale at which the symbiosis would be most efficient. An overview can be made of construction materials and the scales at which those materials can be transferred most efficiently. It might also be connected to the above recommended research on the environmental impact to investigate which materials can be transferred at which scale to achieve greatest environmental benefit.

Regarding the systems approach that urban symbiosis adopts, future research can investigate what the effect of this construction symbiosis is on other urban systems than the supply and waste system and whether additional systems can be combined in this symbiosis. An example is the transport system, which might become more efficient if supply and waste streams are connected. By combining interests from the multiple systems, additional benefits might be achieved.

With respect to the actors involved, the role of stakeholders from the social system in the urban symbiosis of construction materials should be further explored. Although the study's established network of stakeholders acts within the urban system and has to deal with political and social aspects, the network does not include any actors from the public sector yet. A wider investigation on who are involved from this side of the spectrum would be of value here. An example is the investigation of the role of the government, like the municipality of Amsterdam, in (the establishment of) a symbiosis.

In relation the to design proposed, it would be of great value if the platform would be developed and tested in a pilot project. Subsequently, the actual implementation of such a platform and accompanying user experiences should verify whether the tool is able to live up to its expected performance. Additionally, it will give insight in its effect within the larger construction process as well as it would designate aspects for improvement.

One of the main challenges for the implementation of an urban symbiosis for building materials appears to be the acceptation of reused materials. A change in mind-set and behaviour is needed. Future research has to investigate what are concrete steps that can be taken to achieve this aim and who should take the lead in this process. In the same light, research has to be performed on how to spearhead the implementation of the symbiosis approach in such a conventional sector as the construction sector.

Lastly, to move towards the establishment of a symbiotic network for construction materials in the future, a roadmap needs to be created that makes a clear distinction between concrete actions that can be taken in the current situation and which activities have a more futuristic character that can be executed in the coming of years.

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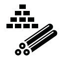 Construction materials, created by Rflor from the Noun Project — figure 5.1, 9.1, 9.2 and 10.1

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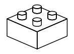 Lego, created by Danil Polshin from the Noun Project — figure 5.1, 9.1, 9.2 and 10.1

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Some of these icons have been adapted in the figures.

APPENDICES

Appendix A: Topic list

The topic list that is used during the study is visualised in figure A.1. It makes a distinciton between concepts, topics and aspects. For further explaination on the topic list tool, see chapter 'Methodology', section 2.3 'Data collection'. The visual furthemore indicates which concepts, topics and aspects are researched by which method. Lastly, red coloured elements have been identified as being part of the list before the interviews, however no findings could be related to those aspects afterwards. In contrast, the green elements represent concepts, topics or aspects that have raised during the interviews.

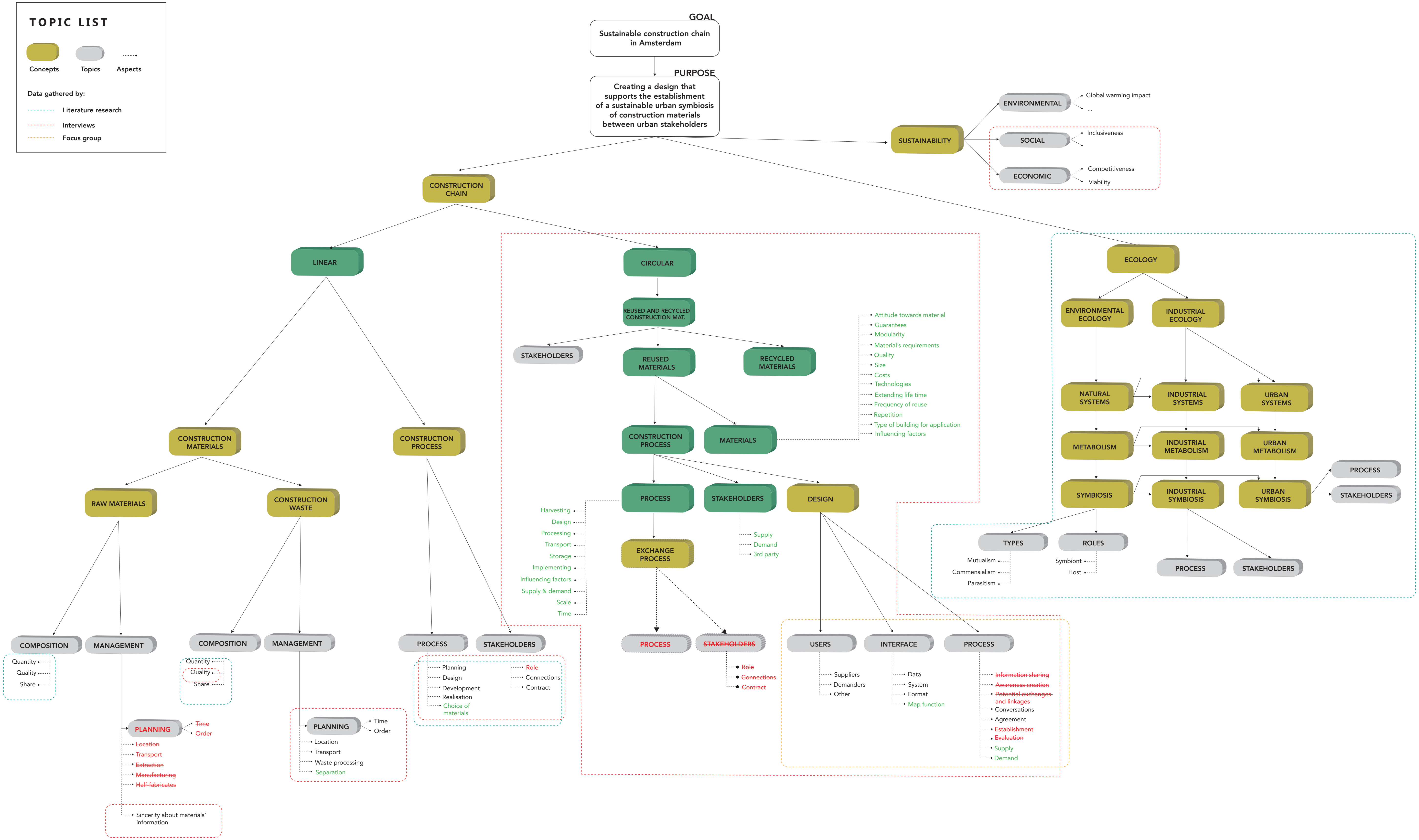

Figure A.1, topic list

Appendix B: Interview guide

Goals of the interviews:

1. Gaining insight in the current construction process and the roles of the stakeholders
2. Defining criteria/opportunities/ challenges for exchange of waste materials in an urban symbiosis.
3. Defining design criteria for the to-be-developed design

Organisation:

- Of every interview a summary is made according to the topics defined. Moreover, if other topics arise, these are also included. The interview will not be transcribed due to time constraints. However, the interview is recorded in case the researcher wants to use quotes. Moreover, this enables the researcher to listen once again to the record to add aspects to the summary that the researcher was not able to write down during the interview.
- Information is anonymised.

Introduction

Questions

General questions:

(to architectural firm, main contractor and project manager)
Concept: construction process
Topic: process
(experience-questions)
From when till when are you involved in the process?
What are your tasks throughout your part of this process?

Topic: stakeholders
Aspect: connections
With whom do you collaborate and communicate?
Aspect: contracts
With whom do you have a contractual relation?

Explanation of symbiosis concepts & Introduction of exchange of materials

(to all interviewees)
Concept: exchange process
Topic: process
(opinion-question)
What should change in the conventional system in order to let exchange take place?
Which possibilities do you see?
What might be challenges?

Topic: stakeholders
(opinion - question)
Aspect: roles
Who are important stakeholders for the exchange of materials? (who are involved?)
Who are suppliers of waste materials?
Who are demanders of waste materials?
Who should take the lead in this exchange process?
What will your new role be?

Introduction of the idea to develop a design

Concept: design
Topic: exchange process
(opinion-question)
Aspect: Information sharing
What information is needed?
Aspect: Identification of potential exchanges and linkages
How can suppliers and demanders be linked?

Topic: users
Who can be the users of the tool?

Closing

Stakeholder specific questions:

(to main contractor)
Concept: raw materials
Topic: management raw materials
Aspect: Location
From which companies are the new materials coming?
Aspect: Materials
Are the product half-fabricates/ final products?
Extraction/ manufacturing process? > who?
Aspect: Transport:
By which type of transport are the materials coming to the construction field?
Aspect: Planning:
What is the role of time?
What is the order in which the building is built

Concept: construction waste
Topic: composition construction waste
Aspect: Quality
What is the quality of the waste?

Topic: management construction waste
Aspect: Planning:
What is the role of time?
What is the order in which the building is broken down?

Aspect: Location
Where are the waste materials going to? Where are they processed?

Aspect: Transport
By which type of transport are they transported?

Aspect: Waste processing
How is the waste being processed?
Do you currently reuse waste materials in the renovated building?

(to architectural designer)
Concept: symbiosis
Which characteristics of a natural symbiosis can be observed in an urban symbiosis?

(to architectural firm, project manager and architectural designer)

Concept: construction process

Topic: design

Aspect: materials

How do you currently choose your materials?
Do you decide where your materials are coming from?
Do you keep the materials in mind when designing? (architectural firm & architectural designer)
How important is the aspect of sustainability when choosing a material?
Do you use reused materials?

(to designer)

Concept: Design

How has the Harvestmap platform developed?

Topic: process

Can you describe the process from the moment someone has a material to offer till the moment is reused somewhere else?
How would you describe the role of the platform?

Topic: users

Who are the users of the platform?

Topic: process

How does your platform facilitate the communication between supply and demand?
Which agreements are made?

Topic: interface

What is the reason behind the use of a map function?
Did you consider other tool option than a platform?
Which data of the material needs to be avaialble for the platform?

Appendix C: Outline focus group

(based on Finch & Lewis (2003))

1. **Scene setting & ground rules (5 min)**
   a. Formal start
   b. Introduction of myself
   c. Outline research topic
   d. Background + purpose study
   e. Confidentiality: recording + photos

2. **Individual introductions (10 min)**
   a. Introduction of each of the group members
   b. Group explanation

3. **Opening topic (15 min)**
   a. General introduction opening topic + short presentation
   b. Discussion on a platform for De Alliantie

4. **Discussion on a platform for Amsterdam (by scenario): (20 min)**
   a. Design criteria
   b. Stakeholders per step and their actions (on the platform)

5. **Ending the discussion (5 min)**
   a. Final words
   b. Thanks
   c. Refer to confidentiality

Appendix D: Scenario focus group

Scenario: the reuse of doors from another project in Amsterdam

Goals:
- Evaluating of design criteria
- Determining which stakeholders play a role in this process and in what way they cooperate

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Introducation + phase 1 (indication of supply)

(researcher tells scenario)
Imagine we are back in 2015, the moment at which was decided that the building (case study) would be renovated.

At that moment, it becomes clear that also another building in Amsterdam Oost (East) will be demolished. This building is not property of De Alliantie, but of owner X. He offers several construction to-be-reused materials from the building on the platform, among which are 200 doors.

During the design process of the building you want to use this platform to see whether you can use some of the to-be-reused materials offered.

Subsequently, you come across the 200 doors offered by building owner X. Those doors might be interesting as they might be useful for the replacement of the front doors of the 112 apartments in the two building blocks.

(activities)
- Evaluating design criteria in the booklet.
- Discussion on who play a role in this process.

Phase 2 (Design)

(researcher tells scenario)
Afterwards, you start designing. It seems that the doors are useful. However, these are too tall and therefore they have to be adapted. They also need a small makeover. Apart from those things, the doors have the right characteristics and they fit in the design. It is decided to buy them.

(activities)
- Evaluating design criteria in the booklet.
- Discussion on who play a role in this process.

Phase 3 (Harvest)

(researcher tells scenario)
Next, the materials are extracted from the old building at the moment the case study building is being built.

(activities)
- No design criteria, are there suggestions?
- Discussion on who play a role in this process.

Phase 4 (Processing)

(researcher tells scenario)
Afterwards, the doors have to be processed (e.g. at a sawing mill).
If they are processed, they might need to be stored or transported.

(activities)
- Evaluating design criteria in the booklet.
- Discussion on who play a role in this process.

Phase 5 (Implementation)

(researcher tells scenario)
Finally, the doors are implemented in your building.

(activities)
- No design criteria, are there suggestions?
- Discussion on who play a role in this process.

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