CHALMERS
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Challenges for implementing reuse in the construction sector

Master's thesis in Industrial Ecology

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CHALMERS UNIVERSITY OF TECHNOLOGY
Gothenburg, Sweden 2021
www.chalmers.se

Master's thesis ACEX30

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Abstract

Reuse in the Swedish building sector is becoming more common and have a high potential of decreasing waste and CO_2 emissions from the sector. However, it requires a new way of working in order to be implemented on a big scale. In this study, barriers for implementing reuse and their causes and effects have been evaluated.

The aim of the project was to find barriers for reuse, and their causes and effects. A literature study was done in order to obtain understanding of different barriers and was used as a base for the interviews. The interviews consisted of 20 experts from different parts of the building sector value chain, and barriers were identified from these interviews and grouped into categories and sub-categories. The categories are: Technology, Market, Infrastructure, Laws and regulations, Knowledge and Culture and norms. The analysis was done by connecting barriers to each other by the help of a visual tool. The strongest connections could be identified, as well as the barriers that are causing and caused by other barriers.

The results show that many barriers are highly interconnected and are strengthening each other or other barriers. Some sub-groups of Culture and Norms and Laws and Regulations were not caused by any other identified barrier, and some were not affecting any other identified barrier. The barriers most strengthened by several connections were identified to be between barriers within Knowledge, within Market and also between Knowledge and Culture and norms. The combined result leads to the conclusion that the sector is experiencing lock-in, which is caused by competition and lack of information and knowledge.

Keywords: reuse, construction, building, barriers, challenges

Acknowledgements

We would first of all like to thank our supervisors Alexander Hollberg and Leonardo Rosado for guiding us throughout the whole project. We would also like to thank AF Gruppen Sverige and especially Eva Johansson for support throughout the master's thesis. A special thanks to all the experts who participated in the interviews and made our thesis possible. Lastly, we would like to express our gratitude to our examiner Holger Wallbaum for feedback and support in our work.

Fanny Frändberg & Evelina Nyqvist, Gothenburg, June 2021

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Acronyms

BAMB Buildings As Material Banks.
BCA Building Codes of Australia.
BfD Barriers for Deconstruction.
BfRR Barriers for Reuse and Recycling.

CCbuild Center for Circular Construction.
CIB International Council for Research and Innovation for Building and Construction.

DfD Design for Deconstruction.
DfMaA Design for Manufacture and Assembly.
DfR Design for Reuse.

HSE Health, Safety and Environment.

QEHS Quality, Environment, Health and Safety.

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1
Introduction

The building sector in Sweden today is one of the biggest waste generators, and characterised by high flows of virgin materials. Construction activities generated 12.4 million tonnes of waste in 2018, which corresponds to approximately 35% of Sweden's total waste (SCB, 2020).

In order to lower the environmental impacts, decrease the amount of virgin material, and deal with the high amounts of waste that is occurring in the society, the Swedish government plans a transition to a circular economy (Government Offices of Sweden, 2020). They say that "Virgin materials must be replaced as far as possible by resources used efficiently in circular flows" (Government Offices of Sweden, 2020, p. 6). Actions, such as re-using and recycling should be implemented in order to treat the amount of waste.

One innovation project for a circular construction sector is Center for Circular Construction (CCbuild), which brings together different actors in the sector, monitors a marketplace for reused products and shares reference projects of reuse and circularity (CCbuild, n.d.-b). Återbruk Väst is one part of the innovation project, a regional project in the west of Sweden (CCbuild, n.d.-a).

The gap between a circular economy in the building sector and the reality today is big. The buildings and infrastructure produced in the sector are mostly technically advanced and highly affect people in their everyday life. At the same time, there is a high need of lowering the environmental impacts from the sector. Reuse might be a way of doing that so why is it not more common? This will be investigated in this study.

1.1 Aim and specification of issue under investigation

In this project, the aim is to understand the main barriers to implement reuse, through the perspectives of different actors in the Swedish construction sector. This will be investigated by answering the following research questions:

- RQ1. Which barriers are mentioned in the literature?
- RQ2. Which barriers are mentioned by different actors in the building sector?
- RQ3. What are the causes and effects of the barriers mentioned by actors in the building sector?

1.2 Limitations

The focus of the study is on reuse, thus other circular measures such as recycling will not be included. Comparing with the R-framework, conservation of buildings is preferred (Potting et al., 2017) compared to demolition, and since it has many similar challenges to keep buildings and renovate instead of demolition, also adaptive reuse is included in the literature study.

In the concept of reuse of building materials or components, the reuse of both used materials and left-over building materials are included. This is the main issue in the interview study. The concept of reuse is adopted as the phenomenon where the material or component keeps its form, although changes by repairing, refurbishing, remanufacturing and repurposing are included. Strategies higher than reuse in the R Framework, presented by Potting et al. (2017) and illustrated in Figure 1.1, such as reducing through prevention are not included for building components. The concepts of recycle and recover, as seen as the lowest strategies in Figure 1.1, are also excluded from this project. Moreover, the concepts of Design for Deconstruction or Design for Reuse are not in the scope since they have only indirect effects on reuse today.

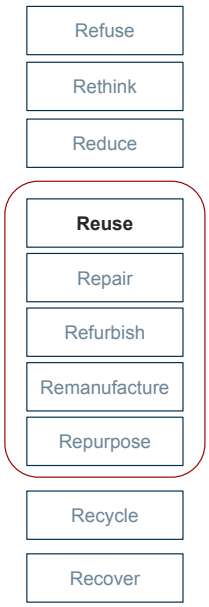

Figure 1.1: R framework based on Potting et al. (2017). The red encirclement shows the limitations of this study.

2
Theory

In this chapter, the concepts circular economy, reuse and adaptive reuse are defined.

2.1 Circular economy

The Swedish vision of a circular economy is "A society in which resources are used efficiently in non-toxic circular flows, replacing virgin materials." CE is described as a tool to reduce resource use (Government Offices of Sweden, 2020). Four important areas are selected (Government Offices of Sweden, 2020, p. 16):

- Circular economy through sustainable production and product design
- Circular economy through sustainable ways of consuming and using materials, products and services
- Circular economy through non-toxic and circular material cycles
- Circular economy as a driving force for the business sector and other actors through measures to promote innovation and circular business models

Circular Economy (CE) is an economy where materials are kept in use for as long time as possible. By extending the use phase, or looping the product or material back in the system in the end-of-life, the economic and environmental value can be kept. This also means that waste is minimised (Hollander et al., 2017). A way to achieve this, is by enhancing industrial ecosystems to replace the linear production system which is the most common today.

Frosch and Gallopoulos (1989) are describing an industrial ecosystem as a production system, where all kinds of materials are transferred between different industries, and waste for one industry means raw material for another. Frosch and Gallopoulos (1989) are comparing industrial ecosystems to the ecology of ecosystems, where organic material and nutrients are cycled between living creatures and the environment. For industries and the society, this would not only have environmental benefits but also an economic since it is a way of introducing new kinds of business models (Lybæk et al., 2021).

2.2 Reuse

The circular economy is based on the three principles "Design out waste and pollution, Keep products and materials in use, Regenerate natural systems" according to

the Ellen MacArthur Foundation (n.d.). In this report, the focus is on the measure to reuse, which is part of keeping products and materials in use. Products and materials can also be kept in use by designing them to last longer, remanufacture or recycle them (Ellen MacArthur Foundation, n.d.). Ellen MacArthur Foundation also states that by keeping materials in use, the value of energy and labour is preserved. However, recycling leads to a loss of embedded energy and labour as well as some material losses and is recognised as a measure of lower value than reuse and remanufacture (Ellen MacArthur Foundation, n.d.).

This hierarchy of circular measures is also described in the R framework by Potting et al. (2017, p. 5), where strategies that are increasing circularity the most are measures of "Smarter product use and manufacture" (Refuse, Rethink, Reduce), followed by strategies to "Extend lifespan of product and its parts" (Re-use, Repair, Refurbish, Remanufacture, Repurpose) and lastly "Useful application of materials" (Recycle, Recover). The framework is illustrated in Figure 1.1, where the strategies to extend lifespan are marked as this is in the scope of the study. In the framework put together by Potting et al. (2017, p. 5), reuse is described as "Re-use by another consumer of discarded product which is still in good condition and fulfils its original function". Repair, which is the next strategy in the framework, is about making a defective product achieve its original function and similarly, to refurbish is to restore the state of an old product. The strategies remanufacture and repurpose are ways to use parts of a product again, in a new product with the same function respectively a product with a different function (Potting et al., 2017).

2.3 Reuse and adaptive reuse in construction

The studies included in the literature review of this study (table 4.1) are agreeing that reuse or adaptive reuse is important for the construction sector to lower its emissions and costs. There are several examples of how this can be implemented in the construction sector. For example structural steel keeps its shape and is being used once again in another building (Dunant et al., 2017). Or doors (Park & Tucker, 2017), also by keeping the shape, and using them in another building. Densley Tingley et al. (2017) mention several kinds of reuse, such as of individual elements, for instance steel sections which are deconstructed and remounted. Furthermore, component reuse can be reuse of a steel truss. It can also be of a foundation, reused on site. Lastly, there is also building reuse, where a big part of the building is reused. The reuse can occur on site or be moved to another location (Densley Tingley et al., 2017). Reuse is not a new phenomenon, but was much more common in the pre-industrial era (Gorgolewski, 2008).

Reuse of a building or structure, usually a heritage building, on its original site, with extensions or changes is called adaptive reuse (Gorgolewski, 2008) (similar to building reuse as mentioned by Densley Tingley et al. (2017)). Changes might be needed because the old function of the building is obsolescent, but with adaptive reuse it is possible to change function and keep the value for a place or a community, without demolishing the building. Moreover, the social and physical function

of the building may be conserved (Conejos et al., 2016; Langston et al., 2008). It is common for heritage buildings, but can also be used for buildings to improve for instance its energy performance to be able to keep on using the building (Gorgolewski, 2008). Renovation might be part of adaptive reuse, since it is upgrading building systems to new (Lai & Kontokosta, 2019). Adaptive reuse might sometimes be a challenge due to the characteristics of heritage buildings, but there are many advantages compared to demolition.

3

Method

This study consists of two main parts: a literature study and an interview study. Both the literature study and the interview study was performed in a qualitative approach. The literature study was done in order to answer RQ 1 and the interview study was done in order to answer RQ 2 and RQ 3. In this chapter, the methods for how the study was performed and analyzed are described.

3.1 Literature review

The literature review was done to answer the first research question: "Which barriers are mentioned in the literature?". *Google Scholar* was used to cover scientific papers and reports. The search phrase that was used was: *reuse AND barrier OR barriers OR challenge OR challenges AND construction OR building*, to include material on reuse in the construction sector. Studies included were published in the years 2008-2019. Articles were sorted by relevance and chosen based on title and abstract to confirm that they study barriers in construction. In total 20 articles were included in the literature review.

First, the studies were sorted according to themes that were found, such as adaptive reuse, structural steel, BAMB, building products et cetera in order to find barriers connected to certain themes. However, since many barriers could be considered to be true disregarding of theme, the barriers were sorted in a spreadsheet by other categories: *Technical, Knowledge, Market, Laws and regulations, Infrastructure*, and *Culture and norms*. The categories were inspired by Bergek et al. (2008) and Geels (2005). The barriers were identified by finding issues, challenges, barriers, problems et cetera that were mentioned in the studies.

For each category, the barriers were analysed by grouping them into sub-categories. Who in the value chain that was experiencing the barrier and in what phase of the building's life-cycle the barrier occur was also evaluated. The sub-categories that were used for analysis can be seen in section 4.3. As the literature review was used mainly as a basis for the interview study, the results were not analysed further, but briefly discussed and concluded.

3.2 Interviews

In order to answer RQ 2: "Which barriers are mentioned by actors in the building sector?", an interview study was conducted. Actors included in the study were from several different parts of the construction value chain and had different experience of reuse.

Actors working with reuse were found by visiting the website of CCbuild. The other group of interviewees was based on people working at or with AF Gruppen. Snowballing was used throughout the study.

3.2.1 Experts

The experts interviewed were categorized in the following stakeholder groups: architects (A), building material industry (B), construction companies (C), consultancy firms (D), end-of-life treatment (E) and real estate owners or developers (F). The types of companies and the roles of the people interviewed can be seen below. There was 18 interviews in total, with 20 experts. Two of the interviews were with two experts at the same time.

Even though the experience of reuse were different, there was not possible to see any difference in the barriers that were mentioned in the interviews. Therefore, the experts were later divided into corresponding stakeholder group (A-F). In the list below, both group 1-3 and A-F are marked.

Experts in group 1, people who do not currently work with reuse.
B. Prefabricated concrete producer, factory manager
B. Prefabricated concrete producer, concrete station manager
C. Construction company, site manager
C. Construction company, Quality, Environment, Health and Safety (QEHS) manager
E. Demolition company, Health, Safety and Environment (HSE) manager
F. Real-estate developer company, senior manager

Experts in group 2, people who have some experience with reuse or are beginning to work with it.
A. Architect company, interior designer/construction engineer
B. Building material reseller, bricks salesman
C. Construction company, QEHS manager
D. Technical consulting company, plumbing, heating, water and sanitation consultant
E. Recycling company, business project leader
F. Real estate owner company, environmental strategist

Experts in group 3, people who have more experience with reuse.
A. Architect company, architect/specialist of passive houses

A. Architect company, architect
B. Building material reseller, CEO
C. Construction company, group manager/sustainability specialist
D. Consultancy company, environmental consultant
D. Consultancy company, environmental/resource economics consultant
D. Consultancy company, reuse consultant
F. Real estate company, project manager/project leader

The spread of stakeholder groups gives a wide perspective on the barriers perceived by many different actors. However, there is not a balance of stakeholder groups (groups A, B, C, D, E and F) or roles between the groups of different experience (groups 1, 2 and 3), which could affect the results due to over- or underrepresentation of one stakeholder group. This lack of balance is due to the unbalanced interest of participation in the interviews. It was hard to get stakeholders not experienced with reuse to accept an interview concerning reuse.

3.2.2 Performing the interviews

All interviewees were contacted by e-mail where it was clear that the interview was for a master thesis about reuse in the construction sector. The interviews were conducted remotely via the video conferencing software *Zoom* and recorded on an audio recorder, with permission from the participants. The language spoken in the interviews was Swedish and the duration was 30-60 minutes. All interviews were semi-structured, which means there are some prepared questions but there are also follow-up questions, and the interviews are in a conversational style. The questions varied for different actors and also varied over time as more knowledge was gained.

The questions that were general for all interviews can be seen below. The first question in the interview was asked in order to get the conversation about reuse started. Next (question 2), the role of the person in the company was asked for, in order to understand how much experience the person had with reuse. This continued in the next question (question 3) to understand the person's involvement with reuse in the construction sector. Follow-up questions were used to gain more knowledge about the experiences and perspectives.

In the end, the interviewees were also asked if they wanted to add anything else and if they had any recommendations of other people or actors to interview (questions 4 and 5).

1. What do you think about when you hear "circularity and buildings"?
Vad tänker du på när du hör "cirkularitet och byggnader"?

2. What do you work with and what is your role?
Vad jobbar du med och vad är din roll?

3. If you are working with reuse, how are you working with it?

Om du jobbar med återbruk, hur jobbar du med det?

4. Do you want to add anything that you think is missing?
Vill du lägga till något som du tycker att vi har missat under intervjun?

5. Could you recommend any person that you think we should talk to?
Kan du rekommendera någon annan person som du tycker att vi ska prata med?

3.2.3 Analysis

In this section, how the analysis was made is described.

3.2.3.1 Coding

In order to answer RQ2: "Which barriers are mentioned by different actors in the building sector?", an analysis of the interviews was made by coding. How the coding was done is described in this section.

After the interview the audio was transcribed. First, the interviews were coded by hand individually by the authors, and then compared. After the comparison, the coding was done in *NVivo*, a qualitative data analysis software. The coding was repeated several times, since the understandings of the barriers were different in the beginning and the end of the project. This made the coding more uniform throughout the project

When coding, barriers were found in the transcripts. The transcripts were read by looking for keywords such as "uncertain", "problem", "obstacle", "difficulty" et cetera. In some cases, two codes were marked for the same bit of transcription, if the interviewee talked about several barriers at the same time. An example from how the coding was done in NVivo can be seen in Figure 3.1. The different codes are on the right, marked with different colours for when they appear in the text. Full code books for the three groups can be seen in Appendix A.

The coding was first done expert by expert. However, when coding in Nvivo, the themes was later compared between the experts and similar or the same barriers were merged. The experts were first divided into three categories and their barriers were merged. Group 1 is experts not working with reuse (with some exceptions), group 2 are experts not working actively with reuse but are participating in CCbuild, and group 3 are experts working daily with reuse. This means that barriers were compared between experts having similar experience of reuse.

The barriers that were found in the interviews were translated from the codes in *NVivo* to a table of barriers, which also has more detailed descriptions of the barriers. The barriers were later categorized into sub-categories, and later into categories which are the same as for the literature. They are collected from Geels (2005) and Bergek et al. (2008): *Knowledge, Laws and regulations, Market, Infrastructure,*

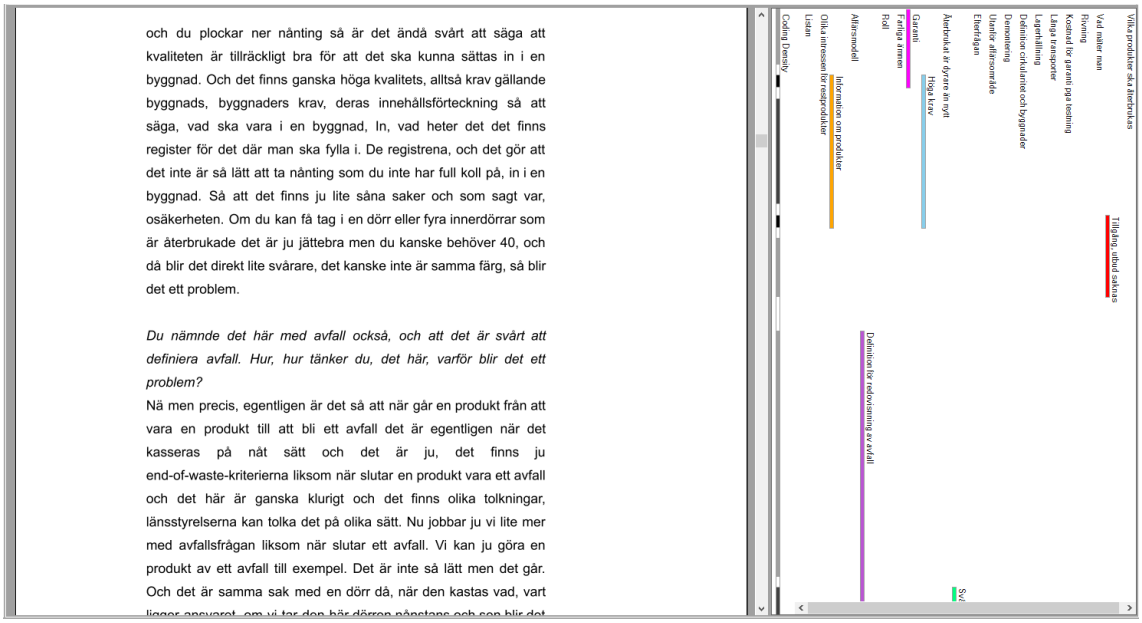

Figure 3.1: Example of the coding in NVivo.

Technical and *Culture and norms*. In this step the three groups of interviewees were put together into a collective result. During the study, it was not possible to see any patterns between the groups, or identify if experts in group 1 or 3 had different or the same "kinds" of barriers. In the end, the experts are divided into stakeholder groups instead.

The results from the table of barriers were sent to each expert in order to get their approval for publishing the work. A few of the interviewees also got a follow up question that came up while coding the interviews, in order to clarify the answers a bit more. The interviewees had the opportunity to make changes to the result. In this way, the RQ 2: "Which barriers are mentioned by different actors in the building sector?" are presented in Appendix C, and discussed when answering the next research question. A short summary of barriers and the categories can be found in section 5.3.

3.2.3.2 Causes and effects

Further analysis of the results of the interview study was done by identifying connections between the barriers, and the causes and effects of the barriers. This was done in order to answer RQ 3: "What are the causes and effects of the barriers mentioned by actors in the building sector?".

The categories and sub-categories that were earlier identified, were illustrated in a visual tool. The sub-categories were "clustered" around their corresponding category. By looking back at the transcript and coding, causes and effects of the barriers were found. Which barrier was the cause and which was the effect was marked with an arrow between the sub-categories, from *cause* to *effect*. When barriers can be seen as both causes and effects, the arrows are pointing in both directions. The

sub-categories having only incoming or only outgoing arrows were supposed to be the final causes/effects.

The causes and effects were found in the coding, and if there were corresponding barriers, it was assumed to be a connection. However, sometimes, the connections are mentioned but not coded. In that case, the barriers were assumed to still have a connection. Sometimes connections were added, which both authors agreed exist, but could not be found in the transcript directly. Connections were also found by the descriptions for the barriers, where they are explained further (barriers and descriptions used are found in Appendix C).

Sometimes the same connections are identified twice, because the analysis was done category by category. Then this is stated where the connection appears in the text. In cases where the connection was the same but found from the perspectives of two different categories, the connection was not done thicker in the illustration.

When a connection was drawn between two sub-categories that already had a connection, the line between them was made thicker. The three thickest connections were then later discussed further. Also sub-categories which only had incoming causes and only outgoing effects were also discussed. These were seen as original "causes and effects".

However, many connections between the barriers are not discovered if not looking at the whole scheme of connections. Therefore, also the thickest connections were discussed. The result from the both discussions were merged and conclusions could be drawn from that discussion. The thick connections were chosen to be discussed for many reasons. First of all, it was possible to include many barriers in the discussion. Furthermore, they have also been mentioned by many experts.

3.3 Evaluation of the methods

In this section, the methods used for both the literature review and the interview study, as well as their implications, will be discussed.

That nine of the 20 studies chosen was from the same collection (International Council for Research and Innovation for Building and Construction (CIB)) could make the results not diverse enough, but they were still chosen because all reports in the collection concerned different countries and were written by different authors. The barriers found from the reports were considered to be different from each other and contributing to the diversity of barriers. However, even more papers could have been studied to gain even more barriers, but since many barriers found were alike, the results obtained from the 20 studies was considered to be a comprehensive basis to conduct the interviews. Swedish papers were not included in the literature study, which means that current development in Sweden is not included. However, that aspect was included by interviewing actors in Sweden.

In the literature review, the search word was for barriers and challenges and thus the studies found were only those focused on identifying the issues with reuse. Another way of doing the literature review could have been to read studies about reuse in general, or even construction in general, and identify the barriers for reuse from them, to maybe find other barriers than studies before have done. The same goes for the interviews, that one can ask directly for barriers, or one can ask more questions around it to obtain barriers from observations. With the method used in the interviews, the result is of the barriers perceived by the actors and the result might have been different if the method was to observe barriers instead of asking for them.

As the research questions and the limitations of the study include the whole construction sector, the results are from a broad perspective. This can be a weakness because nothing is investigated in detail, but also a strength because the whole system is studied which gives a comprehensive view.

The focus of the study also excludes solutions, which could be used for a broader understanding of reuse. In many cases, the difference between a barrier and a solution is simply the phrasing. In both the literature study and the interviews, content phrased as a solution has been excluded. One example of this is when an interviewee says that we need laws that enhance reuse or that laws enhancing reuse are missing. What is a barrier and what is a solution has in some cases been a matter of interpretation.

If also solutions were included in the study, but rephrased as barriers, that would change the result and add more barriers, but they might represent things that could be done rather than things that are hindering reuse. On the other hand, further analysis of the results of this study can be used to find the corresponding solutions to each barrier.

Even though different actors in the sector were interviewed, the barriers found in the interviews were not only concerning the actor who mentioned them. In many cases, the answer to a question was that the barrier was because of another actor, or from the perspective of another actor. Because of this, the results did not show which barriers were actually an issue for which actor, but more which actors that perceive barriers that are issues for the whole sector. The questions in the interviews could have been more focused on the actor that was interviewed and what the barriers were for them, but it was experienced that when asking for personal barriers, the interviewee did not see as many, or got defensive.

Due to this general perspective on barriers in this study, the stakeholder groups were not separated in the result, because the separation of the barriers would not have been "correct" due to the interference of different actors talking about barriers for many different stakeholders. Thus the results were kept general and not analysed from the perspectives of stakeholders.

4

Barriers from the literature review

In this chapter, RQ1: "Which barriers are mentioned in the literature?" will be answered. The chapter starts with an overview of all the studies included in the literature review. Later in the chapter, the barriers for reuse found are described, and a list of all the barriers can be found in Appendix B. This is followed by a discussion and a conclusion for the literature review.

4.1 Overview of the literature

In Table 4.1, all included studies are listed, as well as the object of the study and their country of origin. Lastly, there is also a count of how many barriers that were taken and used for the result of this study. Theme is common aspects that were found between the studies. These are later briefly discussed in section 4.2, since some barriers are specific to their study, and not applicable on the sector as a whole.

Table 4.1: Overview of literature on barriers for reuse.

Source	Object of study	Country	Theme	No. of barriers
Anggadjaja (2014)	Barriers for Deconstruction (BfD): different types of demolition (top-down, controlled). Barriers for Reuse and Recycling (BfRR): concrete/bricks and metals	Singapore	CIB	5
Bohne and Wærner (2014)	BfD: main construction materials (wood, brick/concrete, steel), for different types of houses (size and use). BfRR: construction waste (brick and concrete, wood, asphalt, metals, gypsum + other)	Norway	CIB	4
Chini and Buck (2014)	BfD: wood frame construction, steel structured buildings, concrete/masonry structures. BfRR: concrete, wood, drywall, asphalt roofing shingles, steel	USA	CIB	2
Conejos, Langston, Chan and Chew (2016)	Barriers to adaptive reuse	Australia	Adaptive Reuse	15
Densley Tingley, Cooper and Cullen (2017)	Structural steel	UK	Steel	11
Dunant, Drewniok, Sansom, Corbey, Allwood and Cullen (2017)	Steel	UK	Steel	13
Durmisevic and Binnemars (2014)	BfD: major construction types (concrete panel system and brick facade). BfRR: C&D waste (crushed, sorted, total)	Netherlands	CIB	2
Earle, Ergun and Gorgolewski (2014)	BfD: structural materials (steel frame, wood frame and concrete). BfRR: construction materials (wood, drywall and concrete)	Canada	CIB	6
Gorgolewski (2008)	Investigates problems caused by reuse in the design and procurement of buildings	Canada	Design, Building products	13
Guy (2014)	Design for reuse, studies architects.	USA	CIB	5
Hein and Houck (2008)	In this study the authors visited four projects of historical buildings and challenges of adaptive reuse are identified.	Europe	Adaptive Reuse	10
Hobbs and Adams (2017)	Reuse of building products	UK	BAMB	10
Iacovidou and Purnell (2016)	Adaptive reuse, deconstruction, Design for Deconstruction, Design for Reuse and Design for Manufacture and Assembly are investigated as well as construction materials wastage and management and the infrastructure for recycling and reuse.	Global	Building products	19
Kuehlen, Thompson and Schultmann (2014)	BfD: major building construction types (Masonry and reinforced concrete ceilings, Masonry with timber framed ceiling, Precast concrete slabs with reinforced concrete ceilings). BfRR: C&D waste	Germany	CIB	8
Langston, Wong, Hui and Shen (2008)	Buildings should be flexible designed in order to be able to meet the demands, the obsolescences stated in this paper affects if a building is suitable for adaptive reuse or not	Hong Kong	Adaptive Reuse	3
Nakajima (2014)	BfD: post and beam timber houses, wood frame houses and light steel framed houses. BfRR: wood waste and concrete	Japan	CIB	2
Nordby (2019)	Construction products and technical installations	Norway	BAMB	6
Park and Tucker (2017)	Barriers to re-use, for different stakeholders in the construction sector	Australia	Construction waste	9
Storey and Pedersen (2014)	Barriers both general and applied to New Zealand	New Zealand	CIB	9
Zou, Hardy and Yang (2015)	Reduce, reuse and recycling of C&D waste in the Australian Capital Region	Australia	Construction waste	3

4.1.1 Adaptive reuse

All three of the studies included in this theme are exploring case studies. As mentioned in section 2.3, adaptive reuse is mostly applied on historical buildings. Conejos et al. (2016) examines possibilities to implement regulations to enhance the preservation of heritage buildings in the Australian Capital region. They study barriers to adaptive reuse through qualitative research, composed of a literature review, 11 case studies and some interviews with experts.

Hein and Houck (2008) studied feasibility, construction and structural issues with historical buildings in Europe. Obstacles were studied by visits to four projects, where interviews were also conducted with the workers.

The third and last paper on adaptive reuse is about Hong Kong and written by Langston et al. (2008). They develop a framework for the potential adaptive reuse projects and have the perspectives on financial, environment and social when validating the assessment with the framework. A new tool for estimating the useful life of buildings is proposed by the authors and they also discuss the tool SINDEX.

Apart from the tool, a case study of a historic building is included in the study.

4.1.2 CIB

All reports in the CIB Publication describes BfD and BfRR. Barriers have been identified from both and categorised into the different areas of this study. The creators of the collection sent a template to members of the CIB working commission W115, and thus all reports are similar in structure. What materials that were studied are listed in Table 4.1. The reports mainly concern the construction materials wood, brick, concrete, and metals.

4.1.3 Structural steel

Dunant et al. (2017) performs a quantitative analysis of interviews. The frequency of mentioned barriers was quantified by a novel ranking method, and compared between different actor groups, to see which barriers occur where in the supply chain.

Densley Tingley et al. (2017) identifies the practical barriers to steel reuse through interviews. The study also identifies differences and overlaps between literature of barriers and interviews. Barriers from the literature were identified as more technical, but barriers from the interviews turned out to be rather systemic.

The two studies about steel are one quantitative interview analysis (Dunant et al., 2017) and one qualitative interview analysis (Densley Tingley et al., 2017). They are published in the same period (2016-2017). Dunant et al. (2017) is referring to Densley Tingley et al. (2017), and uses these and barriers from other studies as a pre-study, and conclude that many barriers are perceived as barriers for some actors, but other actors do not perceive them as barriers. This may rise from a lack of communication between actors (Dunant et al., 2017).

4.1.4 Construction waste

The study by Zou et al. (2015) is a conference paper that presents the results of an earlier study to find barriers and strategies to overcome them, to construction waste reduction, reuse and recycling in the Australian Capital Region. Barriers were identified by a literature review in combination with focus groups, interviews and surveys. Zou et al. (2015) found 12 barriers in literature and added 7 barriers from the five workshops with 37 people and the interviews with 7 people.

Park and Tucker (2017) also studied barriers regarding reuse of construction waste in Australia, by doing a literature review. The study looks at the stakeholder groups homeowners, architects, contractors, developers and the legislative bodies. Park and Tucker (2017) also concludes that most barriers are economic, social and political and not connected to the construction sector itself.

Dunant et al. (2017) is also writing about barriers for different stakeholders in the supply chain, however, Park and Tucker (2017) and Dunant et al. (2017) do not

have any common barriers. Dunant et al. (2017) is using an interview approach and concludes that many barriers found in literature are only perceived, while Park and Tucker (2017) performed a literature study.

4.1.5 Design

In the study of Gorgolewski (2008) there were two case studies, including interviews, reviewing relevant studies, and site observations. The study was about challenges for the design team about using a reuse strategy, and how it affects the procurement process. Also the effects for the client are included. The reuse strategy is evaluated in terms of time, process and risk.

4.1.6 Building products

Iacovidou and Purnell (2016) has the most barriers included in this study. Barriers and opportunities for reuse are found by a literature review. Adaptive reuse, deconstruction, Design for Deconstruction (DfD), Design for Reuse (DfR) and Design for Manufacture and Assembly (DfMaA) are investigated as well as construction materials, waste management and the infrastructure for recycling and reuse.

Both Gorgolewski (2008) and Iacovidou and Purnell (2016) are evaluating barriers which can arise when implementing measures for reuse. Gorgolewski (2008) has a focus on usage of reclaimed products in the design/procurement phase, while Iacovidou and Purnell (2016) are focusing on measures for increased reuse in the future, such as DfD and DfR. Even though both are evaluating different measures, there are no common barriers. This can be because the operations are very different and maybe made by different actors. However, incorporating DfD would help in the design phase of a project (Gorgolewski, 2008). Thus, the studies can be complementary.

4.1.7 BAMB

Nordby (2019) performs a pre-study of barriers and opportunities in Norway connected to Buildings As Material Banks (BAMB). They study how materials from demolition can be reused on a big scale, for construction products and technical installations. There is a focus on technical, organisational and market barriers as well as legal restrictions. Hobbs and Adams (2017) is also a study from BAMB about component/building material in the UK. Hobbs and Adams (2017) has studied, by doing interviews, why the market of reclaimed products has declined over the last years. The study explores how the BAMB might be a way of solving the lack of information of building materials, which are needed in order to reuse components/-materials.

4.2 Barriers

From the studies discussed in the previous section, many barriers for reuse were found. Despite the different themes found in the literature, many barriers were repeated throughout the literature study, and only in a few cases similar barriers were found between the common themes. There seems to be only a few connections between theme (what was studied) and barriers that were obtained by the study. Thus, it might be concluded that the barriers are true for many different kinds of cases. According to this, the barriers will be presented in new categories: Infrastructure, Laws and regulations, Market, Technical, Culture and norms and Knowledge, in order to get a more systemic approach.

4.2.1 Infrastructure

Infrastructure includes two sub-categories: *Information* and *transports*. *Information* concerns communication, IT, buy-in of products, and matching supply and demand. The sub-category *transports* includes storage and transportation.

The sub-categories of Infrastructure include mostly the design phase, procurement, and the time a product have to be stored between projects. Several actors are affected by these barriers, such as customer, supplier, designer, buy-in, contractors and sub-contractors.

4.2.1.1 Information

The market of reclaimed products is unpredictable, and it is hard to know if it is possible to get the right quantity, quality, price and size at the right time (Densley Tingley et al., 2017; Iacovidou and Purnell, 2016; Dunant et al., 2017). One reason for this, according to Gorgolewski (2008), Storey and Pedersen (2014) and Iacovidou and Purnell (2016) is that there is a limited supply of reused products. There might be a need to buy from several different small scale suppliers (Storey & Pedersen, 2014). Contrary to this, Earle et al. (2014) state that there is also an unawareness about customer demand and customers do not know themselves that reused components are an option, since retailers do not offer it.

Working with reused products will also require a new way of working, since one needs to be sure that the contractors will have the products (Gorgolewski, 2008). The products need to be purchased early in the design phase, maybe before a contractor has been appointed. If products are not available, the contract needs to be flexible in order to allow for different kinds of products. A way to solve this is that materials might not be specified at the time of tendering (Gorgolewski, 2008). Another issue that arises when using reclaimed products is that there might be a lack of information about old materials (Nordby, 2019) and old drawings might be missing (Conejos et al., 2016) (in the case of adaptive reuse).

There are several different actors involved in construction and deconstruction, and Iacovidou and Purnell (2016) says this makes collaboration more complicated. Dunant

et al. (2017) says it is a question of trust when implementing new practices, that it is easier to rely on the common practice when working in new co operations, rather than trying new things, such as reuse of components. Moreover, Earle et al. (2014) says that the goals and plans of a project are not always known for all participants, which might also hinder the process.

4.2.1.2 Transports

When designing with reused components, they might have to be bought already in the design phase, as mentioned in previous section by (Gorgolewski, 2008). This means that they have to be stored somewhere between uses, if it is not possible to store it on the building site. Moreover, the products also need to be stored so that they are not destroyed during this time (Gorgolewski, 2008). Zou et al. (2015) also mentions lack of facilities for storage of soil.

Furthermore, a barrier obtained from New Zealand is geographic isolation and lack of facilities in small communities. This hinders a large market of reclaimed components due to additional transportation. This is connected to a high cost of transportation and storage (Storey & Pedersen, 2014).

4.2.2 Laws and regulations

When working with reuse, there are some laws that can hinder reuse of old components, and there are few laws that enhance the reuse of building products. This section includes examples from Australia and Norway and some European laws are mentioned.

The laws are an obstacle when building new production with old products or renovating an old building to today's standard. These concern the architect, contractor and eventually the owner of the building. One barrier, the health and safety legislation as a challenge for deconstruction, concerns demolition workers and is encountered at the end-of-life of the building.

4.2.2.1 Building codes and standards

Reused construction products need to comply with several regulations, building codes and standards, marking and certification.

It is difficult to reuse when "Standards give the impression that new materials must be specified" (Storey & Pedersen, 2014, p. 139). A similar issue is also mentioned by Park and Tucker (2017), that the Building Codes of Australia (BCA) lack a method to consider building life cycle vs construction and running costs. Reusing is perceived as complex and results in a lot of additional paper work for certifications and documentation. It is hard to get approval from authorities to use reused products, and there is a lack of regulations to enhance the use of reused products (Park & Tucker, 2017).

In Norway, the building codes that the products need to comply with are: Building technical regulations (TEK), Documentation of construction products (DOK), EU:s health, safety and environmental regulations (CE) and EEA Construction Products Regulation. This is important to follow for the architect/technical consultant or contractor. The laws and regulations do not support sale and reuse of building materials in new buildings (Nordby, 2019).

The health and safety legislation is also mentioned as a challenge for deconstruction by Storey and Pedersen (2014) who studied barriers in New Zealand. The additional safety equipment which is legislated might increase the time needed for deconstruction.

4.2.2.2 Increased legislation

Acoustics/noise control, fire safety and disability access legislation can hinder reuse of old buildings or old building products. These challenges were identified in the studies by Conejos et al. (2016) and Hein and Houck (2008), both studies of adaptive reuse. The increased legislation was identified to be a problem when renovating an old building, since big changes can sometimes be needed to update the building to more recent standards. For example, the acoustics/noise control laws can be a barrier because it is hard to ensure acoustic/noise controls in old buildings (Conejos et al., 2016).

In BCA, if more than 50% of the building is changed, fire safety must be implemented, however, it should be done with the character of the building preserved (Conejos et al., 2016). In Europe, if there is a major change to historical buildings, hallways and doorways must be widened, fire equipment, installations, fire doors and new exits must be installed in the building (Hein & Houck, 2008).

The design for building with access for disabled does not always comply with the character of the old building (Conejos et al., 2016). The accessibility is also mentioned by Hein and Houck (2008), who say that to enhance accessibility, the building should include ramps, washrooms, entryways and hallways of least dimensions to make the building accessible for everyone.

4.2.3 Market

In this section, there are three sub-categories: *time, cost* and *competition*. When using reused components, new processes are needed which will require more time. The phase that is mentioned the most is deconstruction, but also design, remanufacturing, testing and remediation are mentioned. Costs is a sub-category including costs of new processes that are needed for reuse. The last sub- category includes existing functions in the society, where it is possible to save energy or earn some money, and hinders materials/components to become reused.

Actors that are mentioned are demolition/deconstruction workers, fabricators (for steel), designer, and contractors. The category includes phases of deconstruction/de-

molition, design, construction and end-of-life (incineration of materials and recycling).

4.2.3.1 Time

More time is needed for deconstruction (Gorgolewski, 2008; Hobbs and Adams, 2017; Iacovidou and Purnell, 2016). According to Nakajima (2014), time required for deconstruction is 3 times higher than for demolition. It is also requiring more labour compared to demolition (Iacovidou & Purnell, 2016). Since deconstruction and other processes require more time, it will cost more. Thus there is lack of economic incentives to reuse (Nordby, 2019).

In the design phase, more time is needed in order to fit the design to what is available and more time has to be given to the structural engineers. More time is also needed for fabrication, which is the most time consuming phase for reusing of steel. Furthermore, storing of products for a long time is also expensive (Dunant et al., 2017). Both Dunant et al. (2017) and Park and Tucker (2017) are mentioning time pressure for contractors as a barrier for reuse. Lastly, testing of products also requires more time (Gorgolewski, 2008; Hein and Houck, 2008; Iacovidou and Purnell, 2016).

4.2.3.2 Cost

When reusing products today, there are several new processes needed that are expensive today. For adaptive reuse, cost of remediation of hazardous substances is a barrier, as well as the additional time needed for it. Also maintaining and repairing products is costly (Conejos et al., 2016). Gorgolewski (2008) and Hein and Houck (2008) say that old products need to be tested, and this is costly due to testing fees. Hobbs and Adams (2017) mention that this fee might be more expensive than what you save of reusing products.

4.2.3.3 Competition

There are interests in waste materials, and ways to save money when down cycling. For example, wood is incinerated and becomes energy, and there is a profit to recycle steel (Iacovidou & Purnell, 2016). Moreover, Kuehlen et al. (2014) and Durmisevic and Binnemars (2014) mentions that disposal costs and taxes are low. Furthermore, the costs of new materials are usually not high compared to reclaimed products, which makes new products favourable (Bohne and Wærner, 2014; Hobbs and Adams, 2017). One reason for this is the high costs of deconstruction (Hobbs & Adams, 2017).

4.2.4 Technical

The technical barriers found concern the properties of *materials/components* and available *technology*. The barriers are encountered mainly in the deconstruction of

the building and concern the demolition workers, but also indirectly the owner of the building who wants to reuse the products.

4.2.4.1 Material/component

One challenge for reuse is that the buildings were not designed for disassembly when they were built. The building and/or its components were not designed with reuse in mind. Materials are glued to each other, for example gypsum glued to wood, or floor is glued to the concrete slab (Nakajima, 2014). Cement mortar and prefabricated panelized systems are other examples of materials hard to disassemble (Hobbs & Adams, 2017). In-situ technologies like cast-in-place concrete are project specific, heavy, hard to move and analyse if information about reinforcement is not available. The concrete is also hard to separate into parts because there are no joints between them (Storey and Pedersen, 2014; Iacovidou and Purnell, 2016).

In the case of adaptive reuse, the physical restrictions of the present building can be a challenge for reuse. Conejos et al. (2016) mention that some of the limiting factors are current floor layout, number of columns/walls in the building and structural system layouts of the building. There might be a challenge to fit the old building with current availability demand.

Moreover, the materials and components in the existing built environment can be inappropriate for reuse due to hazardous materials or substances. Due to regulation, health and safety, some materials formerly used in buildings are no longer desired to keep in a circular flow because of hazardous substances (Kuehlen et al., 2014; Guy, 2014; Iacovidou and Purnell, 2016; Hein and Houck, 2008; Nordby, 2019; Conejos et al., 2016).

The materials/components can also be inappropriate for reuse because they are deteriorated or damaged. The issue that components and materials have lost their technical or physical functions by time or damage is mentioned by Hein and Houck (2008), Conejos et al. (2016) and Langston et al. (2008). All three studies concern adaptive reuse, but the issue is not limited to concern adaptive reuse since old components could also be reused in new production.

In the case of steel, it was mentioned by Dunant et al. (2017) that the dimensions of the available material might not be the desired ones and this causes a problem with the design because it has to be changed.

4.2.4.2 Technology

There are some challenges mentioned in literature about the technologies connected to the deconstruction process, that are necessary in order to reuse components. In the case studies by Gorgolewski (2008), damage from deconstruction or storage was a challenge for reuse.

Deconstruction may require special equipment which may not be available. Kuehlen

et al. (2014) say that equipment do not yet exist. Iacovidou and Purnell (2016) give the example of timber components which are difficult to deconstruct and may also be a safety risk. Special equipment and careful handling are needed to not damage the components in the process of cleaning, de-nailing and sizing at the cost of time. The risks with health and safety of deconstruction are also brought up by Hobbs and Adams (2017), who identified the risks of manual deconstruction as a reason that mechanical demolition techniques are used.

In the case of adaptive reuse, the existing materials may not be compatible with new materials (Conejos et al., 2016). Conejos et al. (2016) also mentions the technical complexity of refurbishment and installations which require new solutions for each case when performing adaptive reuse of heritage buildings.

4.2.5 Culture and norms

Challenges concerning culture and norms are present for all actors in the construction sector. The sector is bound by tradition and there is an inertia hindering changes in favor of reuse. The prejudices of customers are a problem for the architects, and what the customer wants is also important for the developer. On the company level, building owners are sceptical and many actors perceive risks and uncertainties with reuse.

4.2.5.1 Customer

There are prejudices about reused products and an attitude that new is better. Dunant et al. (2017) identifies that there is a worry that customers will refuse old steel because of inferior properties. Iacovidou and Purnell (2016) identifies prejudice and preference of consumers as barriers, and also the "lack of confidence" that concerns reused components' performance and properties. Moreover, for customers, pre-used products are seen as not as good compared to new products, and architects do not want to use pre-used products if it is not in a fashionable way. The architects and the constructors are also afraid that something might be inferior and they do not want to be responsible if anything goes wrong (Storey & Pedersen, 2014).

Since residents care more about economy than environmentally friendly buildings (Park & Tucker, 2017), there is an economic reluctance to pay more for having sustainable solutions. Hein and Houck (2008) also mention that expectations of the tenants can be a challenge for adaptive reuse, that old buildings can have flaws that make them appear unsafe. Furthermore, there are expectations of for example accessibility, modern plumbing and HVAC systems, and also electrical and telecommunications facilities. Modern tenants also want assurance that the building is safe for their health (non-toxic environment).

The lack of interest from clients is also an attitude that hinders reuse. Park and Tucker (2017) say that architects perceive the barrier of clients having no interest in reusing construction material. Developers and builders also perceive this lack of interest and demand of customers (Park & Tucker, 2017).

4.2.5.2 Company

Building owners are sceptical to specify the use of reused products because they "carry the connotation of being inferior" (Anggadjaja, 2014). Moreover, building code requirements and performance specifications also make it hard to use reused products. In the case studied by Gorgolewski (2008), the risk of specifying reused materials is perceived by the design team, because of the less predictable characteristics of reused components. This risk is also mentioned by Densley Tingley et al. (2017).

There are also uncertainties about cost and the risks associated with it. Conejos et al. (2016) mention that time and difficulty of reuse lead to higher costs, which leads to smaller profit and that is a risk and an uncertainty. There is also a risk of changing business model due to the higher cost (Dunant et al., 2017).

Beyond the perceived risks, there is also a perception of financial and technical barriers. Adaptive reuse is perceived as too costly and demolition is more profitable (Conejos et al., 2016). This assumption of higher costs is also mentioned by Earle et al. (2014), in particular the assumption that deconstruction will lead to higher costs than demolition.

4.2.5.3 Sector

There is an industry scepticism and tradition. Standard practice in the construction sector depend on time, complexity and costs (Gorgolewski, 2008). There is also an inertia in the construction sector and corporate lock-in, due to possible cost increase and unwillingness to change (Densley Tingley et al., 2017).

4.2.5.4 Society

As fashion or behaviour changes, the building becomes outdated and needs renovation or replacement. This is called social obsolescence in the study by Langston et al. (2008).

4.2.6 Knowledge

The different kinds of knowledge that were found were lack of experience, uncertainty about available products in the design phase, and unawareness about positive effects of reuse. The barriers in the Knowledge category showed up at different times in the building process, however, mainly at the projection phase and during demolition. The stakeholders concerned are ranging from demolition workers, to owners, to customers, to everyone in the sector.

4.2.6.1 Lack of experience

There have not been many case studies of reuse, according to Kuehlen et al. (2014) which could be used in order to show economic, environmental and social benefits of reuse (Kuehlen et al., 2014; Iacovidou and Purnell, 2016).

The lack of experience also results in lack of good practice (Gorgolewski, 2008). Since reuse is an uncommon practice, it is hard to make changes in "the usual way of doing things" (Dunant et al., 2017). Examples of this are in the case of deconstruction. Anggadjaja (2014) and Storey and Pedersen (2014) say that successful examples of deconstruction are missing. Iacovidou and Purnell (2016) agree, and say that there is a lack of experience of methods for deconstruction. Connecting lack of case studies to demolition are Earle et al. (2014) who say that the benefits of reuse are not clear and the demolition workers try to finish their work as quickly as possible, unaware of what could be reused. In the case of adaptive reuse, Conejos et al. (2016) state that there is also a lack of experienced workers and experts of renovation work.

4.2.6.2 Design phase

Other uncertainties are occurring in the design phase. Nordby (2019) says that there are uncertainties in the design phase about what products will be available in the construction phase and Guy (2014) says there is a lack of knowledge about availability of reused materials (Guy, 2014). Lastly, Densley Tingley et al. (2017) say that there are uncertainties about where to source the reused steel, and the availability of it. Even who would offer it and procure it is an uncertainty. Gorgolewski (2008) states that using reused products require more flexibility in the design process.

4.2.6.3 Material value

Industry professionals are unaware of the opportunities for reuse, and the value of reused products (Earle et al., 2014). Chini and Buck (2014) also say that workers and owners are not aware of the material value from deconstruction once the materials/products are recovered. Park and Tucker (2017) say that there is a lack of knowledge by all stakeholders how the buildings relate to embodied energy, and how that affects running- and construction costs. Moreover, they also state that customers are more aware of the initial costs of the residents and have little knowledge or awareness of long-term consequences of their choices of products.

4.3 Summary of the literature review

Categorization and description of sub-groups are found in the following list.

Infrastructure barriers
Information: Information that is needed in the design phase is not always available. There needs to be an assurance that it is possible to obtain the right products at the right time. The uncertainty might affect the contract. The last part of this section is about trust between contractors and sub-contractors.
Transports: Is about the need of storage for products between different projects. There are also some barriers connected to transportation and geographic isolation.

Laws and regulation barriers
Building codes and standards: The laws and regulations that reused components need to comply with. The problem with reused components is to get the same certifications as for new products and there is a perception of laws missing to enhance reuse. There are also laws for health and safety that increase the time required for deconstruction.
Increased legislation: Old buildings or old building products can sometimes be obsolete in terms of fulfilling acoustics, fire safety and disability access legislation and standards. This makes it difficult to reuse them, and buildings that are renovated can need extensive changes to fit the standards.

Market barriers
Time: Time was one of the most frequently mentioned barriers, and new ways of working in deconstruction and in the design phase require more time. It might also be more labour intensive.
Costs: Additional processes needed are mentioned, which will cost more. These are remediation of hazardous substances, maintenance, reparation, and testing of products.
Competition: Steel is recycled as scrap metal and wood is incinerated for energy recovery. Due to the high costs of deconstruction and other services for reclaimed components, new materials are often cheaper than reclaimed materials.

Technical barriers
Material/component: One challenge with the materials in existing buildings is that it is difficult to disassemble in order to reuse it. When renovating, the existing system can be a challenge. The materials or components can also contain hazardous substances or be deteriorated or damaged and thus not suitable for reuse.
Technology: Deconstruction equipment might be missing or insufficient to carry out deconstruction in a way so that the components can be reused. There are also technical issues of matching old materials with new.

Culture and norms barriers
Customer: There is an attitude that new is better and customers are not willing to pay for reused products. The expectations of tenants are also a challenge for reuse of old buildings, as they can be perceived as unsafe. There is also a general lack of interest in reused products from clients.
Company: There are perceived risks connected to the quality and costs of reused products. Moreover, there are assumptions of higher costs of deconstruction or adaptive reuse, which gives the impression that demolition is more profitable.
Sector: Industry scepticism, tradition, corporate lock-in and inertia all make the transformation to working with reused products, instead of new, difficult.
Society: Buildings become outdated due to changes in behaviour of people or fashion.

Knowledge barriers
Lack of experience: This sub-category includes lack of case studies, which might be a way of understanding how to work with reuse. The lack of case studies results in lack of methods of working, and unawareness about what could be reused. There is also a lack of experienced workers.
Design phase: Similar to the Infrastructure category, that it is not possible to find reclaimed products brings a lot of uncertainties to the design phase. The uncertainties regard what kinds of products that will be available, already in the design phase and in the construction phase.
Material value: There are both unawareness and lack of knowledge about inherent value of products. For example how much energy that have been used for production.

4.4 Discussion of literature result

The literature review shows a broad range of barriers, going from details of construction to attitudes of tenants. Many barriers were common between the studies, despite the different cases. Therefore, in this literature review, they are all viewed as equally important despite in what circumstance they were studied. By generalising, details might be missed, however, it still gives a basic knowledge about common barriers for reuse that actors might face when trying to implement it. Furthermore, when specific barriers have been found, which can be connected to the objective of the specific study, e.g. fabrication of steel requires a lot of time (Dunant et al., 2017), this is stated.

All the studies agree that reuse is a way of saving waste and emissions from the construction sector. However, e.g. Park and Tucker (2017) and the collection from CIB also include barriers for recycling. The studies concerning adaptive reuse (Conejos et al., 2016; Langston et al., 2008; Hein and Houck, 2008) are mainly focusing on preservation of whole buildings, rather than specific components.

Many barriers are for different actors in the construction sector and in different areas, however, a lot are covering deconstruction and the design phase. Many of the actors concerned with the barriers are designers and demolition workers. These could be the vital spots for reuse, since the challenge can lie in getting products from demolition and designed into new buildings.

Although some studies look at many actors in the value chain. Dunant et al. (2017) and Densley Tingley et al. (2017) include many actors but only study steel. Park and Tucker (2017) who study homeowners, architects, contractors, developers and the legislative bodies, only study the case of Australia.

4.5 Conclusion of the literature study

The research question that should be answered was "RQ1. Which barriers are mentioned in the literature?". Section 4.3 gives a brief description of barriers found in

literature in each sub-category. The barriers are versatile, and highly interconnected to each other. However, how they are connected is only assumed because of many similarities of the findings in the studies. In the next part of this study, the results of the interviews will be presented in order to obtain knowledge about barriers that actors in the Swedish construction sector perceive. Furthermore, a deeper understanding of the barriers by analysing their connections will be gained by studying their causes and effects.

5

Barriers from the interviews

In this chapter the barriers found in interviews are presented and analysed. First, in section 5.1, there is an overview of how different stakeholder groups were giving barriers according to the different categories of barriers. Next, section 5.2 will answer RQ 2: "Which barriers are mentioned by different actors in the building sector?" and here also connections between the barriers are analysed, that later leads to answering RQ 3, "What are the causes and effects of the barriers mentioned by actors in the building sector?". Section 5.3 is a summary of all sub-groups of the barriers.

All barriers found in the interviews can be found in Appendix C. There are tables with the barriers for each category, a description of each barrier and also a count of how many experts that mentioned the barrier.

5.1 Overview of barriers answered by the interviewees

Figure 5.1 shows how many times certain barriers have been mentioned. If one barrier is mentioned by several experts it will show on the chart. Thus, the chart shows what category the experts have been talking mostly about.

In the Technical category, the architects and the real estate companies are mentioning a big portion of the barriers. In the Knowledge category, the construction companies are most represented of all stakeholder groups, but architects and real estate companies also have a big portion of the barriers. In the Laws and regulations category, the stakeholders are fairly evenly distributed, except that the building material companies are not present at all. Real estate owners have the most barriers in Infrastructure, and in Market it is the consultancy and construction companies that have the most mentions of barriers. Lastly, the Culture and norms category is mentioned the most in total, and here the construction companies mention the barriers the most. However, the differences between the stakeholder groups are not further analysed due to reasons described in the methods chapter.

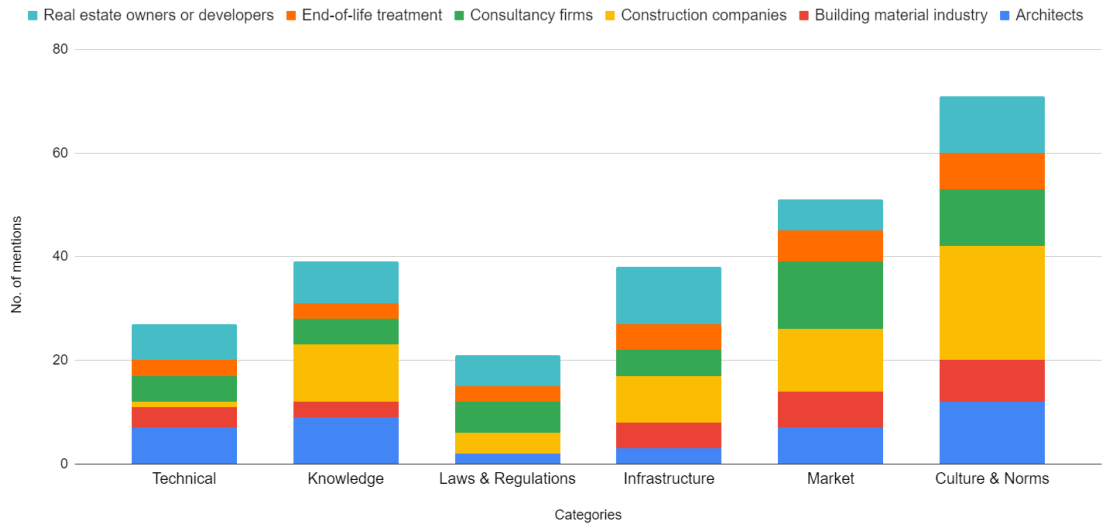

Figure 5.1: Overview of number of answered barriers by each category, divided into stakeholder groups (stacked).

5.2 Presentation and analysis of the barriers

In this chapter, RQ 2 and RQ 3 are answered, "Which barriers are mentioned by different actors in the building sector?" and "What are the causes and effects of the barriers mentioned by actors in the building sector?"

In the text, every barrier is marked with "-" for how they were coded and accepted by the experts who said them to be phrased (seen in Appendix C). The subcategories are written in italic. Culture and norms is written as C&N, and Laws and regulations is written as L&R.

5.2.1 Infrastructure

The category of Infrastructure barriers is divided into *information* and *transports*, in order to divide the non-physical from the physical logistics. As seen in Figure 5.1, the spread of actors mentioning the barriers in this category is fairly evenly distributed. The real estate companies are representing a slightly larger share of the barriers and the construction companies also mention a little more barriers than the other stakeholder groups in this category.

5.2.1.1 Information

The sub-category *information* contains barriers regarding communication, actors, information about materials, timing of products and supply of products.

The communication barriers are "Lack of communication", "Additional co operations are needed" and "Lack of a comprehensive picture" and all concern the collaborations within a project.

The "Lack of communication" is due to that not everyone being involved in the project are fully aware of the goals of reuse. The additional co operations are described by one expert as caused by the limited availability of material, e.g. for a wall only parts of the wall can be made of reused material. This requires additional cooperation between different suppliers for the same wall. The problem of non available materials is also a barrier found in this same sub-group of *information* barriers.

The last barrier on the communication theme is about the comprehensive picture, and explained by one expert as: because there are many actors included in a project, the owner of a building is often not the one who developed nor built it, which leads to a lack of a comprehensive picture.

The barriers concerning actors are "Lack of knowledge about actors", "Lack of knowledge about other actors' processes" and "Use of the same supplier".

The barrier "Lack of knowledge about actors", mentioned by one expert, is about the knowledge about to whom you can sell used products in good quality and which actors that would like to buy used products. This is connected to the barrier mentioned by another expert in the Knowledge category, "Uncertainties about demand" (*future*) where it is stated that it is hard to know if and when someone will buy the reused products. These two barriers both affect each other and it is not certain which is the cause for the other.

The barriers about knowledge about other actors' processes, for example demolition and ventilation, make people not consider reuse in another area than their own. Furthermore, it is common for construction companies to use the same supplier and the contractor gets a return, which makes them keep the same supplier. Both these barriers are explanations to why reuse is not considered and can be explained by the C&N barrier "Habits" (*working group*).

The barriers about information about materials are "Information about materials is missing", "Information that needs to be traced for interior" and "Information that needs to be traced for foundation". The information that is missing about the materials are the history of the product, its quality, content and strength and for concrete, it is hard to determine substances.

For interior, the information needed in order to reuse an interior product are given by one expert as the following: aesthetic condition and function, environmental saving, logistics, requirement fulfilling, quantity, current location and size. For the foundation, the information mentioned by one expert are documents, supplier information, weather conditions, quality and demountability which are needed in order to reuse a foundation.

For all the barriers mentioned in the previous paragraph, finding the information that is missing is a new step in the working procedure. This lack of information of

different kinds leads to the uncertainties "Uncertainties about warranty" and "Uncertainties about reusing products" which both are in *warranty*. The lack of information about the foundation, mentioned by one expert, also causes the barrier "Hard to value reused products" (*weighting*), mentioned by the same expert, since the information is needed to estimate the value.

The barriers "Hard to match availability and supply" and "Products are locked in use" are about the timing of products. It is hard to match products from a demolition site/project with a receiver and it complicates the planning process when guarantee is needed that the products will show up on time and in the right amount. Also, some products that will be available for reuse in the future are currently in use. The issue of matching availability and supply is caused by the lack of storage for construction companies and real estate owners, found in *transports*. This might also be connected to "Routines for projection" mentioned by another expert in *routines*, which is about the routines that are missing for getting products from demolition projects into new production. This is a challenge for construction companies, which are highly dependent on products showing up on the right time and in the right amount.

The barriers "Lack of availability of reused products" and "Lack of an established marketplace" both concern the supply of products. The lack of availability makes it hard to find products in the right quantity and quality. Furthermore, the lack of an established marketplace makes the process of finding the products needed time consuming and complicated. This is because there is no well established marketplace where it is easy to find products. The additional time causes the barriers "Additional time needed to prepare for reuse" and "Additional time needed for the design phase", both found in *time* and explained by the fact that finding reused products takes more time.

5.2.1.2 Transports

The sub-category of *transports* concerns storage, transport and other services.

The barriers about storage are "Storage not available" and "Responsibility for storage". The availability of storage is a space constraint and the need for storage is caused by the matching of availability and supply, mentioned above in *information*. The responsibility is described by one expert as the routines are lacking for storage and responsibility is unclear.

The barrier "Transports" mentions that it is complicated to transport products long distances. The barrier "Lack of actors and services" is about services for storage, supply and remanufacturing. Both these barriers are not clearly connected to any other barriers.

5.2.1.3 Summary of the Infrastructure connections

Within the Infrastructure category, there is a double connection between *information* and *transports*, as they affect each other. There are connections to *time*, *warranty*, *weighting* and connections from *routines* and *working group*. There is one double-sided connection between *information* and *future*. All these connections are illustrated in Figure 5.2.

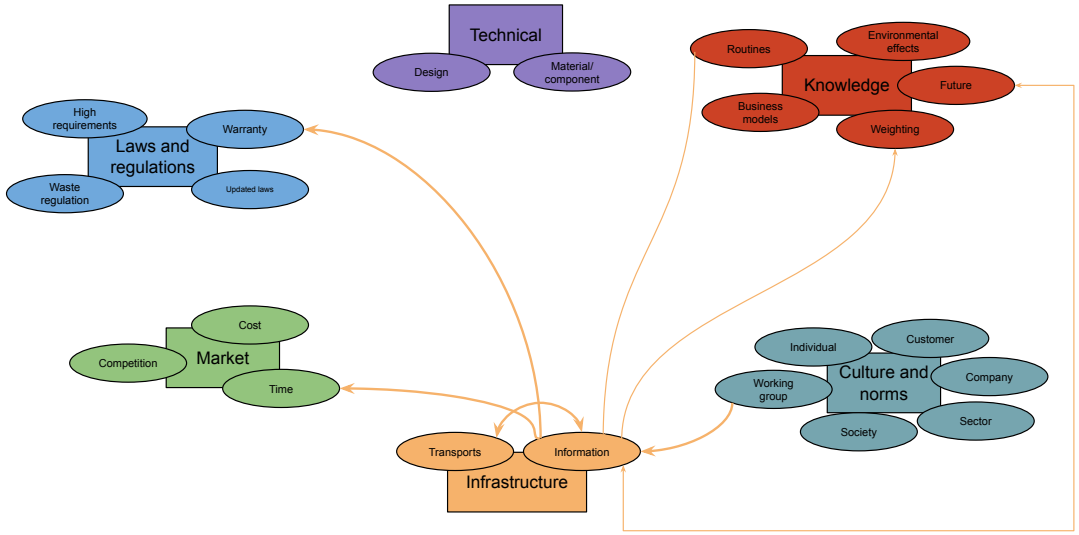

Figure 5.2: Connections drawn in the Infrastructure category.

5.2.2 Laws and regulations

This section is about laws and regulations that hinder reuse. It is about *warranty, waste regulation, updated laws* and *high requirements*. Real-estate companies and consultancy companies are the biggest groups in this category.

5.2.2.1 Warranty

Warranty is a sub-group of barriers including regulations, such as warranty and CE-mark, and uncertainties connected to obtain these when reusing products.

The first barrier is "Warranty", connected to standard agreement about how the contractor has to leave a 5 year warranty on their work (Boverket - National Board of Housing, Building and Planning, 2021). Today, it is the developer that is responsible for the warranty if there is no producer associated to the reused product that is built in, according to one expert. However, also construction companies need to give the warranty on their constructions. Three experts said that this is not possible for reused products, and one of them added that this is because someone needs to be responsible for the risk. For reuse in the future circular business models, another expert says that there are uncertainties about which stakeholder will be responsible

for the guarantee of the reused materials: the property developer, the construction engineer or the construction company.

Similar to warranty, also "CE mark" is necessary for many products today. If CE mark is missing for a product, it is hard to know if the product still have the same performance and can be reused unless it is tested in an accredited laboratory, one expert said. However, another expert talked about how in renovation projects, this is not necessary. CE mark and Warranty affects the barrier "Getting warranty on reused products is costly" (*cost*) because there is a fee for testing of products.

The warranty is a problem because there are uncertainties whether it is possible to obtain a new warranty on used products ("Uncertainties about warranty"). One reason for this is the barrier "Uncertainties about reusing products", because it is often unclear if products still have the same performance if they are moved and remounted. One expert gave the example that ventilation products might need evaluation and testing if they can be used in the new system, and it is hard to predict if they can be used or not. This is called secondary effects.

The uncertainties related to warranty leads to "Perception of high risk to start with reuse" (*company*). One expert from a construction company said that nobody wants to take the risk of something going wrong, when, in the meanwhile, buying a new product does not include the same risk.

5.2.2.2 Waste regulation

Current laws are prohibiting to reuse products, which is seen in the barrier "Waste regulation". One expert says that when accounting for waste, it is not clear how to treat reused products. Depending on if it is waste or a product, different laws are applied (Swedish Environmental Protection Agency, 2020). Another expert also talked about this issue of waste regulation, and said that if waste from a demolition site should be accounted as a product, it might be complicated to get permission to use it as a reused product when it already has been classified as waste.

5.2.2.3 Updated laws

"Old windows do not fulfil energy requirements of today" means that because the U-value is much higher for new windows today it is hard to reuse windows. However, maybe it is possible to renovate the windows to save the material and lower the energy consumption of buildings. It is hard to know what is the right choice to make, due to "Uncertainties about reusing products" (*warranty*), because there are uncertainties if products still have the same performance if they are moved and remounted. It was also mentioned by one of the experts talking about this barrier, that this is mostly a problem for the developer since they are responsible for the warranty.

Another barrier in this sub-category is "Requirements of foundation increases" such as construction requirements and protection against floods, which might make it complicated to reuse foundations from 5 years ago, due to changes in the law. Sim-

ilarly, there is the barrier "Requirements of building products gets updated". A lot of products are not possible to reuse, due to changes in the law, for instance one expert gave the example of new laws for fire safety and accessibility of wheelchairs that makes it hard to reuse doors. This is affected by one barrier mentioned by the same expert who gave the example, "Everyone/everything is set on new materials" (*society*) and it includes laws, regulations, processes and people's mindset.

5.2.2.4 High requirements

"High requirements for building products" is about that due to pre-cautionary measures, laws for materials safety and chemical substances hinder reuse of some products. However, this is not only a bad thing, one expert said, but still it makes it more complicated to reuse. "High lowest standard for residences in Sweden", means that, a residence need to be fully equipped before the resident can move in. This is different from many other countries. One expert said that, if it was possible to move into an apartment without it being fully equipped, it could favour a second-hand market of for example kitchen appliance.

5.2.2.5 Summary of the Laws and regulations connections

From the L&R category, there are connections to *company* and *cost*. There is one connection affecting, which is *society*. There is one connection within the category of L&R, going from *warranty* to *updated laws*. All connections drawn in this category are illustrated in Figure 5.3.

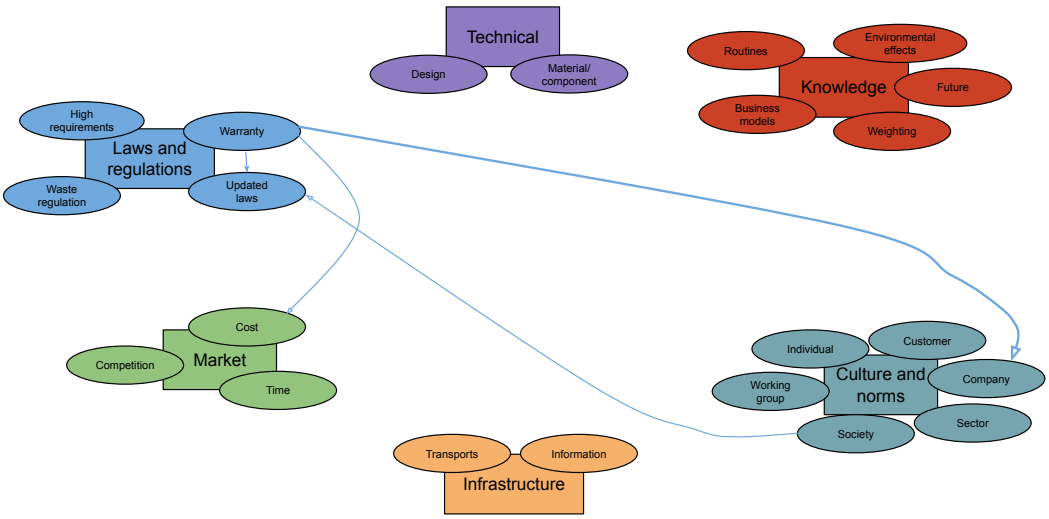

Figure 5.3: Connections drawn in the Laws and regulations category.

5.2.3 Market

In the category of Market, the sub-categories *time, cost* and *competition* are included. It contains processes that take more time, additional costs and competing phenomenons to reuse. It can be seen in Figure 5.1 that the category of Market was the second most mentioned one. The category was most mentioned by consultancy companies and construction companies, but the other stakeholder groups are also present in large shares.

5.2.3.1 Time

In this sub-category of barriers related to time, additional time needed for reuse in different steps of the process are mentioned. The specific steps mentioned are projection/design and deconstruction.

The barriers "Too late in process" and "Complex to handle materials" are more general about the whole process. One expert said that it is hard to make decisions about reuse if it is not implemented from start, which is connected to the barrier "Reuse is not considered by owners" (*customer*). This barrier describes that it is not possible to reuse if the owner does not want to. If the owner is not convinced early in the process, it is almost impossible to make changes in favor of reuse later. These two barriers affect each other, since if it is too late it is hard to convince the owner and if the owner is not interested it is hard to convince them.

The barrier "Complex to handle materials" is about the extra time needed due to additional steps in the working procedure,´such as handling of logistics.

There are four barriers related to the additional time needed in the projection and design phase of construction projects. These are "Reused components might need customized solutions", "Additional time needed to prepare for reuse", "Additional time needed for the design phase" and "Additional time required to evaluate products and design in the projection phase".

The barrier "Reused components might need customized solutions" mentioned by one architect, explains how customizing solutions and integrating reused products take more time. This is partly caused by the design barrier mentioned by the same architect, "Match new and old" (*design*). This is explained further in Technical, design in section 5.2.4.1 and thus the connection is not included here. The difficulties with the routine of design can be connected to "Mindset of workers" (*working group*), since it is mentioned that the process of design gets turned around when working with reuse and this can be a difficulty, thus leading to additional time needed.

The barriers of additional time needed to prepare for reuse and needed for the design phase both mention that finding reused products requires additional time. When preparing for reuse, also inventory takes time and the owner/user does not want to wait additional time when renovating or moving. The extra time needed to find products can be linked to the barrier "Lack of an established marketplace"

(*information*), where the additional time (due to not using the usual marketplaces) is also mentioned. This connection is already mentioned in section 5.2.1.1 and not drawn again in this section.

The barrier of additional time needed in the projection phase is caused by evaluation of the quality of products and lack of routines for designing with reused products according to one expert. This is connected to the difficulties of procurement, "Lack of knowledge about how to procure reused products" (*routines*) and the need for evaluation, "Uncertainties about reusing products" (*warranty*).

The barriers related to the additional time needed for deconstruction are "Additional time needed for deconstruction", "Not profitable to deconstruct" and "Safety measures in the working environment". The main theme is that deconstruction takes more time due to more careful handling and this causes an additional cost which can be connected to the barrier "Labour is expensive" (*cost*). However, the barrier about safety measures for demounting components, mentioned by one construction company, is about the lack of routines for demounting. Since there are no standard procedures for how to safely demount structural components yet, it is more time-consuming to plan. The expert from this construction company also mentioned some problems with the routines that has been coded as barriers in *routines*: "Routines for projection", "Routines are missing for remounting of products" and "Different routines", which are part of the cause for the lack of routines for also demounting the components.

To change the way buildings are demolished, and spend more time to deconstruct them, will cost more and there are risks associated with this for the company that choose to change their procedure. This results in the barriers found in *company*: "Hard to change business model" and "Perceptions of high risk to start with reuse" because, as one expert put it: someone needs to be responsible for the risk.

5.2.3.2 Cost

The barriers in the sub-category *cost* are mainly about the lack of profit from working with reuse. However, one barrier is not about profit but rather about the true cost of a product or material, "Lack of a comprehensive pricing". When the price of a product/material is set, environmental factors such as waste handling are not considered. This issue of environmental effects and value is also mentioned in barriers in *weighting* and the lack of a comprehensive pricing is partly caused by the "Lack of awareness/knowledge about the inherent value in products" and "Lack of knowledge about environmental effects and reuse of products".

The other barriers in *cost* are about the additional costs that make reuse not profitable, such as storage ("Storage is expensive"), handling, deconstruction and testing ("Reused products are expensive"), extra labour costs ("Labour is expensive") and testing of performance to get warranty ("Getting warranty on reused products is costly"). The need for warranty is caused by legal obligations, as seen in "Warranty" (*warranty*). The cost for handling and deconstruction is caused by the additional

time needed, as mentioned above in the sub-category *time*. There is additional time needed in both projection and deconstruction and due to the cost of labour this becomes an additional cost.

There are also barriers connected to the lost income of discounts ("No profit in reuse") and supplement charges ("Suppliers make more profit when selling new products"). "No profit in reuse" is explained by the experts as it is hard to get profitability from working with a circular business model. One expert gave the example that people work voluntarily at reuse centres. Construction companies do not make much profit from installing reused products, they usually get discounts when they are buying from their usual supplier, who are not offering reused products, one consultant said. These discounts are similar to the supplement charges, two experts mentioned that some profit can not be made for present products on a building site, due to supplement charges for new products. These issues with profitability results in the barrier "Hard to change business model" (*company*), since it is hard for companies to change to less profitable ways of working with reuse,

Moreover, this lost income and more costly way of working is also contributing to the "Competition in procurement process" also found in this sub-category of *cost*, where it is stated by one expert that the procurement does not generally enhance reuse, because the contractor with the cheapest way of doing things will win. Two experts from construction companies said that additional man-hours required for implementing reuse is not profitable for a construction company, due to competition. This is a problem for a construction company since the procurement has to require reused products in order for it to be profitable for the contractor to implement reuse. Thus the root of this problem can be explained by the issues in procurement, as the barrier "Lack of knowledge about how to procure reused products" (*routines*) would solve the competition problem if it were to be improved.

5.2.3.3 Competition

In the sub-category competition, the barriers are not about the same competition mentioned above in cost, but rather about phenomenons competing with reuse. These are waste and the linear system of new production.

For waste, the barrier to reuse is that there are other interests in the materials, these are energy recovery or recycling ("Different interest in waste materials") or that is is more beneficial to recycle ("Financial benefit to recycle metal") or discard ("Cheap to discard products/materials"). District heating companies have an economic interest in waste materials for energy recovery, according to one expert. Other experts said that recycling or energy recovery has a lower cost compared to being reused, due to existing systems and services, and it is for example possible to sell metals for recycling. There are also no charges to downcycle products and landfilling is cheap. There are little to no costs of throwing things out instead of reusing them. Because of these reasons mentioned by different experts, it can be more beneficial to recycle or discard materials. Also because of the additional costs for reusing products, by factors mentioned above in the sub-category cost.

The costs of reused products are also the reason for that new materials can be cheaper, taking into consideration the costs of handling reused components ("New materials are cheap"). But as said by one expert, the value of new products are not reflected in the price so people are used to choose whatever product they want, and are not economical with resources. This can be connected to the barriers about environmental effects and prioritisation of them, from *weighting*: "Lack of awareness/knowledge about the inherent value in products" and "Lack of knowledge about environmental effects and reuse of products".

The barrier "Companies have to pay for having a circular business model", mentioned by one expert is about how, due to the linear system, companies who adapt a circular business model and work with reuse have to pay the difference. The reason for that companies have to pay for having a circular business model is that the linear system is the norm, and when the system is linear, all laws, regulation, processes, certifications and people are set on new production, as said by another expert in the barrier "Everyone is set on new materials" (*society*).

5.2.3.4 Summary of the Market connections

All connections that have been identified in this category are illustrated in Figure 5.4. Within the category of Market, there is a connection between *time* and *cost*, strengthened by several barriers and therefore marked thicker in the figure. Within the category, there is also a connection from *cost* to *competition*. There are also connections from *warranty*, *routines*, *weighting*, *working group*, *society* and *company*. The barriers in Market also affect the sub-category of *company* and there is one double-sided connection between *time* and *customer*.

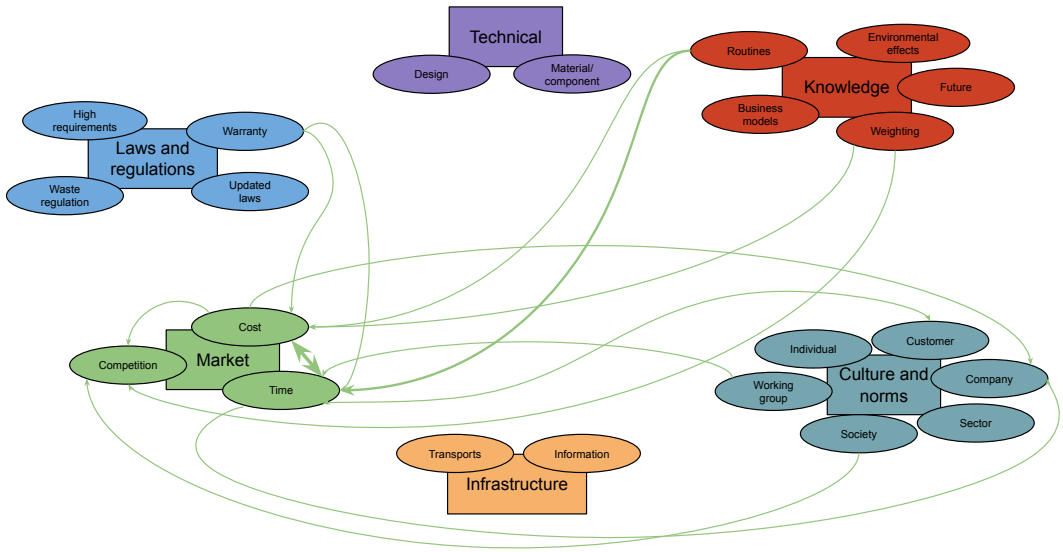

Figure 5.4: Connections drawn in the Market category.

5.2.4 Technical

Technical has two sub-categories. These are *design* and *material/components*. The sub-category *design* includes barriers which are related to design and the design phase, due to physical obstacles by material components. *Material/components* are barriers connected to the existing products, their quality, condition, and how they are constructed.

5.2.4.1 Design

The first barrier in this sub-category is "Adapt design to what is available". This might be a challenge for architects, because the design will be steered by products that are available. This is affected by the barrier "Components available for reuse are not always the desired ones" (*individual*), which means that, from architects, there might be a resistance against working with reused products, because they might be boring, ugly and uninspiring to work with. Another reason for the resistance might also be "Habits" (*working group*), because people are used to doing as they always did. Moreover, since "new and fresh" is the norm, there might be a challenge to get acceptance from customers to use reused products, so the barrier is also affected by "Mindset of customers" (*customer*).

It is also a challenge to "Match new and old", one expert gave the example that old products are not compatible with a new module system. This might require more time in the projection phase, so it affects: "Reused components might need customized solution" (*time*). It also requires more time in the projection phase "Additional time needed to prepare for reuse" (*time*) because of the material inventory that is necessary. This is also due to "Lack of an established marketplace", which also increases the time needed (*information*). Furthermore, this also has to do with "Products available for reuse are not in the right size", because the lack of an established marketplace increases the difficulty to find reused products that have the right dimensions.

5.2.4.2 Material/components

This group of barriers are connected to material properties, how they look, their condition and their quality. The first barrier, "Not designed for disassembly" means that, some products are glued or mounted to the wall, and hard to disassemble without breaking. Foundation and cast concrete are also problematic to disassemble. This leads to "Not profitable to deconstruct" (*time*) because there is more time needed for deconstruction instead of demolition, and that is expensive.

Connected to this, since it is not designed for disassembly, it may be "Hard to separate components". One expert gave the example of tiles, another talked about glued floors. Two building material experts talked about cement-based mortar for bricks, which is harder to separate to reuse the bricks compared to lime mortar.

This leads to buildings and materials being demolished instead of deconstructed since there are no charges to downcycle products and landfilling is cheap, so it is affected by "Cheap to discard products/materials" (*competition*).

"Polluted or hazardous materials in present buildings" is a barrier because there are certain chemicals that are not wanted in the built environment, e.g. PCB, asbestos and flame retardants in insulation. However, for certain chemicals, there are pre-cautionary measures: "High requirements for building products" (*high requirements*) which means that laws for materials safety and chemical substances hinder reuse of some products. One expert said that it does not have to be a bad thing to be careful about chemical usage, but sometimes it might be an obstacle for reuse.

The next barrier on the list is "Materials are worn out", from wear and tear. However, this is not always the reason for products being discarded, sometimes it may only be aesthetic reasons, and the products are discarded because of "Mindset of customers" (*customer*). This barrier says that new and fresh is the norm, and that customers do not want reused products because it has a rumour of being "dirty". This is strengthened by one expert who said that demolition many times occur before the technical lifetime of for example an office is over, and that products that are worn out are not the main reason for offices being renovated too early. However, some materials might be old and in bad condition, and then it could be better to recycle them. This is connected to the next barrier: "Materials/components are of poor quality", which is mostly mentioned about buildings from the 70s and 80s. If it is not possible to reuse them because the material is already worn out, recycling might be a better option. A reason for bad quality of materials might be "Competition in procurement process" (*costs*) which makes the companies find cheap and quick solutions which often do not enhance reuse.

There are some barriers regarding the environment which the building products are situated in. "Products are made for certain weather conditions" one expert said, for example a foundation at the seaside have other requirements than if it will stay inland. Furthermore, "Reuse is not suitable for all environments and materials/products", examples given from one expert were heavy duty environments like travel centers which need products that wont break easily, or environments like hospitals which need to be sterile. An example from another expert is that a radiator needs to have the right efficacy for its new environment in order to be reused. This makes it hard to set goals "Uncertainties about ambitions for a company" (*business models*). This means there is an uncertainty about how much reuse should/can be implemented in a strategy and what products should be included.

5.2.4.3 Summary of the Technical connections

The technical category is affected by *High requirements*, *costs*, *information*, *individual* and twice by *customer*. It is affecting *business model*, *working group*, *competition* and *time* twice. All connections drawn in this category are illustrated in Figure 5.5.

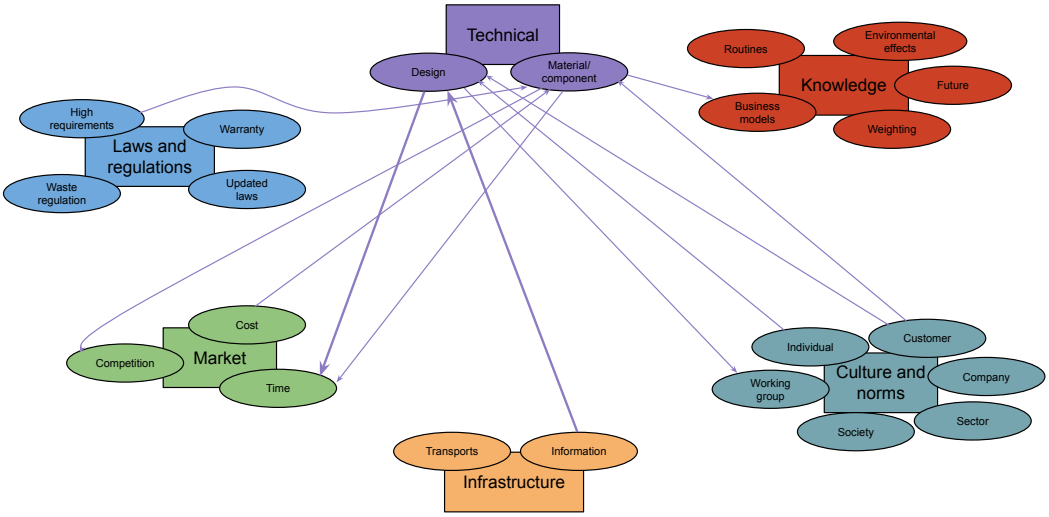

Figure 5.5: Connections drawn in the Technical category.

5.2.5 Culture and norms

The category of Culture and Norms contains everything that is related to attitudes, thoughts and norms. Customers, workers, or company's strategies are included, as well as mindsets of individuals or the sector as a whole, or even the whole society. There are sub-categories for each "level", from smallest to largest: *individual*, *working group*, *customer*, *company*, *sector* and *society*. This category was most mentioned by the experts, as can be seen in Figure 5.1. In the figure it is also clear that the construction companies mention the most barriers in this category.

5.2.5.1 Individual

The barriers on the individual level are about the personal responsibility and a reluctance towards working with reuse. The individual that the barrier concern can be anyone working in the construction sector.

The personal responsibility can be seen in the barriers "Not everyone in the sector are engaged in the issue" and "Hard to act alone for individuals". The personal responsibility of being involved in the issue of reuse is not visibly connected to any cause, and might be totally cultural and a question of interest. One expert mentioned that at reuse events, mostly people working with environmental questions are engaging, there is a lack of CEOs and decision makers.

The cause for that it is hard for the individual to act alone is the risks with reuse. It is hard to push for reuse in your company if it is not implemented by the company or asked for by the customer. It is hard for individuals to take the risk by themselves. In the case of a construction company, one expert from a construction

company said that one risk is taking the legal responsibility for warranty of reused products. This can be seen in the barrier "Warranty" (*warranty*), where the same expert said "Construction companies need to give a 5 year warranty, which can not be given for reused products, this is not possible today for reused products because someone needs to be responsible for the risk."

It is also hard for individuals to convince customers to implement reuse in projects, another expert said, which is caused by the "Mindset of customers" (*customer*), as the customer's mindset have to be changed by the person wanting to implement reuse.

The reluctance towards working with reuse can be seen in the barriers "Components available for reuse are not always the desired ones" and "Lack of motivation". The reason for that components can be undesirable is that they can be "boring, ugly and uninspiring to work with for architects", this is a barrier mentioned and perceived by architects only. However, the lack of inspiring products is connected to the availability of products on the market, which is mentioned in the barrier "Lack of availability of reused products" (*information*) and also which products that are possible to reuse, for example if they are not designed for disassembly or hard to separate, as mentioned in *material/component*, in the barriers "Not designed for dissassembly" and "Hard to separate components".

The lack of motivation, that workers are not motivated to find reused components even when compensation is given, was explained further in the example given from a real estate owner who mentioned the barrier. They proposed the theory that this was mainly because of habits, that they are hard to change and that leads to the lack of motivation. This makes a connection between *working group* and *individual*, both within the category of Culture and norms.

5.2.5.2 Working group

The barriers in *working group* are about the barriers present in the culture of teams and groups. These are "Collaboration between actors is lacking", "Mindset of workers" and "Habits". The collaboration mentioned by one expert, was explained: "Might be seen as fuzzy". Moreover, construction projects are usually not evaluated by the people who were included in the project, this makes it hard to learn from the last project when working with new people in the next project.

The mindset of workers is about how the whole process of design gets turned around when working with reuse, which can be hard to grasp for everyone included in the project. Similar to this, the barrier "Habits" is about how people are used to practices that are easy and quick to do, stopping them from trying new things, "Do as we always did". This culture in the working group and the way of doing things is connected to the barriers about the routines mentioned in *routines*: "Lack of knowledge about how to procure reused products", "Routines for projection", "Routines are missing for remounting of products", "Different routines". The lack of knowledge about routines leads to that the collaboration of actors does not improve, it is hard

to change way of working, to work with reuse, and workers stay in their usual way of working. This is a two-way connection since the routines in practice affect the habits and the habits can also hinder routines from changing.

5.2.5.3 Customer

The barriers in the sub-category *customer* are connected to the reluctance towards reuse and also lock-in. This sub-category holds both barriers for the real estate owner as the customer of a job, and barriers for the end customer, such as the buyer or tenant of the building.

The reluctance can be seen in the barriers "Mindset of customers", "Even if the price is the same, new is preferred", "Lack of demand" and "Reused products are too expensive". There is a perceived lack of acceptance from customers of reused products in new buildings according to many experts. Some experts say there is an expectation of high standards and "new and fresh" is the norm. Moreover, reused materials or products do not always become cheaper in the end, which makes reuse even less desirable for some customers.

This reluctance is also mentioned by the expert who mentioned "Reused products are too expensive": if the cost of handling and reconditioning a product makes it cost the same as a new product, the customer prefers the new. There are also few customers willing to pay for reused products, according to the experts who mentioned "Lack of demand". In addition, the expert who mentioned "Reused products are too expensive" said that companies are not willing to pay more for reused products, even if they know it is good for the environment. These barriers all show a reluctance towards using reused products, thus the cause is partly the cost, as the customer is not willing to pay for reused products, but also the norm that new is better. The higher price for reused products that makes the customer unwilling to pay in the barrier "Lack of demand" might be caused by some of the costs mentioned in *cost*: "Storage is expensive", "Reused products are expensive", "Labour is expensive", "Getting warranty on reused products is costly".

The barriers determined by existing systems are "Reuse is not considered by owners", "The customer decides" and "Reuse is not considered by the owner, for certain products". The first, that reuse is not considered, is explained as "Not possible to reuse if the owner do not want to keep a material" and points towards a non-flexible routine that is set by the customer, bound by time and cost and thus connected to *time* which in turn causes costs. This connection is already mentioned in section 5.2.3.1 and will not be included in the figure in this section.

Also the barrier "The customer decides" is caused by lock-in, since the construction company has to follow what the customer is asking for and cannot implement reuse if it is not asked for.

The barrier that reuse is not considered for certain products, is about that some products can be forgotten because they are small, not visible or not a big cost. Small

products might be forgotten even though they are of high quality, one expert gave the example of hooks of stainless steel. Installations are usually not considered to be reused, because they are not visible nor expensive, another expert said.

5.2.5.4 Company

The barriers on the company level are mainly about the risks perceived for reuse and the business models of the company. These barriers can concern any company active in the construction sector.

About risks are the barriers "Perception of high risk to start with reuse" and "Perception of high costs". The perception of high risk is caused by many uncertainties and leads to nothing happening in the company or in the sector. The perception of high cost is caused by lack of knowledge about the costs, in the cases where the cost actually is not as high as perceived. There is a connection to the knowledge about business models, "Lack of knowledge about costs" (*business models*) which is causing the uncertainties about costs and maybe wrongful perceptions.

There are also barriers concerning the business model: "Mindset of company", "Hard to change business model" and "Not in business model". The mindset of the company is about the lack of company policy or incorporation of reuse. Hard to change business model is about the difficulty of making the transformations needed to implement reuse, due to many uncertainties. Also, some activities are not included in the companies' business models, examples given by different experts were selling of products and take-back scheme of leftover building materials. Real estate managers do not have storage space in their assets and waste companies do not have possibility to run a store or facilities needed to do so. All these barriers are caused by the lack of change in policy or business model, which in turn can be caused by the lack of knowledge of many factors. Many uncertainties that cause these risks are listed in the Knowledge sub-groups *routines*, *business models*, *weighting* and *future* and will be handled in these sub-categories.

5.2.5.5 Sector

On the sector level are the barriers concerning the whole construction sector. There are some barriers on the theme of united action, "Companies are waiting for someone else to try reuse before them", "Hard to act alone for companies" and "Collaboration between construction companies is lacking". The reason for that no one wants to be the first is again the perception of high risk, thus connected to the perception of high risk on the company level. Moreover, the barrier of "Hard to act alone for companies" is about how it is a big responsibility for solitary companies to be predecessors in reuse, which is connected to that no one wants to be the first. The collaboration between companies is about how information will not be shared between companies due to competition, which is caused by culture in the sector.

Apart from the theme of united action, there are also two more unique barriers, "Perception of barriers" and "The market is focused on wood". In "Perception of

barriers", one expert explained that some barriers are perceived as big, such as laws, regulations, CE marks, sound requirements and hazardous substances. Even if they are important to keep track of, they are not the biggest barriers, and possible to get around. The barrier that the market is focused on wood was mentioned by another expert and explained as a problem because people consider wood as the most sustainable option for new production, forgetting about other solutions for sustainability.

5.2.5.6 Society

On the society level there are barriers about the culture of society that affects the construction sector in some way. There are three barriers mentioned by one expert each, "Everyone is set on new materials", "To repair and take care of products is not the norm" and "Reluctance to deconstruct buildings". "Everyone is set on new materials" is about the norms that hinder reuse: Laws, regulation, processes, certifications and people are set on new production. "To repair and take care of products is not the norm" is about how people are not used to taking care of products and repair them. "Reluctance to deconstruct buildings" is a barrier about how some buildings should not be deconstructed because they are in good condition and/or have a historical value. These barriers make working with reuse hard, as they hinder some processes and no materials will be available for reuse in other projects if no buildings are deconstructed.

5.2.5.7 Summary of the Culture and norms connections

All connections drawn in this category are illustrated in Figure 5.6. There are connections between the levels in this category. The *working group* and the *customer* affects the *individual* and *companies* affect the *sector*. Moreover, there are some connections from *warranty*, *information*, *cost*, *material/component* and *business model*. There is also a double-sided connection between *routines* and *working group*, strengthened by several barriers and therefore marked as thicker in the figure.

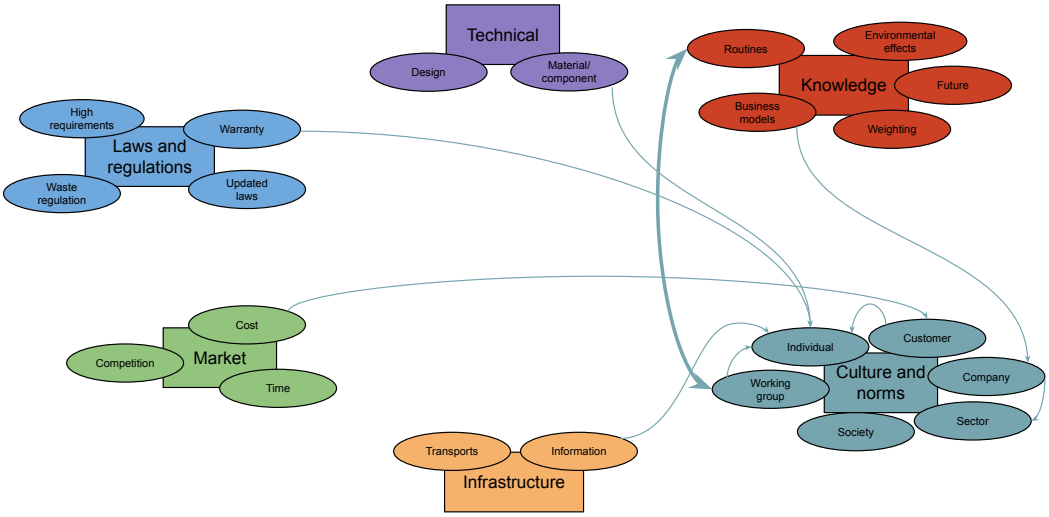

Figure 5.6: Connections drawn in the Culture and norms category.

5.2.6 Knowledge

Knowledge is a category of barriers connected to uncertainties and lack of knowledge. The sub-categories in this category are *routines*, *business models*, *weighting*, *future*, and *environmental effects*. Architects, Real-estate owners and construction companies are the ones mostly present in this category.

5.2.6.1 Routines

This subsection includes how complex it might be to change and adapt to new routines, and the first barrier is "Lack of knowledge about how to procure reused products". That means that, even if there are instructions, it is hard to implement them because there are many uncertainties about how to phrase the procurement.

One reason for this is "Lack of an established marketplace" (*information*), where two experts mention that it is hard to find the right quality and quantity when searching for products. Since it is hard to find products, there are many uncertainties in the procurement phase.

The barrier about uncertainty of the procurement also results in "Additional time required to evaluate products and design in the projection phase" (*time*), (this barrier is also mentioned in section 5.2.3.1 and thus not drawn in Figure 5.7). One example is that there is a risk of not getting any tender if suggesting a procurement in a non-conventional way, one real estate owner said. Since the real-estate owners are usually the ones writing the procurement this can be a barrier for them. This also results in "Hard to change business model" (*company*), where the same real estate owner describes that it is hard to change path from the linear business model.

Since remounting of products is different from what is usually constructed today, one expert says that "Routines are missing for remounting of products" and "Different routines" are barriers. "Different routines" means that depending on what type of product that will be reused, it is complex to set up routines because of the diversity of products in buildings. Some examples are that interior products mainly need to have good aesthetics and functional condition and structural elements need a further quality assurance and testing.

The barrier do not have any direct connections but might be similar to "Routines for projection" which, similar to "Hard to match availability and supply" (*information*) means that routines are missing for getting products from demolition projects into new production (this is already mentioned in section 5.2.1.1 and will not be drawn in Figure 5.7).

"Lack of knowledge about how to procure reused products" are also affected by "Lack of an established marketplace" (*information*) since it is dependent on getting the product on time and in the right amount. It is also affected by "Habits" (*working group*), that people are used to work in a certain way which is usually the easy and quick thing to do. This might be one of the explanations to why it is hard to change routines. That is why this one also is affecting "Mindset of workers" (*working group*), that the process gets turned upside down and everyone have to change the order they do things, which might be very complicated.

One reason for changing of routines is that "Products available for reuse are not in the right size" (*design*) where one expert describes another way of both designing and procuring, because of materials that have different dimensions than what is common today (e.g. pillars).

One reason it might be complicated to change routines is that there is a "Lack of case studies", which could be a way of practice to work with the new routines. The lack of case studies is both affecting and affected by "Perception of high risk to start with reuse" (*company*). Since there is just a few case studies, it means that only a few companies have tried reuse and might have prejudices about it being too expensive or complicated.

5.2.6.2 Business models

This sub-category includes barriers connected to uncertainties and lack of knowledge about costs and business models.

"Uncertainties about ambitions for a company" is the barrier mentioned the most in the Knowledge category. It means that it is unclear how to work with reuse for companies: how much reuse should/can be implemented in their strategy and what products should be included. This barrier is affected by "Uncertainties of demand" (*future*), for example one expert means that there is an uncertainty if anyone will buy this product and, if someone does it is also uncertain when it will hap-

pen. It is also affected by "Considerations of different factors" (*weighting*), which are questions such as, mentioned by one expert, when choosing products for reuse, weighting design and demountability. Moreover, another expert said that it is hard to know how to prioritize when weighting design, costs, antiquarian value, indirect, and direct environmental costs of buildings when considering reuse. This is different for different products and it might be hard for companies to know what to prioritise.

"Lack of knowledge about how to work with reuse" means that there are uncertainties about what reuse means, and routines for the working procedure are missing. This is also affected by "Habits" (*working group*), that it is easier to do as one is used to, and also it is the quick and easy way of doing things. This barrier is also connected to "Uncertainties about which expertise is needed", because it is unclear how new roles will be managed. The expert mentioning the barrier gave the example of performing inventory and the question is whether or not the expertise exists already within the company or if the company should hire someone.

Because of the uncertainties about how to work with reuse and how to implement it within a company it leads to "Reuse is not prioritized", that was mentioned by one expert. Another reason it is not prioritised is because there is a lack of demand, and the expert's perception is that "Reuse is not considered by owners" (*customer*). The owners are the customers and choose what they want, thus, the lack of demand from the customers also affects *business models*.

"Economic effects are not known" means that positive effects of reuse, such as shorter construction time, are not clear and this might hinder companies from trying. A similar barrier is "Lack of knowledge about costs", which concerns companies who want to work with reuse but fail because of lack of knowledge and experience about how much reuse will cost. This might be why "Companies are waiting for someone else to try reuse before them" (*sector*). This means that no one wants to be the first to start with reuse, and this is also connected to "Reuse is not prioritized" in the strategy of a company.

"Lack of knowledge about costs", that it is hard to know if it is profitable or not to use reused products, is connected to "Lack of knowledge about transports and reuse" (*weighting*), if the environmental benefits will be neglected by a higher economic cost. Another reason is that storage, which at the moment is not available for some companies, will cost extra: "Storage not available" (*transports*). Another factor is "Additional time needed to prepare for reuse" (*time*) which also might be an increased cost because of the inventory that is needed, as well as "Additional time needed for deconstruction" (*time*).

This group of barriers are caused by other sub-categories in Knowledge, such as uncertainty about *future*, *weighting* and *routines*. Although not explicitly stated in an interview, but it might be assumed that it is affecting *company*, because of "Perception of high risk to start with reuse *company*). This might be an explanation to why many companies are hesitating about starting with reuse, or why it is hard:

because there are many uncertainties.

5.2.6.3 Weighting

Weighting is a category where different factors have to be chosen between. Some of the factors - or the outcome of choosing between them, are not known.

"Companies focus on productivity and not on waste" is a description of the current situation of most demolition and construction companies, mentioned by one expert, because "New materials are cheap" (*competition*). If changing focus, the whole business model need to change because of "Additional time needed for deconstruction" (*time*).

"Lack of knowledge about transports and reuse" is affecting "Lack of knowledge about costs" (*business models*). "Lack of knowledge about transports and reuse" means that additional transports might override the positive environmental effects of reuse. It is similar to the next barrier on the list, "Lack of knowledge about environmental effects and reuse of products" which means that the amount of CO_2 emissions that are saved and other positive effects from reuse are not always known. One expert gave the example of changing windows to more efficient windows or keep old ones and save materials. So these barriers are about how to prioritize what products to reuse.

"Lack of awareness/knowledge about the inherent value in products". One expert said that the environmental effects, such as resources and climate effects caused by the product are usually not included in the cost. Another expert also said that the time and work that have been put into a product are hard to estimate. By not mirroring the right prices, customers are not aware of the benefits of reused products, and this results in the perception of "Reused products are too expensive" (*customer*), because of the price of handling, deconstruction and testing. In turn, it affects "Mindset of customers" (*customer*), when the reused products are not as cheap as expected, that will make reuse even less desirable for customers.

"Hard to value reused products" is a barrier mentioned by one expert. Due to several uncertainties, demountability, transport, warranty, positive environmental effects, avoided waste and sale value for the reused product, compared to buying new material (its transports and negative environmental effects), it is hard to know the exact price for reused products compared to new ones. "Considerations of different factors" is a similar barrier which have been mentioned before (in *business models*), which affects "Uncertainties about ambitions for a company" (*business models*).

5.2.6.4 Future

This group of barriers are about uncertainties about the future of products, customer demand and availability of products.

"Uncertainties about lifetime" means that it is difficult to know the remaining life-

time of a product and also how long the lifetime needs to be. It is affected by several technical aspects, such as possibility to disassemble and quality of the products (*material/components*). It is similar to "Uncertainty about the future", which means that the long life-time of building products gives uncertainty about how the products will be treated in the end of life. This might affect "Uncertainties about ambitions for a company" (*business models*) because it is hard for companies to know how to implement reuse in their strategy when they do not know what will happen to the buildings in the end-of-life. "Uncertainty about the future" is also affected by "Lack of a comprehensive picture" (*information*), where one expert says it is not the same company who plans a building and who owns it or demolish it which results in lack of action in the building phase.

Another barrier, although not explicitly connected, is that reuse is "Not the only solution" to a sustainable building sector, just as wood is not the one and only solution to make the sector environmentally sustainable, one expert said.

"Uncertainties about demand", that it is unclear if and when someone will buy a reused product, is affecting "Perceptions of high risk to start with reuse" (*company*). One factor that makes this a risk is "Storage not available" (*transports*) since for companies trying to start with a new business model, the uncertainties about costs, connected to for example storage, is perceived as a risk.

"Uncertainty about customer demand" is that it is not known how customers want reused products or not. It is affected by "Mindset of customer" (*customer*), that there is a lack of acceptance from customers of reused products in new buildings.

5.2.6.5 Environmental effects

"Lack of awareness of how much waste that is generated" was mentioned by one architect, that there is a general lack of knowledge about how much waste that is generated in the construction process and how it can be avoided by different design choices, such as "Adapt design to what is available" (*design*). "Tenants lack knowledge" is about how their working/living environment is causing emissions. This in turn affects "Reuse is not considered by owners" (*customer*) and thus not implemented if it is not asked for by customers.

5.2.6.6 Summary of the Knowledge connections

Routines is affected by *design* and *information*, and has two double connections between *working group* and *company*. *Business models* is affected by *time, transports, working group, customer, future* and *weighting*. It is affecting *sector*, and is double connected with *company*.

Weighting is affected by *competition* and *time*, affects *business models* and has a double connection with *customer*. *Future* is affected by *customer, transports*, *information* and *material/components*. It is affecting *company* and *business models*. Lastly, *environmental effects* are affecting *customer* and is affected by *design*.

All connections drawn in this category are illustrated in Figure 5.7.

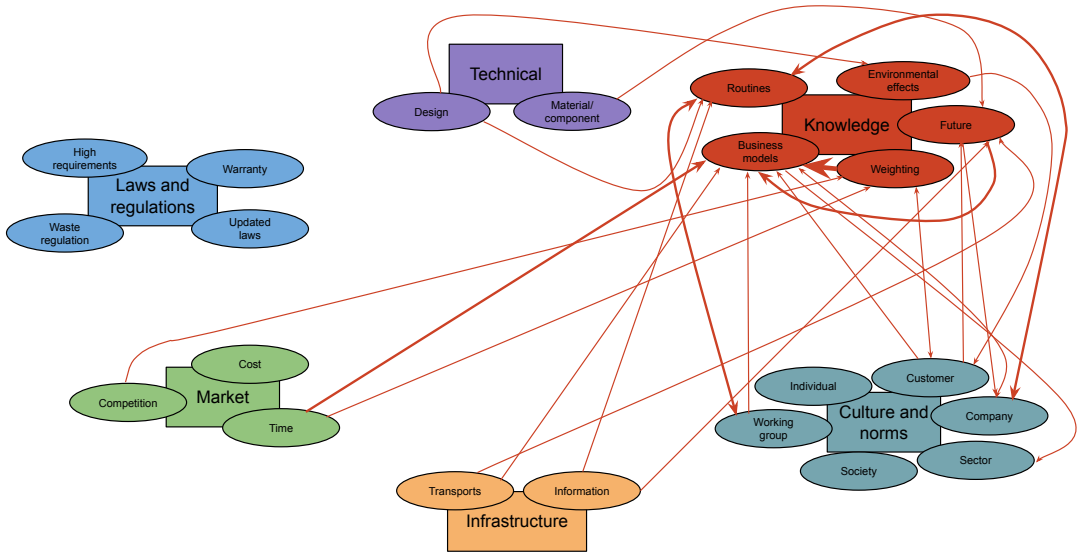

Figure 5.7: Connections drawn in the Knowledge category.

5.3 Summary of categories

Here are presented the kind of barriers that were found, by category and sub-category.

Infrastructure barriers
Information: The sub-category information contains barriers regarding communication, actors, information about materials, timing of products and supply of products.
Transports: The sub-category of transports concerns storage, transport and other services.

Laws and regulation barriers
Warranty: This group of barriers are connected to warranty and standards, and if products are in a condition they can be reused.
Waste Regulation: How laws for waste are making it complicated to make it a product.
Updated laws: Laws that get updated with time, which means that old products cannot be used because they were produced when these new laws were not implied.
High requirements: Similar to updated laws, certain products cannot be used because their content is prohibited because of safety.

Market barriers
Time: In the sub-category of barriers related to time, additional time in different steps of the process are mentioned. The specific steps mentioned are projection/de-

sign and deconstruction.
Cost: The barriers in the sub-category cost are mainly about the lack of profit from working with reuse. (However, one barrier is not about profit but rather about the true cost of a product or material)
Competition: About the phenomenons competing with reuse. These are waste and the linear system of new production.

Technical barriers
Design: The sub-category design includes barriers which are related to design and the design phase, due to physical obstacles by material components.
Material/components: This group of barriers are connected to material properties, how they look, their condition and their quality.

Culture and norms barriers
Individual: The barriers on the individual level are about the personal responsibility and a reluctance towards working with reuse.
Working group: About the barriers present in the culture of teams and groups.
Customer: The barriers in the sub-category of customers are barriers about both the owner and the end customer.
Company: The barriers on the company level are mainly about the risks perceived for reuse and the business models of the company.
Sector: On the sector level, there are some barriers on the theme of united action. Also unique barriers (perception of barriers, focus on wood).
Society: The norms that hinder reuse: systems set on new production, people not used to taking care of products and keeping old buildings.

Knowledge barriers
Routines: Barriers connected to lack of routines, and uncertainties occurring due to a new way of working. This might be because of lack of routines, which is also included
Business models: Connected to uncertainties for companies, both how they can work with reuse and what the effects of that is. Also the current state at companies, and how they do not prioritize reuse, is included.
Weighting: About weighting different factors together for companies in order to make decisions, such as environmental effects, saving waste, additional transports and costs. One barrier is about what companies focus on at the moment.
Future: Also for companies, uncertainties about products and how to implement reuse in the strategy, and uncertainty about how the customers will react.
Environmental effects: This group is about awareness and knowledge about how the built environment is affecting the environment.

6
Discussion

In this chapter, the results from the interviews are compared to the results of the literature study. Next, the connections that were drawn in the previous chapter are discussed. Lastly, conclusions and recommendations are given.

6.1 Comparison of results from interviews and literature

The barriers found in literature were collected from sources spread globally. This difference in area of study from the interview study, of actors active in Sweden, can be the cause for some differences in the results. The literature sources were mainly focused on deconstruction and several were about steel reuse, which might give a result steered towards the technical and operational types of barriers. The result of the interview study was more about the culture, which might be because many of the interviewees were experienced with reuse and see challenges in the mindsets of others.

Some differences between the literature and the interviews can be noted in the themes found. The themes in Infrastructure and Market were the same for both literature and interviews, although the barriers found in the themes were similar but not identical.

In the Technical category, *technology* was a theme in only literature and *design* was found as a theme in the interviews. *Technology* can be more represented in the literature since some of the literature studied were focusing on the technology of deconstruction, and some studies looked at technical issues for reuse of structural steel. In the interviews, the presence of a *design* theme can be explained by the fact that three architects were included in the study.

The category of Culture and norms was also similar between the literature and interviews, although in the literature there were no themes of *individual* and *working group*. The personal responsibilities and habits in the working group could be more present in the interviews since this is more personal communication. However similar barriers were found in the literature, but on a higher perspective such as inertia in the sector.

In the categories Laws and regulations and Knowledge, the themes found differ

the most. For Laws and regulations, in the literature the themes found were *building codes and regulations* and *increased legislation*, while in the interviews they were *warranty, waste regulation, updated laws* and *high requirements*. The themes of *increased legislation* and *updated laws* are similar in character, as they both concern the laws that have been changed in a way that makes old buildings or building products obsolete. The other L&R themes are different and can be explained by the fact that the literature studied were from many different countries but not Sweden, while the experts interviewed were all active in Sweden. Since laws differ between different countries, only laws on European level found in the literature can be assumed to also apply in Sweden.

The Knowledge category was divided into *lack of experience, design phase* and *material value* in the literature study and into *routines, business models, weighting, future* and *environmental effects* in the interview study. *Lack of experience* and *routines* are about barriers of similar character, about knowledge of how to work with reuse. *Material value* in the literature is also similar to *weighting* in the interviews, since they both include barriers about the value. However, the *weighting* category include the difficulties of the different factors when evaluating the value and thus has a broader perspective on value. In the *material value* in literature, there is a bit of the environmental effects included, that was its own theme in the interviews. However, the themes *business models* and *future* are unique for the interviews and not found in the literature. These barriers that were found in this study could be considered to be new knowledge in this area and implies that there are uncertainties for companies to change their business models and uncertainties about the future which contributes to the challenges with reuse. These themes were also found in the analysis to have many connections and their causes are analysed in section 6.2.

The category of barriers in Culture and norms was the most mentioned in interviews but earlier not much highlighted in literature. This study has also found the importance of knowledge and how this is connected to many of the other barriers perceived by actors in the construction sector. This study shows that many connections are to knowledge and how increased knowledge and awareness could solve many of the challenges for reuse. However, the knowledge might already exist but the problem lies in that not everyone implements it. For the barriers of Culture and norms, the solution might be more difficult since norms are not easily changed.

6.2 Discussion of connections

The causes and effects of the barriers mentioned by actors in the Swedish building sector have been analysed in the previous chapter category by category. Here all categories are put together and discussed. In Figure 6.1, all connections between the sub-categories are illustrated. First, there is a small discussion about how the interpretation of Figure 6.1 can be made. Second, the sub-categories with only incoming or outgoing connections are discussed in section 6.2.1. This will answer RQ 3. The result is further discussed by also looking at the three thickest connections in Figure 6.1, this is done in section 6.2.2, 6.2.3 and 6.2.4.

The illustration of the connections in Figure 6.1 shows that there are many connections to Knowledge. Many barriers are caused by lack of knowledge or uncertainties. As seen in the earlier Figure 5.1, Knowledge was not the most mentioned category of barriers but as the analysis shows there are nevertheless many connections to it. There are also many connections to the most mentioned category, Culture and norms, which can be explained by the behaviour and culture of individuals, working groups, customers, companies, the sector and society which affect many other barriers.

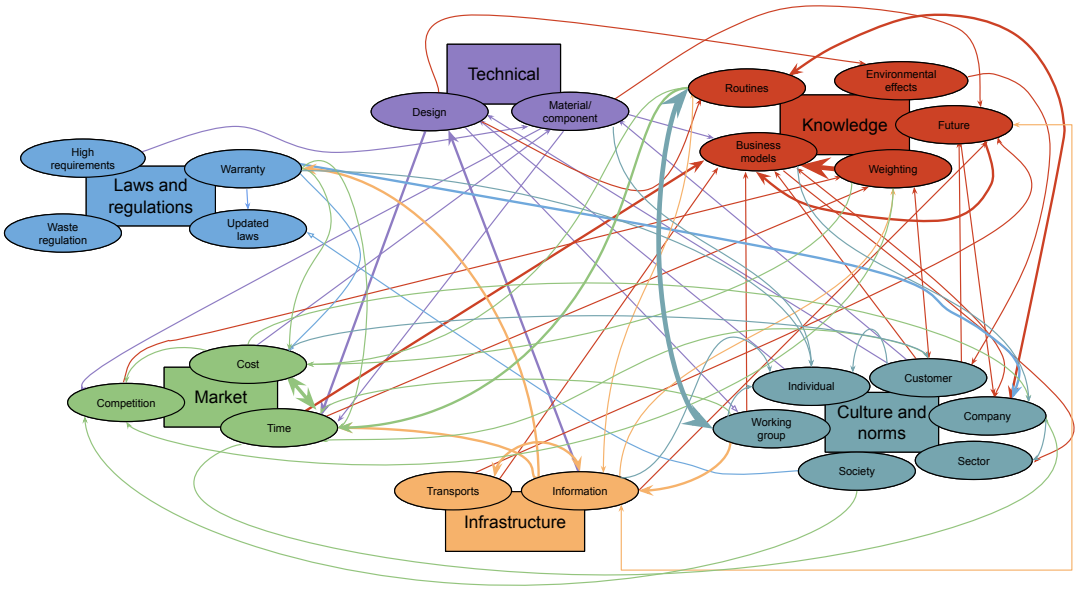

Figure 6.1: Illustration of connections between the themes found in interviews.

The many connections (illustrated in Figure 6.1) show that the barriers are intertwined and many parts of the system need to change in order to implement reuse on a big scale. The illustration shows what is the cause and effect for different groups, but does not distinguish which one is more important. This can be different for different cases and this study was done considering all sorts of projects and cases and thus some barriers are not present in all projects.

The connections are often double-sided, because there is not always one cause and one effect, in many cases the barriers affect each other both ways. The double-sided connections can also concern different specific barriers but within the same sub-category as there is no distinction between specific barriers in the illustration. However, many connections are one-way cause and effect.

There is one sub-category that have no connections to any other: *waste regulation*. This sub-category holds two barriers and each barrier is mentioned by only one expert. The reason for that there are no connections to them could be that the barriers are very specific for the case of the actor who mentioned it and thus not

connected to barriers connected to other situations.

The category of Laws and regulations has the smallest number of connections in the illustration (Figure 6.1) and was also the least mentioned category in the interviews, (Figure 5.1). Thus it seems that laws are not as big of a challenge in the Swedish construction sector as earlier portrayed in literature. However, two of the categories, *high requirements* is seen as solely cause and *updated laws* is seen as solely effect. There are two other sub-categories like this, in C&N: *sector* is only being affected, and *society* is only affecting. In section 6.2.1 it will be evaluated what this means for the result.

6.2.1 Causes and effects

Some sub-categories are affected by more barriers than they are causing, and thus have more incoming than outgoing connections. The opposite also exists, where there are more effects of one category than there are causes for it. There are only a few sub-categories which have only incoming or only outgoing connections which can be seen in figure 6.1. The only sub-categories with only outgoing connections are *society* and *high requirements*.

Society is a group of barriers concerning norms in the society, "Everyone is set on new materials", "To repair and take care of products is not the norm" and "Reluctance to deconstruct buildings". The two first barriers contradicts the last one, because the wish to keep old buildings should enhance the willingness to take care of what is already present in the society. On the other hand, buildings from the 70s were frequently mentioned as containing hazardous substances and material of low quality which are not possible, or not desirable, to reuse. There are many measures to enhance increased reuse but many of them need to be taken in the design phase by starting to make the components attractive for a second and third use, e.g. by DfD or by incorporating flexible design in buildings.

High requirements is a sub-category in L&R concerning both chemicals and residences. It is about keeping out hazardous substances by pre-cautionary measures and regulations about what a newly produced residence should contain. The first barrier might not be a bad thing, although it may be complicated to reuse products, unsafe chemicals should be kept out of the living environment. The second barrier about residences make the market of apartments special for Sweden. The question is what the effects are of taking away these laws and regulations, and maybe there are other ways of regulating and increasing the second hand market. Although, it was also mentioned in one of the interviews that it is hard to find buyers of second hand kitchen appliances. There seem to be a mismatch, a lot of new production and a lot of products that are discarded before their technical lifetime is over. There is a need of an increase of a second hand market.

The sub-categories that are only affected by other barriers are *sector* and *updated laws*. In *sector*, it is clear that there is a lack of cooperation between companies

and they are waiting for others to try reuse before them. It is also clear that the sector is focused on new production in wood. There is one different barrier, and that is "Perception of barriers", coming from a real-estate company working with reuse. That the sector is not affecting any barrier seems unlikely, since there is an ongoing inertia in the sector. However, this sub-group tells about how difficult it is to change business models and focus, although the need of doing that is clear to everyone. The lack of cooperation was clear in the interviews. Although managers want to learn about reuse, there is a lack of them on reuse events. Increasing the presence of CEO's and decision makers at events could engage the companies further.

Updated laws is a group of barriers saying that because of increased regulations, materials produced some years ago cannot be used today. This one is affected by the society in that case that everyone are set on new materials, laws, regulations and the mindset of people. There is a need of a bigger awareness in the society about new production and how it affects the environment.

That *society* and *high requirements* are only affecting and *sector* and *updated laws* are only being affected are the starts and ends of a complex and complicated chain of barriers seen in Figure 6.1. The result might also depend on several issues, such as not being mentioned by that many experts. To discuss the results a bit further, causes and effects within the chain will also be evaluated. This will be done by discussing the three thickest connections in Figure 6.1.

6.2.2 The connection between *weighting* and *business model*

This connection means that uncertainties about how to prioritize different factors, such as indirect and direct environmental factors, additional transports, antiquarian value and functional aspects of the materials/components, are increasing the uncertainties about the business models of companies, making it hard to implement reuse when the effects of different choices are not known.

Weighting is affected by *time*, *competition*, *information*, and *customer*. *Time* is a group of barriers concerning time in different parts of the projection and construction phase and is affecting weighting because of additional time needed for deconstruction. However, *time*, includes other steps in the projection phase, such as design, that might require additional time, which also could affect *weighting*. This is not visible in the result. It shows that there might be connections missing in the result, between other categories as well. The reason for that might be the choice of method, and how it was chosen to draw connections, based on transcripts and coding, and that because an expert is not saying that the connection is there - does it mean that it exists? The reason for doing the method was to not be biased by assumptions, and drawing based on the transcript gave a deeper understanding of the problems, since the interviewees own experiences were included.

However, in some way, the results are based on quotations, and the method used is a bit of a detour, and there is a risk of mixing together and loosing essential

information when the barriers were made. However, this was somewhat avoided by getting the allowance to publish the barriers from the experts, where they could change the barriers if they did not agree to them.

Market, *competition*, because new products are often cheaper than reused ones, this affects *weighting*. Another last sub-category affecting *weighting* is Infrastructure, *information*, because the lack of information about products also makes it hard to value them.

Affecting (and being affected by) *weighting* is also *customer*, since the inherent value of products is not known, for instance embodied energy and amount of work that have been put into new products, customers might think that reused products are expensive. In turn, since reused products are expected to be cheaper, but due to several costs connected to for example handling, testing and repainting, it might be even more expensive and many customers are not prepared to pay for that. The connections between*weighting, competition, information* and *customer* seems reasonable because many things must be included in different choices for, in the end, business model, which creates uncertainties.

The *weighting* category for the interviews is somewhat similar to *material value* from the literature, as described in section 6.1, however, in the literature, there is mostly knowledge about inherent value in products that is lacking (Earle et al., 2014), and Park and Tucker (2017) write about how the building relates to embodied energy, and how that effects running and construction costs. However, what is clear in the interview study, is how this affects companies and make them hesitate.

Business models, on the other hand, is being affected by many other barriers and not only by those from *weighting*. There are uncertainties concerning what products that are available, the quality of them, additional time required, it is easier to "do as we always did", lack of demand from customers and finally, lack of storage. However, it is only affecting one other subgroup, and that is *company*. "Perception of high risk to start with reuse", but this was the authors own interpretation, and not something that could be found in the coding. Since the business model category has barriers about uncertainties for companies that makes the companies hesitate.

Comparing with the literature, the category of *business models* is not included in the results. As described in 6.1, it might be because the interviews were direct conversations, however, the results from the literature study only catches the barriers, and not the implications for a company to the same extent as when connections were drawn for the results of the interview study.

However, the interviews gave a deeper insight in the problems facing actors who want to work with reuse, and it is clear all these factors make it hard to motivate companies to start with reuse, since the risk might seem big. This might also affect the sector, as mentioned in section 6.2.1. On the other hand, it is clear that companies need support and help to prioritize. It might be open source-projects, like

Reuse West, or sharing information in some other way between companies.

6.2.3 The connection between *time* and *cost*

The connection between *time* and *cost* is caused by barriers concerning deconstruction, projection, handling, testing and the fact that labour is expensive. The expensive labour causes processes to not be profitable and all steps that are needed for reuse of products which needs extra time, will result in an additional cost. However, this connection between labour and costs was not explicitly mentioned by the experts, but interpreted by the authors as costs for labour should result in higher costs when more labour is needed, for instance for more careful deconstruction or refurbishing of products for reuse.

Although it was not coded from the interviews with the experts, the additional time can also be a problem merely because the pressured time frame of the project and not dependent on the cost. This is due to the implications of taking longer time than planned for, such as activities that are dependent on for instance the construction time. However, if planning carefully, this should not be a problem.

The barriers found in *time* also affects, apart from *cost*: *business models* and *weighting*. In particular, time causes a need for the business model to change, to change focus of how companies work and the additional time also cause a lack of knowledge about the costs of implementing reuse. These effects can also be connected to cost, but also more operational factors such as what is important to care about and measure when working on construction projects. However, this issue of focus of companies was only mentioned by one expert in the interviews. It could be that this is not a common view or it could be that other experts see this as an obvious issue and thus did not mention it in a way that was coded when analysing the interviews.

The connection is mainly going from *time* to *cost*, but one barrier in *cost*, about expensive labour, causes a barrier about profitability found in *time* and thus forms the double-sided connection. The barriers that are about the additional time caused by reuse are in turn caused by *design, material/component, working group, customer, information, routines, warranty.*

The issue with *design* is to match new and old, and the *material/component* aspect is that buildings were not designed for disassembly. This leads to more time to customize design solutions and more time for deconstruction, if it even is possible to deconstruct products or buildings for reuse. In the literature study, barriers concerning buildings not designed for disassembly were also identified (Nakajima, 2014; Hobbs and Adams, 2017) but the connection to time was not as clear. The focus of the studies who mention the challenge of disassembly are more talking about the technical issues than the extra time needed. Although the careful deconstruction is mentioned in the *time* category in the literature, and how this will result in higher costs (Gorgolewski, 2008; Hobbs and Adams, 2017; Iacovidou and Purnell, 2016; Nakajima, 2014; Iacovidou and Purnell, 2016; Nordby, 2019). The connection of

deconstruction, time and ultimately cost therefore seems reasonable.

When materials are not designed for disassembly, this can be overcome either by new technology or by giving the deconstruction process more time. The problem can be solved, but it might require so much time that it is not profitable because the cost of new products are lower, or the costs of deconstruction or refurbishing become so high that it is not achievable to do. To overcome this in the future, DfD can be implemented. However, the costs of that today are also higher since these materials are more expensive, however, it seems rather to be lack of demand which results in a lower cost. Also, since the lifetime of a building is long, the effects of DfD if implemented in all new projects from today will not be visible in the deconstruction process in a long time. However, if buildings are seen as material banks and as a resource, this might change the ways buildings are built, because it is possible to get some money from them in the future. However, the time aspect might be too big in order for this to work. Moreover, this could be regulated by L&R, sector initiatives, or change of time perspective. Maybe buildings should not be built to last for very long, since usage is changing quickly in the society. On the same note, reuse will not be the only way to lower the emissions and resource consumption in the sector, as mentioned in one barrier ("Not the only solution" in *future*), and the true potential of reuse has to be investigated more before it can be said that it is the most sustainable way of constructing buildings. However, implementing reuse to some degree will almost always result in saved emissions and resources, but the route to climate neutrality is far and requires many changes.

The barriers in C&N that affect the *time* barriers are regarding *working group* and *customer*. The *working group* holds the barrier about how it is hard for workers to change the way they work, "Mindset of workers", which leads to additional time for understanding and implementing the new way of working, when working with reuse.

The connection between *customer* and *time* is about how it is hard to convince the customer to implement reuse and depending on phase in the project it can be even more difficult. The lack of interest from clients is also strengthened by more barriers in C&N, *customer* as well as in the corresponding sub-group C&N, *customer* in the literature study (Park & Tucker, 2017). However, trends change and the customer demand for more sustainable buildings might increase. This is also connected to the problems of everyone being involved, which could be improved by sector initiatives, in order to make it equal for all companies, so they are offering the same products. One expert that talked about the difficulties of convincing the customer also talked about how presentation and phrasing of reuse play a role when the customer decides. Another expert talked about how, when leasing a space, they do not have to tell the renter that the space is reused and it is quite normal to rent a "used" space as long as all needs are fulfilled. Another way could be laws or regulations, to make everyone follow the same rules. However, a sector initiative could be a better idea, since it is built upon cooperation and might work as inspiring instead of punishing. Furthermore, laws and regulations take long time to be put in place, and this in a time when action is required quickly.

The *information* that cause additional time is about the difficulties of finding reused products, due to the lack of an established marketplace and the availability of reused products. There are marketplaces available, but there is a perception that this is not established. It is not used by that many actors that are needed, and the process of finding enough products and in the correct quality and dimension is still a challenge until the market has grown. In order for the market of reclaimed products to grow, more actors need to use it.

In some other interviews, it has been clear that the availability of reclaimed bricks is small, and that many people prefer to preserve, rather than deconstruct, in order to save historical and antiquarian value. Furthermore, since this have a potential to save emissions from construction, this might be a preferred option, and also a way to avoid green washing, since reuse sounds environmentally friendly, but if it is of the cost of deconstructing another building, it is not environmentally friendly. Therefore, following the R-framework, preservation is preferred over reuse and should be done.

There are several barriers about *routines* that due to the uncertainties about them, cause additional time in different parts of the process. Learning how to work in new ways take time and this is a challenge when construction projects are time pressured or when the performer of the work, such as the construction company, wants to make profit. However, the learning can be improved by more sharing of knowledge between companies and learning from pilot studies. This is also mentioned in literature, in the sub-category *lack of experience* found in Knowledge, where the lack of case studies and the lack of experience are mentioned by several studies (Kuehlen et al., 2014; Iacovidou and Purnell, 2016; Gorgolewski, 2008; Dunant et al., 2017; Anggadjaja, 2014; Storey and Pedersen, 2014; Earle et al., 2014; Conejos et al., 2016). On the other hand, since there have been projects with reuse, one can argue that there are case studies available, and in order to learn from more projects someone needs to perform them.

One reason for the evaluation and testing of products, which can take additional time, is the uncertainty about *warranty* (L&R), connected to the legal obligations of warranty but also safety and quality of products. The testing of products was earlier discovered in the literature study, categorised in Market, *time* (Gorgolewski, 2008; Hein and Houck, 2008; Iacovidou and Purnell, 2016). However, the issue of warranty was only found in interviews and not in the literature due to the specificity of warranty to the case of Sweden, which was not included in the literature review. The barrier can be assumed to be true for the case of Sweden, since several experts from different companies mentioned warranty as a barrier to reuse and it is confirmed by regulation by Boverket - National Board of Housing, Building and Planning (2021).

The effects of the additional time for reuse mainly leads to higher costs, which in turn causes problems of profitability for companies and competition. To justify

the additional cost, the procurement process needs to require reuse so that the competition is on the same grounds, or by some other requirements so it becomes fair for everyone who implements reuse. However, the effects of this for companies are not known, and if it is possible or not to implement it on a bigger scale is also not known. There are uncertainties about availability of products, and also many new routines must be implemented in the companies. It is hard to predict what the implications are, and there is need for learning, the change will not happen overnight.

The sub-category *cost* is not only affected by *time*, the barriers are also caused by L&R, *warranty* and the Knowledge sub-groups *routines* and *weighting*. In turn, *cost* also affects the *customer* (C&N), *company* (C&N), *material/component* (Technical) and *competition* (Market).

In turn, these barriers cause other challenges in a long chain of causes and effects. Furthermore, the causes and effects of time and cost are more than those discussed in this section. The many mentions of time as a barrier for reuse in both literature (16 sources) and interviews (several different barriers) indicates that time is one of the most common barriers for reuse and thus if the causes for additional time could be solved, the construction sector could come one small step closer to implementing reuse on a big scale, because today, it is usually not profitable at all to work with reuse. However, many more things need to be solved at the same time for the transition to work.

6.2.4 The connection between *routines* and *working group*

There are routines missing for getting products from demolition into new projects, how to remount products (when routines are made for new constructions), and, moreover, the diversity of products is big, which makes it hard to put up general routines. Lastly, it is also unclear how to phrase the procurement when it is done in a new way. This is affected by habits, and that people are used to doing it in a certain way. Some of these barriers are because of lack of information, and IT systems that do not yet exist. In the other barrier, it is rather a need of learning. Furthermore, the connection is also going in the other direction, because the routines in practice also affects the habits and habits might be an obstacle for routines to change.

"Habits" is not directly mentioned in the literature review, however, many of the studies connected lack of routines and lack of experience as an obstacle to new habits. Gorgolewski (2008) writes that the lack of experience also results in lack of good practice, and Dunant et al. (2017) also say it is hard to change from the usual way of doing things, and reuse is an uncommon way of working. Furthermore Earle et al. (2014), also highlight that since the positive aspects of reuse are not known, demolition workers are continuing their way of working and finish their job as quickly as possible, unaware of what could be reused. In this study, it was clear by interviewing demolition workers and contractors, that unawareness is not the biggest issue and many of the experts were aware. However, rather systemic issues,

such as unprofitably and lack of demand, made it hard for demolition workers to both deconstruct and sell products, e.g. refrigerators. However, in some of the interviews, it was clear that changing way of working and making people aware of why it is necessary to save the amount of waste, might still be a challenge. On the other hand, it seems to be an issue in the whole sector, and not only for demolition workers.

The impression obtained from the interviews about awareness in the sector could be because of the selection of experts interviewed, which was some people working with environmental issues and therefore interested and aware. Some experts were or had been working with reuse, and thus interested in the questions. Many of these experts were also involved in Reuse West, which means they have cooperated and therefore might share a similar picture. It turned out to be hard to obtain interviews with people not working with reuse, even though some were interviewed, it would have been interesting to investigate more from this group, and what kind of barriers they experience.

Many of the barriers in *routines* are coming from the same expert. Even though many barriers are mentioned by several experts, these concerning routines are specific for a certain expert and might be very dependent on the selection of experts. The other thick connections in the result might be seen as more "robust" because they were mentioned by more experts. Even though it is not robust, it is still a reasonable result, because new routines might be a challenge for people and might have a big impact. As mentioned earlier, learning how to work in new ways takes time, and has an impact on the working group.

6.3 Conclusion and recommendations

This study has investigated the barriers in global literature and the barriers perceived by different actors in the Swedish construction sector. The results are presented in the categories Infrastructure, Laws and regulations, Market, Technical, Culture and norms and Knowledge. Connections for the causes and effects of the barriers were analysed for the barriers found by interviewing the actors. Barriers in some sub-groups of Laws and regulations and Culture and norms are solely causing and being affected. To explore this further, the three most strengthened connections (caused by the most barriers) were discussed. The conclusions from these connections are:

- There is an inertia in the sector, making companies hesitate to start with reuse
- Companies need support and help to prioritise and information needs to be shared between companies due to the perceived risk of starting with reuse
- Allowing for extra cost or reducing the time needed for reuse through development of routines, could solve problems of profitability and competition
- Some systems need to be developed and the sector needs to learn more about reuse and how to work with it, this must happen simultaneously

For future research, the following research questions can be studied:

- What would the effects be of including environmental factors in the procurement process?

- What are the potentials of reuse? Both social, economic and environmental potentials?
- How to increase the acceptance of reused products from customers and in the sector?

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A

Codebooks

A.1 Group 1

- Technical
  - Förorenat,Farligt avfall
  - Icke demonterbar, fastlimmad
  - Prestandakrav
    - Energikrav
  - Uttjänt material
- Knowledge
  - Kunskap saknas
    - Återbruk prioteras inte
    - Produkters inbyggda värde
  - Osäkerhet
    - Framtiden
    - Garanti
    - Kundkrav
- Market
  - Brist på aktörer
  - Efterfrågan saknas
  - Inget värde i materialet
  - Marknad saknas
  - Olika intressen för restprodukter
  - Utbud saknas
- Laws
  - Brist på lagkrav
  - Garanti
  - Hög lägstastandard i bostäder
  - Krav uppskruvas, lagar
- Logistics
  - Lagerhållning
  - Logistik
  - Matcha mellan projekt
- Operations
  - För sent att ändra
  - Information om material saknas
  - Tid

        - Byggprocessen
        - Demontering
            - Dyrt med personal
    - Vanebeteenden
- Business models
    - Ej vinst i återbruksmodell
    - Ekonomi hantering vs nytt
    - Konkurrens
    - Utanför affärsområde
- Design
    - -
- Culture and norms
    - Brist på initiativ
    - Mindset individ
    - Mindset organisation
    - Stort ansvar för företag
    - Van vid hög standard

A.2 Group 2

- Technical
    - Dålig kvalitet
        - Inget värde i materialet
    - Farliga ämnen
    - Icke demonterbar, fastlimmad
    - Bindemedel för starkt
    - Nya förhållanden i ny geografi
    - Prestandakrav
        - Energikrav
        - Funktionskrav
    - Slitet, uttjänt
- Knowledge
    - Inte gjorda för en andra montering
    - Kunskap saknas
        - Information om produkter
        - Kravställning
        - Kunskap om andra aktörer i branschen
        - Kunskap om kostnader
        - Kunskap om varandras processer
        - Miljöeffekter
            - Energikrav fönster
    - Osäkerhet
        - Efterfrågan
        - Garanti
        - Kan orsaka mer transporter
        - Målsättning svårt

            - Vilka produkter ska återbrukas
        - Miljöpåverkan
        - Olika faktorer, Gestaltning
        - Rivning
    - Vad mäter man
- Market
    - Brist på aktörer
    - Marknad saknas
    - Olika intressen för restprodukter
    - Tillgång, utbud saknas
- Laws
    - Definition för redovisnning av avfall
    - Garantitid
    - Höga krav
- Logistics
    - Lagerhållning
    - Långa transporter
    - Matcha mellan projekt
    - Ut,inflytt
    - Vem ska lagerhålla
- Operations
    - För sent i process
    - Installationer glöms bort
    - Inte i åtanke att ta hand om gammalt
    - Processer, tar inte med lärdomar
    - Samarbete svårt
    - Tid
        - Demontering
        - Kort tidsram
        - Pressad byggtid
        - Projektering
    - Vanebeteenden
- Business models
    - Återbrukat är dyrare än nytt
    - Billiga lösningar hindrar återbruk
    - Billigt att slänga
    - Ej prioriterat
    - Entreprenörer tjänar inte så mycket på det
    - Inte villiga ta tillbaka
    - Kostnad för garanti pga testning
    - Svårt att ändra affärsmodell
    - Tjänar på att sälja nytt
    - Utanför affärsområde
- Design
    - Få ihop nytt och gammalt
    - Tid, specialanpassningar

- Culture and norms
  - Bara miljöintresserade som har kunskap,medvetenhet
  - Historiskt och estetiskt värde
  - Mindset individ
    - Inställt på nya material
  - Mindset organisation
  - Samverkan
  - Stort ansvar för företag
  - Stort ansvar för individen
  - Uppfattas dyrt
  - Uppfattas riskfyllt
    - Affärsmodell
  - Vill inte gå först

A.3 Group 3

- Technical
  - Farliga ämnen
  - Icke demonterbar
  - Nödvändiga material passar inte alltid för återbruk
  - Svårt att separera
- Knowledge
  - Kunskap saknas
    - Goda exempel saknas,är för få
    - Hur mycket ens val vid ritbordet gör skillnad (som arkitekt)
    - Avfall
    - Medvetenhet om påverkan
    - Klimateffekter
    - Kunskap om kostnader
    - Kvalitetsklassning
    - Nytt arbetssätt
    - Omedvetenhet om värde i material
  - Osäkerhet
    - Livslängd
    - Målsättning svårt
      - Svårt att förstå plan
    - Olika faktorer
    - Osäkerhet vilka kompetenser
      - Demontering, personal
- Market
  - Efterfrågan saknas
  - Köper hos samma leverantör
  - Olika intressen för restprodukter
  - Utbud saknas
- Laws
  - Avfallslag

    - Deponi för billigt
    - Garanti
    - Husen passar inte för nya behov
    - Krav uppskruvas, lagar
    - Tillgänglighetsregler
    - Uppfylla lagar, CE och brandskydd
- Logistics
    - Lagerhållning
    - Logistik
    - Matcha mellan projekt
- Operations
    - Återbruk ej i tanke
    - Brist på kommunikation
    - Ekonomiska incitament hjälper inte
    - Information som behövs
    - Många olika aktörer
    - Olika material kräver olika hantering
    - Osäkerhet demontering
    - Planering för demontering och projektering
    - Rutiner saknas
    - Tänka om arbetssätt
    - Tid
        * Demontering
        * Tajt tidsplan
    - Vanebeteenden
- Business models
    - Begränsad affärsmodell
    - Dyrt med arbetskraft
    - Ej universal lösning
    - Helhetsbild saknas
    - Högre pris
        * Cirkulära affärsmodeller får betala mellanskillnaden
    - Konkurrens
    - Kostnad hantering
        * Provning ingår i värdet
    - Material är för billigt
    - Styrda av kundkrav
    - Svårt att få lönsamhet
    - System baserat på linjär affärsmodell
    - Tjänar på att sälja nytt
- Design
    - Anpassa efter vad som är tillgängligt
    - Ej roliga,fina hus tillgängliga
    - Tillgängliga produkter avviker från standard (mått)
        * Fel dimension
- Culture and norms

- Behåller lösningar för sig själva
- Inställt på nya material
  - Slutkund ska vilja betala
- Mindset individ
- Mindset organisation, omställning svårt tänka om
- Nyproducerat i trä dominerar över återbrukat tegel
- Stort ansvar för företag
- Stort ansvar för individen
- Uppfattas dyrt
- Uppfattas riskfyllt
  - Svårt att övertyga
- Upplevda barriärer

B

Barriers from literature

Table B.1: Infrastructure barriers.

Barrier	Short description	Source
Information		
Lack of documentation of materials, traceability	By law, documentation of products are needed when both new and reused products are used at construction sites, which might not be available for used products (Nordby 2019). In the case of adpative reuse, drawings of old buildings might also be missing (Conejos, Langston, Chan and Chew 2016)	Storey and Pedersen (2014), Densley Tingley, Cooper and Cullen (2017), Dunant, Drewniok, Sansom, Corbey, Allwood and Cullen (2017), Hobbs and Adams (2017), Iacovidou and Purnell (2016), Nordby (2019), Conejos, Langston, Chan and Chew (2016) (7)
Limited supply of reused components	Currently not available "on the shelf", usually limited quantities (Gorgolewski, 2008)	Gorgolewski (2008), Dunant, Drewniok, Sansom, Corbey, Allwood and Cullen (2017) (2)
Components needs to be purchased early in the design phase	When designing with reuse, purchasing of components must be done early that it is before a contractor has been appointed. If products are not available at the time for design, the contract needs to be flexible snce final materials might not be specified at the time of tendering.	Gorgolewski (2008)
General lack of developed market for reclaimed building materials	Contractors might have to search for products from many different small-scale suppliers (Storey and Pedersen, 2014). Insufficient regional market for reused components (Iacovidou and Purnell, 2016)	Earle, Ergun and Gorgolewski (2014), Guy (2014), Densley Tingley, Cooper and Cullen (2017), Gorgolewski (2008), Storey and Pedersen (2014) (5)
Lack of guaranteed quality and quantity of products	Unpredictable market of reclaimed products (price, quality, size). Mismatch of supply and demand. Complex to get the right product at the right time (steel structure) (Densley, Tingley, Cooper and Cullen, 2017), (Iacovidou and Purnell, 2016).	Densley Tingley, Cooper and Cullen (2017), Dunant, Drewniok, Sansom, Corbey, Allwood and Cullen (2017), Iacovidou and Purnell (2016), Hobbs and Adams (2017) (4)
Coordinate demand with supply	Having the right product at the right time is vital because it effects the design and construction phase	Gorgolewski (2008)
Lack of communication between actors and cooperation of all parties	The large number of actors in deconstruction makes collaboration harder in construction and deconstruction (Iacovidou and Purnell 2016). Dunant et al (2017) identifies the barrier as a question of trust, where communication is harder with actors outside of the usual patterns. Earle, Ergun and Gorgolewski (2014) writes that not always all parties have understanding of the goals and plan, which hinders the process.	Dunant, Drewniok, Sansom, Corbey, Allwood and Cullen (2017), Zou, Hardy and Yang (2015), Earle, Ergun and Gorgolewski (2014), Storey and Pedersen (2014), Iacovidou and Purnell (2016) (5)
Transports		
Geographic isolation	Geographical isolation in some parts of New Zealand makes it hard to sustain a large market due to additional transportation needed (Storey and Pedersen, 2014).	Storey and Pedersen (2014)
Warehousing/storage and logistics/transports	Lack of facilities in small communities. High costs of storage and transports (Storey and Pedersen, 2014). Storage of material between usage is needed, storage need to be in a good condition so the material or products are not destroyed (Gorgolewski, 2008)	Storey and Pedersen (2014), Densley Tingley, Cooper and Cullen (2017), Gorgolewski (2008), Hobbs and Adams (2017), Iacovidou and Purnell (2016), Zou, Hardy and Yang (2015) (6)
Insufficient infrastructure	For refurbishment and warehousing	Iacovidou and Purnell (2016)
Space constraints	Contractors are reponsible for storage of materials (Park and Tucker, 2017). Might be hard to store products/materials on site due to space constraints (Gorgolewski, 2008)	Gorgolewski (2008), Park and Tucker (2017) (2)

Table B.2: Laws and regulations barriers.

Barrier	Short description	Source
Building codes and standards		
Reused construction products need to comply with several regulations, building codes and standards, marking and certification	Standards give the impression that new materials must be used (Storey and Pedersen, 2014). The Building Codes of Australia (BCA) lack of a method to consider building lifecycle vs construction and running costs. Reusing is percieved as complex and results in a lot of additional paper work for certifications and documentation. It is hard to get approval from authorities to use reused products, and there is a lack of regulations to enhancing the use of reused products (Park and Tucker, 2014). In Norway, these are: Building technical regulations (TEK), Documentation of construction products (DOK), EU:s health, safety and environmental regulations (CE) and EEA Construction Products Regulation. This is important fo follow for the architect/technical consultant or contractor. The laws and regulations do not support sale and reuse of building materials in new buildings (Nordby 2019)	Bohne and Wærner (2014), Storey and Pedersen (2014), Densley Tingley, Cooper and Cullen (2017), Park and Tucker (2017), Dunant, Drewniok, Sansom, Corbey, Allwood and Cullen (2017), Hobbs and Adams (2017), Hein and Houck (2008), Conejos, Langston, Chan and Chew (2016), Nordby (2019), (9)
Health and safety legislation	Additional safety equipment which are legislated might increase the time needed for deconstruction (Storey and Pedersen 2014)	Storey and Pedersen (2014), Hein and Houck (2008) (2)
Increased legislation		
Acoustics/noise control	Hard to ensure acoustic/noise controls in old buildings	Conejos, Langston, Chan and Chew (2016)
Fire safety	In BCA, if more than 50% of the building is changed, fire safety must be implemented, however, it should be done with the character of the building preserved (Conejos et al., 2016). In Europe, if there are a major change to historical buildings, hallways and doorways must be widened, fire equipment and installations, fire doors and new exits must be installed in the building (Hein and Houck, 2008)	Hein and Houck (2008), Conejos, Langston, Chan and Chew (2016) (2)
Disability access legislation	The design for building with access for disabled does not always comply with the character of the old building (Conejos et al., 2016). To enhance accessibility, the buildings should include ramps, washrooms, entryways and hallways of least dimensions to make the building accessible for everyone (Hein and Houck, 2008)	Hein and Houck (2008), Conejos, Langston, Chan and Chew (2016) (2)

Table B.3: Market barriers.

Barrier	Short description	Source
Time		
Increased workload, more staff required	Contractors are experiencing labour intensity and time pressure, which gives no space to implement reuse.	Park and Tucker (2017)
Time for deconstruction	The issue of more time for deconstruction is mentioned by Gorgolewski (2008), Hobbs and Adams (2017), Iacovidou and Purnell (2016).	Gorgolewski (2008), Hobbs and Adams (2017), Iacovidou and Purnell (2016) (3)
Cost of deconstruction	Deconstruction is labour intensive compared to demolition (Iacovidou and Purnell 2016). One example from Bohne and Wærner (2014) is that little wood is reused because of high deconstruction costs for doors, windows and construction elements.	Bohne and Wærner (2014), Hobbs and Adams (2017), Iacovidou and Purnell (2016) (3)
Time for fabrication	More time is needed for fabrication, especially because of aesthetical factors	Dunant et al (2016)
Storage	Storage is costly	Dunant et al (2016)
Time pressure, procurement	Dunant, Drewniok, Sansom, Corbey, Allwood and Cullen (2017) identifies the issue of delays because of change in the procurement. Park and Tucker (2017) identifies the time pressure for contractors.	Earle, Ergun and Gorgolewski (2014), Kuehlen, Thompson and Schultmann (2014), Nakajima (2014), Anggadjaja (2014), Chini and Buck (2014), Storey and Pedersen (2014), Guy (2014), Densley Tingley, Cooper and Cullen (2017), Gorgolewski (2008), Park and Tucker (2017), Dunant, Drewniok, Sansom, Corbey, Allwood and Cullen (2017), Hobbs and Adams (2017), Iacovidou and Purnell (2016), Hein and Houck (2008), Nordby (2019), Conejos, Langston, Chan and Chew (2016) (16)
Lack of economic driving forces, which results in lack of actors.	There are more time required for a more complex building process, which makes it more expensive, thus it lacks actors.	Nordby (2019)
Cost		
Cost of maintenance and repair	The cost of maintenance and repair are high when materials are in bad conditions	Conejos, Langston, Chan and Chew (2016)
Cost of remediation	To take way hazardous chemicals is costly and can also delay the construction process	Conejos, Langston, Chan and Chew (2016)
Structural properties need to be tested	Risk for the designer if using old products, so quality of the products needs to be ensured. This is costly due to additional time and testing fees.	Gorgolewski (2008), Hein and Houck (2008) (2)
Cost of testing of performance	Hobbs and Adams (2017) says that testing of performance can be expensive, which might cost more than what is saved by reusing the material/component. Iacovidou and Purnell (2016) mentions that construction components needs to be assessed on-site, which is costly due to time consumption	Hobbs and Adams (2017), Iacovidou and Purnell (2016) (2)
Competiton		
It is possible to sell materials for recycling or energy recovery, instead of reusing them	Wood becomes energy instead of being reused, structural steel is being recycled instead of reused (Iacovidou and Purnell, 2016)	Iacovidou and Purnell (2016)
Costs of demolition exclude some factors	Energy and waste disposal costs of demolition usually do not include all the environmental and social costs	Langston, Wong, Hui and Shen (2008)
Disposal/landfill is cheap	Disposal costs and taxes are often low	Kuehlen, Thompson and Schultmann (2014), Durmisevic and Binnemars (2014), Bohne and Wærner (2014), Storey and Pedersen (2014), Guy (2014) (5)
Low value in used components	New materials are cheap. In the case of cheap materials or products, the cost of deconstruction might be more than the value of the reused material/product (Hobbs and Adams 2017).	Bohne and Wærner (2014), Storey and Pedersen (2014), Hobbs and Adams (2017) (3)

Table B.4: Technical barriers.

Barrier	Short description	Source
Material/component		
Not designed for disassembly, dismantling, deconstruction	The building and/or its components were not designed with reuse in mind. Not designed for disassembly, dismantling, deconstruction The building and/or its components were not designed with reuse in mind. Materials are glued to each other, e.g. gypsum glued to wood, or floor is glued to the concrete slab Nakajima (2014). Cement mortar and prefabricated panelized systems are other examples of materials hard to disassemble Hobbs and Adams (2017)	Kuehlen, Thompson and Schultmann (2014), Nakajima (2014), Durmisevic and Binnemars (2014), Storey and Pedersen (2014), Densley Tingley and Cullen (2017), Iacovidou and Purnell (2016), Anggadjaja (2014), Dunant, Drewniok, Sansom, Corbey, Allwood and Cullen (2017), Hobbs and Adams (2017) (9)
In-situ technology, e.g. cast-in-place concrete	Project specific, heavy, hard to move and analyse if information about reinforcement is not available. The concrete is hard to separate into parts because there are no joints between them	Storey and Pedersen (2014), Iacovidou and Purnell (2016) (2)
Physical restrictions of present buildings	Some of the limiting factors are current floor layout, number of columns/walls in the building and, structural system layouts of the building.There might be a challenge to fit the old building with current availability demand.	Conejos, Langston, Chan and Chew (2016)
Hazardous materials/substances in the existing, built environment	Due to regulation, health and safety, some materials formerly used in buildings are no longer desired to keep in a circular flow because of hazardous substances.	Kuehlen, Thompson and Schultmann (2014), Guy (2014), Iacovidou and Purnell (2016), Hein and Houck (2008), Nordby (2019), Conejos, Langston, Chan and Chew (2016) (6)
Deteriorated/damaged components/materials, technical/physical obsolescence	Components and materials have lost their technical or physical functions by time or damage	Hein and Houck (2008), Conejos, Langston, Chan and Chew (2016), Langston, Wong, Hui and Shen (2008) (3)
Desired dimensions not available	When designing with reused elements, the design might need to be changed to fit what dimensions of elements that are available. This is a barrier concerning steel in Dunant et al (2017)	Dunant, Drewniok, Sansom, Corbey, Allwood and Cullen (2017)
Technology		
Damage to components from deconstruction process	In the case studies by Gorgolewski (2008), damage from deconstruction or storage was a challenge for reuse	Gorgolewski (2008)
Missing equipment for dismantling/deconstruction	Deconstruction may require special equipment which may not be available. Iacovidou and Purnell (2016) gives the example of timber components which are difficult to deconstruct and may also be a safety risk, that can need special equipment and careful handling to not damage the components in the process of cleaning, de-nailing and sizing at the cost of time. Kuehlen, Thompson and Schultmann (2014) says equipment do not yet exist.	Kuehlen, Thompson and Schultmann (2014), Iacovidou and Purnell (2016) (2)
Health and safety risks of deconstruction	Iacovidou and Purnell (2016) gives the example of deconstructing timber to be dangerous. Hobbs and Adams (2017) identifies the risks of manual deconstruction as a reason that mechanical demolition techniques are used.	Hobbs and Adams (2017), Iacovidou and Purnell (2016) (2)
Compatibility of new materials with existing materials	In the case of adaptive reuse, the existing materials may not be compatible with new materials.	Conejos, Langston, Chan and Chew (2016)
Technical complexity	Technical complexity of refurbishment and installations which requires new solutions for each case when performing adaptive reuse of heritage buildings	Conejos, Langston, Chan and Chew (2016)

Table B.5: Culture and norms barriers.

Barrier	Short description	Source
Customer		
Attitude 'new is better' / old is 'inferior'	Dunant et al (2017) identifies the barrier that there is a worry that customers will refuse old steel because of inferior properites. Iacovidou and Purnell (2016) lists the barrier as prejudice and preference of consumers, and also the "lack of confidence" that concerns reused components performance and properties.Moreover, for customers, pre-used is seen as not as good compared to new products, and architects do not want to use pre-used products if it is not in a fashionable way. The architects and the constructors are also afraid that something might be inferior and they do not want to be responsible if anything goes wrong (Storey and Pedersen, 2014)	Storey and Pedersen (2014), Dunant, Drewniok, Sansom, Corbey, Allwood and Cullen (2017), Iacovidou and Purnell (2016) (3)
Economic reluctance	Residents care more about economy than environmental friendly buildings.	Park and Tucker (2017)
Perceived safety by building tenants	An old building can have flaws that makes it appear unsafe	Hein and Houck (2008)
Expectations of modern tenants	E.g handicap accessibility, modern plumbing and HVAC systems, and electrical and telecommunications facilities. Modern tenants also want assurance that the building is safe for their health (non-toxic environment).	Hein and Houck (2008)
Lack of interest from clients	Architects perceive the barrier of clients having no interest in reusing construction material. Developers and builders also perceive this lack of interest and demand of customers.	Park and Tucker (2017)
Company		
Scepticism from building owners	Sceptical to specify the use of reused products because they "carry the connotation of being inferior". Moreover, building code requirements and performance specifications also make it hard to use reused products (Anggadjaja 2014)	Anggadjaja (2014)
Perceived risk in specifying reused materials	In the case studied by Gorgolewski (2008), the risk is perceived by the design team, because of the less predictable characteristics of reused components	Densley Tingley, Cooper and Cullen (2017), Gorgolewski (2008) (2)
Risk and uncertainty with reuse	Time and difficulty of reuse leads to higher costs, which leads to smaller profit	Conejos, Langston, Chan and Chew (2016)
Risk of changing business model	When the business model is changed, there might be a higher cost and changing the model is percieved as a risk.	Dunant, Drewniok, Sansom, Corbey, Allwood and Cullen (2017)
Perception of financial and technical factors	Adaptive reuse is perceived as too costly and demolition is more profitable.	Conejos, Langston, Chan and Chew (2016)
Assumption of higher costs of deconstruction	Many people in the industry assume that deconstruction will lead to higher costs than demolition as usual.	Earle, Ergun and Gorgolewski (2014)
Sector		
Industry scepticism and tradition	Standard practice in the construction sector depend on time, complexity and costs	Gorgolewski (2008)
Corporate lock-in	Due to possible cost increase and unwillingness to change, there is an inertia in the construction sector	Densley Tingley, Cooper and Cullen (2017)
Society		
Social obsolescence	As fashion or behaviour changes, the building becomes outdated and needs renovation or replacement	Langston, Wong, Hui and Shen (2008)

Table B.6: Knowledge barriers.

Barrier	Short description	Source
Lack of experience		
Lack of case studies to show benefits	Lack of cases that show economic, environmental and social benefits (Kuehlen et al., 2014), (Iacovidou and Purnell, 2016). Successful examples of deconstruction is missing (Anggadjaja, 2014), (Storey and Pedersen, 2014)	Kuehlen, Thompson and Schultmann (2014), Anggadjaja (2014), Storey and Pedersen (2014), Iacovidou and Purnell, (2016)
Lack of experience	Lack of experience of methods for deconstruction (Iacovidou and Purnell, 2016).	Iacovidou and Purnell (2016)
Lack of standardised best practice, guidelines	Since reuse is an uncommon practice, it is hard to make changes in "the usual way of doing things" (Dunant, Drewniok, Sansom, Corbey, Allwood and Cullen 2017). Good practice for reuse is missing (Gorgolewski 2008)	Kuehlen, Thompson and Schultmann (2014), Anggadjaja (2014), Gorgolewski (2008), Dunant, Drewniok, Sansom, Corbey, Allwood and Cullen (2017) (4)
Lack of workers	Lack of experienced workers and experts of renovation work (Conejos et al., 2016).	Conejos et al. (2016)
Lack of knowledge about waste management	Lack of knowledge about what can be recycled or reused, and how to avoid waste on a building site	Park and Tucker (2017)
Lack of knowledge in the design phase about what products are possible to obtain at the time for construction	Uncertainties in the design phase what products will be available in the construction phase	Nordby (2019)
Lack of supply chains	There are gaps in the supply chain, although who would be the supplier and who would procure reused steel is unclear (Densley et al., 2017)	Densley Tingley, Cooper and Cullen (2017), Iacovidou and Purnell, (2016) (2)
Lack of knowledge about reuse in the design phase	Lack of knowledge about availability of reused materials (Guy, 2014). There are uncertainties about where to source the reused steel, and the availability of it (Densley Tingley, Cooper and Cullen, 2017)	Guy (2014), Densley Tingley, Cooper and Cullen (2017)
Design needs to be flexible for reuse of components that are available	Using reused products require more flexibility in the design process (Gorgolewski 2008)	Gorgolewski (2008)
Uncertainty about costs	For dismantlig/deconstruction	Kuehlen, Thompson and Schultmann (2014)
Material value		
Lack of knowledge about the material value	Industry professionals are unaware of the opportunities for reuse, and the value of reused products. (Earle, Ergun and Gorgolewski, 2014). Workers and owners are not aware of the material value from deconstruction once the materials/products are recovered (Chini and Buck, 2014). Lack of knowledge across industry (Zou, Hardy and Yang, 2015). Customers are more aware of the initial costs of the residents and have little knowledge or awareness of long-term consequences of their choices of products (Park and Tucker, 2017).	Earle, Ergun and Gorgolewski (2014), Chini and Buck (2014), Zou, Hardy and Yang, (2015), Park and Tucker (2017)
Lack of awareness of the demolition staff	The benefits of reuse are not clear, which makes demolition workers try to finish their work as quickly as possible, unaware of what could be reused	Earle, Ergun and Gorgolewski (2014)
Lack of awareness of the potential of reuse	Prejudices and lack of awareness about the potential of reuse (Iacovidou and Purnell, 2016)	Iacovidou and Purnell (2016)
Not all stakeholders are aware of the buildings' lifecycle and costs	How the buildings relates to embodied energy, and how that effects running- and construction costs	Park and Tucker (2017)

C

Barriers from interviews

Table C.1: Infrastructure barriers.

Barrier	Description	No. of mentions
Information		
Lack of communication	Not everyone involved in a project are aware of the goals of reuse	1
Additional cooperations are needed	Due to limited availability e.g. for a wall, only parts of the wall can be made of reused material. This requires additional cooperation between different suppliers for the same wall	1
Lack of a comprehensive picture	There are many actors included in a project, the owner of a building is often not the one who developed nor built it, which leads to a lack of a comprehensive picture	1
Lack of knowledge about actors	Hard to know to whom you can sell used products in good quality	1
Lack of knowledge about other actors' processes	Lack of knowledge about other things than your own area, e.g. demolition process and ventilation, which makes people not consider reuse in another area	2
Use of the same supplier	When buying from the same supplier the contractor gets a return, which makes them keep the same supplier	1
Information about materials is missing	The history of the product, its quality, content and strength. It is hard to determine substances in concrete	4
Information that needs to be traced for interior	Aesthetical condition and function, environmental saving, logistics, requirement fulfilling, quantity, current location and size are needed in order to reuse an interior product. Finding this information is a new step in the working procedure	1
Information that needs to be traced for foundation	Documents, supplier information, weather conditions, quality and demountability are needed in order to reuse a foundation. Finding this information is a new step in the working procedure	1
Hard to match availability and supply	Hard to match products from a demolition site/project with a receiver. Complicates the planning process when guarantee is needed that the products will show up on time and in the right amount	4
Products are locked in use	Some products that will be available for reuse in the future are currently in use.	1
Lack of availability of reused products	Hard to find products in the right quantity and quality	5
Lack of an established marketplace	The process of finding the products needed is time consuming and complicated because there is no well established marketplace where it is easy to find products	3
Transports		
Storage not available	Lack of storage for materials between projects	6
Responsibility for storage	Routines are lacking and who is responsible for storage is not clear	1
Transports	Complicated to transport products for reuse long distances	1
Lack of actors and services	Lack of storage, supply and remanufacturing services	3
	Sum of mentions	**37**

Table C.2: Laws and regulations barriers.

Barrier	Description	No. of mentions
Warranty		
Warranty	Construction companies need to give a 5 year warranty, which can not be given for reused products, this is not possible today for reused products because someone needs to be responsible for the risk. It is the developer that are responsible for the warranty if there is no producer associated to the reused product that are built in. Uncertainty in which stakeholder will be responsible for the guarantee of the reused materials, the property developer, the construction engineer or the construction company?	4
Uncertainties about warranty	Uncertain if it is possible to get the same warranty for reused products as for new	2
Uncertainties about reusing products	Unclear if products still have the same performance if they are moved and remounted (for instance for the developer). E.g. ventilation products might need evaluation and testing if they can be used in the new system, and it is hard to predict if they can be used or not. This is called secondary effects	4
CE mark	If CE mark is missing for a product, it is hard to know if the product still have the same performance and can be reused unless it is tested in an accredited laboratory	1
Waste regulation		
Waste regulation	Depending on if it is waste or a product, different laws are applied. For waste from a demolition site, it is complicated to get permission to use it as a reused product when it has been classified as waste	1
Waste regulation	In accounting of waste, it is not clear how to treat reused products. Depending on if it is waste or a product, different laws are applied	1
Updated laws		
Old windows do not fulfil energy requirements of today	Energy requirements of windows get updated, which means that the U-value of old windows is too high to be used in new buildings	2
Requirements of foundation increases	Construction requirements change and a foundation from some years ago might be outdated	1
Requirements of building products gets updated	Products from some years ago might no longer fulfil requirements of today, due to changes in the law. E.g. fire safety, accessiblity and energy requirements	3
High requirements		
High requirements for building products	Laws for materials safety and chemical substances hinder reuse of some products	1
High lowest standard for residences in Sweden	In Sweden, due to regulations, a residence need to be fully equipped before the resident can move in.	1
	Sum of mentions	**21**

Table C.3: Market barriers.

Barrier	Description	No. of mentions
Time		
Too late in process	Hard to make decisions about reuse when it is too late in the process, if there are no requirements of reuse from start	1
Complex to handle materials	Might require extra time to work with reused products, due to additional steps in the working procedure	1
Reused components might need customized solutions	To make customized solutions and integrate resued products, more time is required	1
Additional time needed to prepare for reuse	Finding reused products and doing an inventory requires more time, and usually the owner/user do not want to wait additional time when renovating or moving	2
Additional time needed for the design phase	Finding products is time consuming	1
Additional time required to evaluate products and design in the projection phase	Quality of products needs to be evaluated, and there is a lack of routine for designing with reuse, thus it requires more time	1
Additional time needed for deconstruction	Deconstruction requires more time than demolition, since the products need careful handling in order to not break	4
Not profitable to deconstruct	Deconstruction instead of demolition is expensive due to additional time needed	5
Safety measures in the working environment	Routines are missing for how to safely demount structural components, or takes more time to plan since it is not standard procedure	1
Cost		
Lack of a comprehensive pricing	When the price of a product/material is set, environmental factors are not considered, such as waste handling	1
Storage is expensive	Storage is needed between projects, which is costly	3
Reused products are expensive	Due to handling, deconstruction and testing, reused products will often cost more	2
Labour is expensive	The extra handling needed for reuse is expensive due to high costs of labour, often reuse organisations are driven by volunteers	2
Getting warranty on reused products is costly	Due to testing of performance for reused products, it is costly for the supplier	2
No profit in reuse	It is hard to get profitability from working with a circular business model. E.g. people work voluntarily at reuse centres. Construction companies do not make much profit of installing reused products, they usually get discounts when they are buying from their usual supplier, who are not offering reused products	3
Suppliers make more profit when selling new products	Some profit can not be made for present products on a building site, due to supplement charges for new products	2
Competition in procurement process	The procurement does not generally enhance reuse, because the contractor with the cheapest way of doing things will win. Additional man-hours required for implementing reuse is not profitable for a construction company, due to competition	3
Competition		
Different interest in waste materials	District heating companies have an economic interest in waste materials for energy recovery. Recycling or energy recovery has a lower cost compared to being reused, due to existing systems and services	3
Financial benefit to recycle metal	Metals can be sold for recycling instead of being reused	2
Cheap to discard products/materials	There are no charges to downcycle products and landfilling is cheap. There is little to no costs of throwing things out instead of reusing them	3
New materials are cheap	The value of new products are not reflected in the price so people are used to chose whatever product they want, and are not economical with resources. New products are cheaper than the costs of handling reused component	6
Companies have to pay for having a circular business model	Due to the linear system, companies who adapt a circular business model and work with reuse have to pay the difference	1
	Sum of mentions	**50**

Table C.4: Technical barriers.

Barrier	Description	No. of mentions
Design		
Adapt design to what is available	The design is steered by the products that are available, which could be a challenge	4
Match new and old	E.g old products are not compatible with a new module system	1
Products available for reuse are not in the right size	E.g doors do not fit, pillars are too low for ceiling heights required	3
Material/components		
Not designed for dissassembly	Glued, hard to dissassemble without breaking it, foundation and concrete which are stuck, foundation and concrete are casted and not possible to dissassemble, wardrobes that are mounted to the wall	3
Hard to separate components	E.g. tiles, glued floors and when there is cement-based mortar for bricks which is harder to separate to reuse the bricks, compared to lime mortar which can more easily be separated	4
Polluted or hazardous materials in present buildings	Asbestos and/or PCB in buildings from the 1970s. Asbestos, PCB, mercury (flourescent lamps), electronics, flame retardants in insulation, in asphalt. Lead in faucet, softener in PVC	5
Materials are worn out	Materials are degraded from wear and tear	2
Materials/components are of poor quality	Materials are already broken or breaks easily when it is being used. E.g airbricks or other products/materials	2
Products are made for certain weather conditions	When moving a product geographically, the product might not be adapted to its new environment	1
Reuse is not suitable for all environments and materials/products	E.g in heavy-duty environments like public spaces or sterile environments like hospitals. For large-scale catering establishment, stainless steel might be required and it is not possible to reuse galvanised steel sheet. Moreover, a radiator need to have the right efficiacy for its new environment in order to be reused	2
	Sum of mentions	**27**

Table C.5: Culture and norms barriers.

Barrier	Description	No. of mentions
Individual		
Hard to act alone for individuals	It is hard to push for reuse in your company if it is not implemented by the company or asked for by the customer. Hard for individuals to take the risk by themselves. It is hard for individuals to convince customers to implement reuse in projects	3
Not everyone in the sector are engaged in the issue	E.g at reuse events, mostly people working with environmental questions are engaging. There is a lack of CEOs and decision makers	1
Components available for reuse are not always the desired ones	Reused products can be boring, ugly and uninspiring to work with for architects	2
Lack of motivation	Even though compensation is given, workers are not motivated to find reused products	2
Working group		
Collaboration between actors is lacking	Might be seen as fuzzy. Moreover, construction projects are usually not evaluated by the people who were included in the project, this makes it hard to learn from the last project when working with new people in the next project	1
Mindset of workers	The whole process of design gets turned around when working with reuse, which can be hard to grasp for everyone included in the project	2
Habits	People are used to practices that are easy and quick to do, stopping them from trying new things. "Do as we always did"	6
Customer		
Mindset of customers	Lack of acceptance from customers of reused products in new buildings. There is an expectation of high standards and "new and fresh" is the norm. Moreover, reused materials or products do not always become cheaper in the end, which makes reuse even less desirable for some customers	7
Even if the price is the same, new is preferred	If the cost of handling and reconditioning a product makes it cost the same as a new product, the customer prefers the new	1
Lack of demand	Few customers willing to pay for reused products	3
Reused products are too expensive	Companies are not willing to pay more for reused products, even if they know it is good for the environment	1
Reuse is not considered by owners	Not possible to reuse if the owner do not want to keep a material	2
Reuse is not considered by the owner, for certain products	Small products might be forgotten even though they are of high quality, e.g. hooks of stainless steel. Installations are usually not considered to be reused, because they are not visible nor expensive	2
The customer decides	A construction company has to follow what the customer is asking for and cannot implement reuse if it is not asked for	1
Company		
Perception of high risk to start with reuse	Uncertainties lead to the perception of high risk, which leads to nothing happening in the company or in the sector	5
Perception of high costs	It is percieved that reuse will cost more	2
Mindset of company	Lack of company policy or incorporation of reuse	2
Not in business model	Some activities are not included in the companies business model, such as selling of products (demolition company) or take-back scheme of leftover building materials. Take-back scheme of leftover building materials, real estate managers do not have storage space in their assets, waste companies do not have possibility to run a store or facilities needed to do so	6
Hard to change business model	Due to many uncertainties, it is hard to make the transformations needed to implement reuse	3
Sector		
Companies are waiting for someone else to try reuse before them	No one wants to be the first to start with reuse, it is percieved as a big risk	3
Collaboration between construction companies is lacking	Due to competition, information will not be shared between companies	3
Hard to act alone for companies	Big responsibility for solitary companies to be predecessors in reuse	8
Perception of barriers	Some barriers are perceived as big, such as laws, regulations, CE marks, sound requirements and hazardous substances. Even if they are important to keep track of, they are not the biggest barriers	1
The market is focused on wood	People consider wood as the most sustainable option for new production, forgetting about materials that could be reused	1
Society		
Everyone is set on new materials	Laws, regulation, processes, certifications and people are set on new production	1
To repair and take care of products is not the norm	People are not used to taking care of products and repair them	1
Reluctance to deconstruct buildings	Some buildings should not be deconstructed because they are in good condition and/or have a historical value. Then no materials from them will be available for reuse in other projects	1
	Sum of mentions	**71**

Table C.6: Knowledge barriers.

Barrier	Description	No. of mentions
Routines		
Lack of knowledge about how to procure reused products	Even in cases where there are instructions, it is hard to implement reuse in the procurement process, because there are many uncertainties about how to phrase the procurement	2
Routines for projection	Routines are missing for getting products from demolition projects into new production	1
Routines are missing for re-mounting of products	Different method of constructing when remounting already used products	1
Different routines	Depending on what type of product that will be reused, it is complex to set up routines because of the diversity. E.g. interior products mainly needs to have a good aesthetical and functional condition, structural elements need a further quality assurance and testing	1
Lack of case studies	The examples of reuse are just a few which leads to limited learning from experience	1
Business models		
Uncertainties about ambitions for a company	Unclear how to work with reuse for companies: how much reuse should/can be implemented in strategy and what products should be included	6
Lack of knowledge about how to work with reuse	There are uncertainties about what reuse means, and routines for working procedure are lacking in the sector	1
Uncertainties about which expertise is needed	E.g for reuse inventory or deconstruction, it is not clear who will have the expertise and if it comes from new actors in the sector, or is already present in the company	1
Reuse is not prioritized	Hard to understand how to implement reuse in a company. It is unclear what should be reused and how, which leads to not prioritizing the question	1
Lack of knowledge about costs	Hard to know if it will be profitable or not to use reused products	3
Economic effects are not known	It is not clear what the positive economic effects of reuse are, such as shorter construction time due to keeping the old building	1
Lack of knowledge about costs	Even if goals about reuse in construction projects are high, knowledge about how much it will cost to implement reuse is lacking, which makes the goals fail in the end	2
Weighting		
Companies focus on productivity and not on waste	Companies measure and are more concerned about productivity than waste generation	1
Lack of knowledge about transports and reuse	Additional transports might override the economic and environmental benefits of reuse	1
Lack of knowledge about environmental effects and reuse of products	The amount of CO2 emissions that are saved and other positive environmental effects from reuse are not always known. Unclear which option will have the best environmental effect, e.g. to keep old windows with high U-value, or change to new ones which requires more virgin material	3
Lack of awareness/knowledge about the inherent value in products	The environmental effects, such as resources and climate effects caused by the product are usually not included in the cost. The time and work that have been put into a product is hard to estimate	2
Hard to value reused products	It is hard to know the value due to several factors (demountability, transport, warranty, positive environmental effects, avoided waste and sale value) for the reused product, compared to buying new material (its transports and negative environmental effects)	1
Considerations of different factors	When choosing products for reuse, weighting design and demountability is difficult. Hard to know how to prioritize when weighting design, costs, antiquarian value, indirect, and direct environmental costs of buildings when considering reuse	2
Future		
Uncertainties about lifetime	It is difficult to know the remaining lifetime of a product and also how long the lifetime needs to be	1
Uncertainty about the future	Long life-time of products gives uncertainty about how the products will be treated in the end-of-life (concrete)	2
Not the only solution	Reuse is not by itself the only slution to a sustainable construction sector, it has limitations and more actions, such as building flexible, are needed	1
Uncertainties about demand	Unclear if and when someone will buy a reused product	1
Uncertainty about customer demand	Lack of knowledge about whether the residents want reused products or not	1
Environmental effects		
Tenants lack knowledge	Lack of awareness of CO2 emissions caused from their working/living environment, which makes tenants not consider reuse	1
Lack of awareness of how much waste that is generated	There is a general lack of knowledge of how much waste that is generated in the construction process and how it can be avoided by different design choices, such as adapting design to what is available	1
	Sum of mentions	**39**

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CHALMERS UNIVERSITY OF TECHNOLOGY
Gothenburg, Sweden 2021
www.chalmers.se

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