THE SYSTEM OF CIRCULAR MATERIAL HUBS IN THE NETHERLANDS

An exploratory research on practices performed within the system of circular material hubs in the Netherlands: its challenges, opportunities, potential future developments and the connection to architects.

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Author
Irina Köhrer

Supervisors
Mart van Uden
Bas van Vliet

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Master thesis

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Author

Irina Köhrer
Student number Delft University of Technology: 5669669
Student number Wageningen University & Research: 157302

MSc. Metropolitan Analysis, Design & Engineering

Delft University of Technology, Wageningen University & Research,
Amsterdam Institute for Advanced Metropolitan Solutions (AMS Institute)

Academic supervisors

Ir. Mart van Uden
Delft University of Technology
Faculty of Architecture and the Built Environment
Chair Group Design & construction Management

Dr. Ir. Bas van Vliet
Wageningen University & Research Department
of Social Sciences
Environmental Policy Group

Third examiner

Dr. Jaap Vleugel
Delft University of Technology
Civil Engineering and Geosciences

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ABSTRACT

Purpose: The construction industry is responsible for great amounts of resource consumption, waste generation and both carbon and greenhouse gas emissions in the European Union. The currently still predominant linear mindset of take-make-consume-dispose must shift to reduce the industry's environmental impact and enable the transition towards a circular construction industry. Circular material hubs facilitate more circularity by collecting, processing, and redistributing secondary building components to make them available for another life cycle. In literature, little can be found about the system circular material hubs are embedded in and their connection to architects. This study investigates the system of circular material hubs in the Netherlands, its challenges, opportunities, and potential future developments in the transition towards a circular construction industry. A special focus is placed on the role of architects within this system, as a circular construction industry also needs designers to include secondary building components in designs. The Netherlands is one of the top nations in the reuse of secondary raw materials and therefore provides as an exemplary setting for this exploratory research.

Methodology: An exploratory, qualitative research approach was chosen. Fourteen semi-structured interviews were conducted with representatives from circular material hubs, architects, as well as experts in the fields of circular economy, circular construction industry and construction logistics. Practitioner interviews aimed at identifying practices performed within the system of circular material hubs, and detecting challenges, opportunities and potential future developments as perceived by practitioners in the field. Expert interviews were conducted to validate the information gathered through literature review and practitioner interviews.

Findings: The research found four practice bundles which are important for the system of circular material hubs. These practice bundles are acquisition practice, processing practices, sales practices, and material harvesting practices. Within these practice bundles, different practices and performances of these practices were identified. The practices influence each other. Which building components are acquired influences which processing practices need to be performed. The type of building component also influences the sales practice as different building components target different groups of clients and are sold through different communication channels. It is also crucial whether the building components are sold offline or online. The online marketplace of Insert was found to be particularly helpful, as it is specifically designed for the construction industry and used by circular material hubs as well as architects. This shows the influence of the choice of communication channel on a circular design practice and scouting practices. By providing as much information as possible about the secondary building component at hand, circular material hubs also facilitate a circular design practice. Additionally, challenges, opportunities, and potential future developments of the system of circular material hubs were identified. Challenges the system faces are related to uncertainty and irregular assortment, guidelines, costs, and the provision of guarantees, while opportunities are governmental decisions, the provision of information and the use of shared online marketplaces. Missing collaborations are both a challenge and an opportunity. Future developments are primarily related to changes in the provision of secondary building components,

Research limitations: The limitations of this study are that social practice theory was not applied to the entire research as it is not suitable for the assessment of challenges, opportunities, and potential future developments. A greater variety of circular material hubs, not in number but in their field of activity, could present a different view on the system. Semi-structured interviews also always have certain limitations. Identifying the practices while they are being performed could also have led to more in-depth results.

Originality/value: By providing a comprehensive view on the system of circular material hubs in the Netherlands, this research helps to understand the dynamics within the system and allows the identification of potential interventions based on the practices that constitute the system.

Keywords: circular construction industry, circular material hubs, material scouting, circular design, social practices

PREFACE

In front of you is the result of a twelve-month journey that has been characterized by a few setbacks, highs and, finally, many new experiences for which I am truly thankful. This journey I am talking about is my very personal journey of writing a master thesis, the biggest challenge and yet most rewarding project I have worked on so far. Despite this thesis being the culmination of my two year MADE journey, it has thought me much more about myself than I had ever expected.

Twelve months ago, I was confronted with the question which topic I want to work on for my master thesis and for once in my life it was easy to make a decision. I knew that I want to work on a topic that is related to the construction industry and circularity. My interest for circular material hubs and building component reuse stems from my background in architecture and the realization that what I love so much, namely buildings and the beauty of the built environment, have a great environmental impact. Therefore, I wanted to do research on a topic that has the potential to decrease the environmental impact of the construction industry while also supporting the industry's transition towards more circularity. All these requirements in mind, circular material hubs seemed like the perfect topic and now at the end of this journey, I am still happy with my choice.

At this point in my master‘s thesis, it is time to thank the people who have supported me over the last few months. First, thanks to my supervisors Mart van Uden and Bas van Vliet. Mart, thank you for supporting me from the first second of this thesis onwards. You helped me to narrow down my topic, you taught me and, what I am most thankful for, you helped me to navigate through a time of major doubts by believing that this research can be finished. Bas, thank you for joining the team quite late in the process when I was in need for a second supervisor and for making the team complete. You have always been there to advise me, and your constructive criticism has helped me to complete this work. Next in line to be thanked is Quinten, thank you for our regular discussions on the topic and especially on Social Practice Theory. Your approach to understanding this complex, yet very interesting theory was inspiring and helped me to understand myself how it can be applied. Now, it is time to thank my friends who have been by my side the whole time. They encouraged me in my decisions, listened to my when I was in doubt, comforted me when I needed it, celebrated every little milestone with me and gave me honest feedback. Not to forget, thank you to my family. Even though they were over 1000 kilometers away, they helped me to overcome the challenges along the way by always believing in me. Finally, thanks to all those who were willing to be interviewed and thus enabled me to collect the data for this thesis.

Without the help and support of all of you, wiring this thesis would not have been possible, so all I can say is, thank you!

Now that I have thanked everyone, it is time to wish you a lot of fun reading this work. I hope it provokes you to reflect on what all of us can do, no matter how little, to take care of the earth we are living on and gives you new insights into a world that still offers much to explore.

Irina Köhrer
Amsterdam, February 2024

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ABBREVIATIONS

Abbreviation	Definition
CE	Circular Economy
C&D waste	Construction and Demolition Waste
EU	European Union
LE	Linear Economy
RE	Recycling Economy
SDG	Sustainable Development Goal
SPT	Social Practice Theory

GLOSSARY

Building component harvesting

In the construction industry, harvesting refers to the dismantling of building components from buildings that are deconstructed. Depending on the building components, the harvesting process can be done either manually using tools or with machines (e.g. doors and windows can be harvested by hand, while heavy elements require machines) (Lukkes, 2019).

Building component scouting

This study understands building component scouting as the practice of looking for secondary building components and deciding which ones match the requirements. Contrary to the harvesting practice, the building components are not dismantled by the scout. Scouting practices can be performed online, by visiting online marketplaces and online shops, or offline, by visiting for example a donor building (explanation by the author).

Built environment

The built environment is everything in our daily living space that is made by humans, not only those parts which are evidently created by people, such as buildings or streets, but also those that intend to bring a sense of nature into a city, for example, parks and green spaces, also including humans themselves as inhabitants of the built environment (definition by the author).

Circular built environment

The circular built environment must „(1) support human-wellbeing and natural systems; (2) be guided by system thinking; (3) be leveraged by digital technology; (4) implement holistic urban planning; (5) foster continuous material cycles; (6) design for maintenance and deconstruction; (7) provide flexible productive buildings; and (8) combine integrated infrastructure systems“ (Anacapi et al., 2022, based on Ellen MacArthur Foundation, 2018).

Circular construction industry

A circular construction industry applies the circular economy concepts to the construction industry. This translates into a more responsible use of materials and building components and regarding construction and demolition waste as a source for new building components. It focuses on recycling and reusing the industry's waste (Lieder and Rashid, 2016 & Schroeder et al., 2019 & Tukker, 2015 & One et al., 2015, as cited in Osobajo et al., 2020) and the handling of a building (component) at its end-of-life phase.

Circular economy

The CE is a „human-centred regenerative and restorative socio-economic system which increases human choices and builds human capabilities by recapturing value of materials and waste for people through slowing, closing, and narrowing material and energy loops that minimise resource inputs and waste, emissions, and energy leakage. This can be achieved by empowering workers, enabling social inclusion and fostering sustainable lifestyles through applying practices and policies for long-lasting human-centred design, maintenance, ensuring rights to repair, reusing and sharing, remanufacturing, refurbishing, and recycling” (Schröder et al., 2020, p. 5).

Circular material hubs

Circular material hubs are hubs which, by processing and supplying secondary building components, help to enable more building components to be reused in the construction industry. They contribute to improved logistics for and facilitate the use of secondary building components by bridging the gap between various actors in the material cycle (definition by the author).

Sustainable Development Goals

The Sustainable Development Goals (SDGs) are seventeen internationally agreed sustainability indicators which were presented by the United Nations in 2015 „as a universal call to action to end poverty, protect the planet, and ensure that by 2030 all people enjoy peace and prosperity“ (United Nations Development Program, n.d. para. 1).

REGULATIONS, LAWS & INSTITUTIONS

Here, all national and international regulations, laws and institutions mentioned in this work are listed.

Dutch Coalition Agreement:

The Coalition Agreement is a plan developed by the Dutch government (i.e. the coalition parties) which includes the planned achievements for the next Cabinet period. This thesis refers to the 2021 to 2025 coalition agreement between the People's Party for Freedom and Democracy (VVD), Christian Democratic Alliance (CDA), Democrats '66 (D66) and Christian Union (CU) (People's Party for Freedom and Democracy et al., 2021).

EU Taxonomy for sustainable activities

The EU taxonomy is an EU-wide classification system for sustainable activities which aligns with the net goal zero goal and the European Green Deal (European Commission, n.d.-b).

European Green Deal

The European Green Deal is a set of policy initiatives designed to guide EU countries in their goal to be climate neutral by the year 2050 (European Commission, 2021).

Housing program (Programma Woningbouw)

The Housing program (programma woningbouw) is a plan of the Dutch government that facilitates the construction of 900,000 new homes required by 2030 as a rection to the housing shortage in the Netherlands (Ministry of the Interior and Kingdom Relations, 2022).

Waste Framework Directive

The Waste Framework Directive provides a description and definition of principles linked to waste management (European Commission, n.d.-c).

World Green Building Council

The World Green Building Council is a national network working towards a more sustainable and healthier built environment (World Green Building Council, 2023-a).

1. INTRODUCTION

The construction industry is not only one of the largest resources consumers but is responsible for over 35% of the waste that is created in the European Union (EU) (European Commission, n.d.-a). On a global level, the industry is responsible for 40% of the carbon emissions (Osobajo et al., 2020) and five to twelve % of greenhouse gas (GHG) emissions on a national level within the EU (European Commission, n.d.-b). However, while generating large amounts of waste, only 30% of the materials and components that become available during the demolition of a building are reused or recycled (Ellen MacArthur Foundation, 2013, as cited in Osobajo et al., 2020). In 2022, the resources available each year were consumed within the first seven months of the year (Green Building Council, 2023). According to the World Green Building Council (2023), „by 2050, the global demand for conventional materials, such as steel, cement and aluminum, is projected to increase by a factor of two to four". Due to the production of large amounts of waste, the emission of GHG and the consumption of primary resources, the sector contributes significantly to environmental pollution. Hence, when thinking about the future of the construction industry, it must be placed in the context of environmental pollution, exploitation of natural resources and climate change. Since „climate change and environmental degradation are an existential threat to Europe and the world" (European Commission, 2021), the EU has developed the European Green Deal. Through this concept, the EU does not only want to become resource-efficient but be the first climate-neutral continent by 2050. To do so, one of the first milestones is to reduce the net GHG emissions by 55% by 2030 compared to 1990 levels (European Commission, 2021). Due to the high GHG emissions caused by the construction industry, the sector plays a major role in reaching the targets set by the EU.

The Netherlands is one of the top recycling nations in the EU and ranked third on a European level in 2016 (Centraal Bureau voor de Statistiek, 2018; Centraal Bureau voor de Statistiek, 2021; European Environment Agency, 2022). Depending on the source, the recycling rates in the Netherlands are between 57% (European Environment Agency, 2022) and 80% (Centraal Bureau voor de Statistiek, 2018). In the Dutch construction industry, 38% of the materials that were used in this sector in 2016 were recycled materials (Centraal Bureau voor de Statistiek, 2021). Due to its relatively advanced recycling activities in an EU comparison, the Netherlands were chosen as the research area for this study.

In line with the targets of the EU and the European Green Deal, the Dutch government is also working on reaching its climate objectives. Both the European Green Deal as well as the new Dutch coalition agreement stress the importance of the circular economy (CE) in the process of achieving climate objectives (European Commission, 2021; People's Party for Freedom and Democracy et al., 2021). In a CE, the take-make-consume-dispose mentality of the linear economy is replaced by the circular approach of prolonging the life cycle of materials instead of regarding them as waste. In order to reach the targets set by the European Green Deal, decrease the environmental impact and contribute to the transition towards a CE, the EU aims to increase material reuse while decreasing waste production through its Waste Framework Directive (European Commission, n.d.-a). Next to this, the EU published a taxonomy for sustainable activities (European Commission, n.d-b.). This EU-wide classification system helps to achieve the net zero goal by 2050 and aligns with the European Green Deal. It „allows financial and non-financial companies to share a common definition of economic activities that can be considered environmentally sustainable“ (European Commission, n.d.-b). Annex II of the Taxonomy published by the European Commission in 2023 contains a chapter on construction and real estate activities, including numbers that must be met for the construction of new buildings, the renovation of existing buildings and their demolition to qualify as a contribution to the transition to a CE.

For an economic activity, and therefore also for a construction project, to qualify as a contribution to the transition towards a CE, the EU Taxonomy (EC, 2023) defines the following numbers: When it comes to the construction of new buildings, a minimum of 90% of non-hazardous construction and demolition (C&D) waste must be prepared for reuse or recycling. Additionally, the primary raw material consumption must be minimized by using secondary raw materials. For the renovation of existing buildings, a minimum of 70% of non-hazardous C&D waste has to be prepared for reuse or recycling and at least 50% of the structure of the existing building must be retained. To achieve these goals, a change in thinking is needed to make material reuse a standard feature rather than an additional hurdle. This starts, for example, with deconstructing buildings rather than demolishing them, collecting, controlling, and preparing materials and making them available for reuse (EC, 2023).

The need for reducing the environmental impact of the construction sector contrasts with the growing demand for housing and the building of new housing units. As the Netherlands is currently facing a housing shortage, the government has set a target to create 900,000 new homes by 2030 (Interior and Kingdom Relations, 2022). In its housing program (Programma Woningbouw), the Ministry of the Interior and Kingdom Relations (2022) states half of the annual housing production shall be achieved through circular and industrial construction by 2030. Although increased circular construction is an objective, it is put in the context of industrial construction, including digitalization, automation, unification, and standardization. All this contributes to more circularity and can reduce waste production, but it does not aim at extending the life cycle of materials that are already available and still usable. Since C&D waste is generated throughout the entire life cycle of a building, from the design stage, through the construction stage, maintenance stage, to its end-of-life stage when it gets demolished, many materials would be available for reuse. To make construction materials that can be found in already existing buildings at their end-of-life phase available for reuse, deconstruction must be chosen over demolition.

However, released building components are not always reused, but often downcycled instead, which leads to a loss of material value. To give an example: Even though it was found that materials with a value of 688 million euros are released through renovation and demolition in Amsterdam, down cycling leads to a loss of 50% of this value (Rau and Oberhuber, 2022, Madaster section). This shows that even in countries like the Netherlands, which are among the top nations in material reuse, there is still work to be done to establish reuse practices in the construction industry. The fact that the construction industry is a sector that is slow to change (Zulu et al., 2023) does not help to achieve success quickly, but it is a reason to start making changes now.

1.1. Problem statement

The construction industry is one of the biggest resource consumers and waste producers in the EU (European Commission, n.d.-a). To reduce both of these numbers and decrease environmental impact, the construction industry must become more circular.

Some authors, such as Hosseini et al. (2015), state that designers should take the lead in the transition towards more material and building component reuse and by that a circular construction industry. To use secondary building components in architectural designs and consequently in new construction projects, they must be available for reuse. If there are no secondary building components available, it is, first, hard to justify why to include them in designs and, second, impossible to build new projects with them. In line with this, Gorgolewski (2020) states that a shift in the design process may occur when provision of secondary materials and building components becomes more available. This, again, points back towards the availability of secondary materials.

For already used building components to be available for reuse, buildings must be deconstructed instead of demolished once they reached their end-of-life phase. Currently, it is not always possible to bring the dismantled building components directly to the new construction site. Therefore, in some cases harvested or scouted building components must be stored until they are reused. This is where circular material hubs become relevant since they offer space to store secondary building components temporarily. Circular material hubs, as defined for this study, are hubs which, by processing, storing, and supplying secondary building components, help to enable more building components to be reused in the construction industry. They contribute to improved logistics for and facilitate the use of secondary building components by bridging the gap between various actors in the material cycle. From a transition perspective, circular material hubs can support the transition towards a circular construction industry. By storing and providing previously used building components, they become more easily accessible for reuse.

When it comes to the transition towards a circular construction industry, we know much about circularity indicators for the built environment (e.g. Heisel & Rau-Oberhuber, 2019; Cottafava & Ritzen, 2020), C&D waste management (e.g. Ruiz et al., 2020; Kabirifar et al., 2020; Zhang et al., 2021), life-cycle assessments (e.g. Lei et al., 2021; Has et al., 2020; Rios et al., 2019) and the importance of resource reuse and designing for reuse (e.g. Kozminska, 2019; Bertin et al., 2022). Yet, little can be found on material hubs, let alone circular material hubs, since this is a concept that is only emerging in the last few years. Studies published on the topic of circular material hubs focus mainly on spatial parameters and factors influencing site selection (e.g. Tsui et al.,2023; Yang et al., 2023; Duarte et al., 2023). There is an increasing number of student theses about circular material hubs focusing on types of circular material hubs (Nieuwhoff, 2022), their profitability of as a waste management strategy (Karamanou, 2019), how they support the transition of building material circularity in the cities (Shan, 2023), or factors that influence practices within their supply process (Isselman, 2023). In literature, however, little can be found about the system of circular material hubs, i.e. the target group of circular material hubs, the channels through which they sell secondary building components, by whom they then in turn get scouted and how these practices influence a circular design practice performed by architects. This knowledge gap subsequently leads to a lack of research on the system of circular material hubs, the correlation of practices performed within this system and its contribution towards a circular construction industry.

1.2. Research objective

The main objective of this research is to gain more knowledge on the phenomenon of circular material hubs in the Netherlands.

As mentioned already, the construction industry consumes a great number of natural resources and produces large quantities of waste (European Commission, n.d.-a). To decrease the industry's environmental impact, the construction sector must become more circular. This includes, for example, an increased reuse of building components. This is when circular material hubs enter the picture. Secondary building components are processed in circular material hubs and prepared for reuse. The question, however, is what happens once the materials can be resold. Who are the customers, how are they reached, who is scouting building components, and how can this be linked to a circular design practice?

This research therefore aims at investigating (1) what the system of circular material hubs consists of, (2) which practices are performed within the system, and (3) how they together can facilitate a transition towards a circular construction industry.

1.3. Research question

The main research question investigated during this study is as followed:

What does the system of Circular Material Hubs in the Netherlands currently consist of, and which practices performed within this system facilitate material reuse in architectural design practices in the Dutch construction industry?

To answer the research question, four sub-questions are explored:

SRQ1: Which practices are performed in circular material hubs to reintroduce secondary building components into the material cycle and make them available for reuse?

SRQ2: Which practices performed in circular material hubs facilitate the reuse of building components in circular designs?

SRQ3: Which different building component scouting practices are there in connection to circular material hubs?

SRQ4: What are opportunities, challenges, and potential future developments of circular material hubs in the Netherlands?

1.4. Academic relevance

In academic literature, little can be found on the topic of circular material hubs and the system they are embedded in. As a recently emerging topic in research, a more in-depth understanding of circular material hubs is needed. This includes the need to gain a broader view on the system they are embedded in. Circular material hubs as physical locations where secondary building components are handled are not only interesting because of the physical work that happens directly at the location to prepare building components for reuse, but also because of the role they potentially play in increasing the reuse of building components. Next to the focus on the circular material hub itself, it is important to understand the system they are embedded in, or better the system they constitute. It is important to understand the connection between circular material hubs and other actors in the construction industry to develop a more in-depth understanding on the role they play in the transition towards a circular construction industry. By understanding the role of circular material hubs within the system they are embedded in allows to gain a better understanding of their role in the transition towards a circular economy. Circular material hubs facilitate the use of secondary building components by making them available to other actors in the construction industry. Hence, they inherently contribute to the transition towards a more circular construction industry. However, it is important to understand how they, next to the mere provision of secondary building components, potentially contribute to greater building component reuse. Detecting the connections and influences that appear within the system does not only help to understand how the system works, but also how it can be improved. By improving the system, the aim is to achieve a greater contribution to the transition towards a circular construction industry.

1.5. Societal relevance

This research contributes to gain a more comprehensive view on circular material hubs and the system they are embedded in. This is not only interesting for practitioners in the construction industry, but also benefits society. As the construction industry is a major contributor to GHG emissions, waste production and therefore environmental pollution, it has a significant impact on people and the planet. Practices that are directly related to circularity and therefore resource protection or efficiency as well as waste prevention add value to both humans and the environment. Circularity contributes to greater sustainability and helps to achieve the climate goals that are necessary. As circular material hubs provide secondary building components, they inherently contribute to building component reuse. Providing a more in-depth understanding of this system therefore also contributes to an increased understanding of potential factors that influence the transition towards a circular construction industry. The more circular the construction industry becomes, the less impact it has on the planet, and therefore also on humans. Replacing the take-make-consume-dispose mentality by the circular approach of prolonging the life cycle of materials instead of regarding them as waste decreases the need of primary raw materials. Additionally, if more materials are reused, less waste is produced, which in turn also contributes to a healthier environment.

The societal relevance of the present research can also be explained by means of the Sustainable Development Goals (SDG). SDGs are seventeen internationally agreed upon sustainability indicators which were presented by the United Nations in 2015 „as a universal call to action to end poverty, protect the planet, and ensure that by 2030 all people enjoy peace and prosperity“ (United Nations Development Program, n.d. para. 1). According to Ogunmakinde et al. (2022), several SDGs can be directly and/or explicitly associated with the construction industry. By providing a more comprehensive understanding of the system of circular material hubs, this research contributes to the following SDGs: SDG 8 (decent work and economic growth), SDG 11 (sustainable cities and communities), SDG 12 (responsible consumption and production), and SDG 15 (life on land). Figure 1.1 provides an overview of the SDGs this research contributes to.

Figure 1.1 Overview of the SDGs, this research contributes to. From United Nations Development Program.

The SDGs, European Green Deal and Dutch coalition plan can all be linked to each other. Since the CE contributes to reaching the set climate targets, it also contributes to the SDGs. The circular construction industry, in turn, is placed is the context of the transition towards a CE and therefore also contributes to the SDGs. Ultimately, all of this provides a contribution to reach the climate objectives and limit exploitation of both the environment and humans.

1.6. Scope

The present research was conducted over a period of twelve months and focuses on the investigation of the system of circular material hubs in the Netherlands.

Qualitative data was collected through semi-structured interviews. The interviewees relevant for this study can be categorized into three different groups: representatives of circular material hubs, architects who consider secondary building components in their designs, and experts who are knowledgeable on different topics related to a circular construction industry.

The study draws a clear line between material hubs, which are mostly contributing to improve transport logistics, and circular material hubs, which are contributing to material reuse by collecting, processing, and offering secondary building components. Only circular material hubs are considered in this study. It is not considered important what exactly these hubs call themselves, as long as they work with secondary building components and fulfil the other criteria (see Table 5.1). Circular material hubs which only offer components to produce secondary raw materials, e.g. ground concrete or shredded wood, but no building components which can be used immediately, i.e. structural elements, non-structural elements, or furniture, are not within the scope of this study. For further information on all criteria that must be fulfilled by the chosen circular material hubs, see table 5.1. Circular material hub representatives interviewed for this study are working in management positions. This means that their field of work does not include manual work in the circular material hub (e.g. cleaning or remanufacturing secondary building components).

Further, within the scope of the study are architects who already include secondary building components in their designs and therefore perform a circular design practice. Architects who are not working with secondary building components are not included in the present study. All architects must be located and active in the Netherlands to be considered part of the investigated system of circular material hubs.

Experts incorporated in this study must have knowledge on the circular economy, the circular construction industry, construction logistics, circular material hubs, and designing with secondary building components. Interviewees who are considered experts do not have to be active in the Netherlands but must have knowledge about the current situation in the country.

The decision to only consider circular material hubs in the Netherlands can be explained by the country's position amongst the top countries when it comes to the reuse of secondary raw materials. For this reason, it was decided to investigate what the system of circular material hubs consists of in a country that is one of the pioneers to form a basis for future research on this topic. The exact location of the circular material hubs within the Netherlands had no influence on whether they were eligible for the study. This means that the circular material hubs did not have to be located in a specific province due to the limited geographical extent of the country, the resulting spatial proximity and embedding in a similar systemic environment.

The circular material hubs under investigation represent a variety of circular material hubs in the Netherlands, e.g. by targeting different groups of clients, their size, and the building components they work with. The research recognizes that there are many other circular material hubs and architects present within the system of circular material hubs in the Netherlands whose inclusion could lead to a broader view of the system of circular material hubs in the Netherlands, e.g. because of different practices that potentially could have been identified. However, by choosing circular material hubs according to predefined criteria (see Table 5.1.), it was possible to intentionally select them based on their differences and similarities. By choosing circular material hubs based on their differences, a wide range of the system could be represented. Those differences are, for example, the target groups they focus on or the building components they handle. At the same time, circular material hubs were also chosen based on certain similarities such as their location in the Netherlands and their ability to supply secondary building components for middle to large scale construction projects to enable comparisons.

1.7. Outline

This document is structured in a way that guides the reader to understand the research from the start to finish. Chapter 2, Theoretical background, provides the reader with the most important information, concepts and strategies related a circular economy and circular construction industry that form the basis to understand the topic under research. In chapter 3, Theoretical framework, an explanation of social practice theory is provided. This can be understood as the lens through which the topic of research is looked at. Chapter 4, Research methodology, is an explanation of the analytical framework and the data collection methods is provided. Following this, chapter 5, Results, presents the findings of the research. This chapter forms the base for chapter 6, Discussion, where the findings are synthesized, discussed, and compared to literature. Finally, chapter 7, Conclusion, provides the conclusion of the present research, including its limitations and recommendations for both practitioners and future research. Table 1.1. visualizes the study outline and shows in which chapters the sub-research questions are targeted.

Reader's guide

The general outline of each chapter is as follows: in the beginning, an introduction provides an outlook on the content of each chapter, including a summary of the most important topics. In the main body of each chapter, the respective chapter topics are covered, explained, and discussed in detail. At the end of each chapter, a chapter summary brings together the most important information and take aways.

			Related sub-research question
Chaoter 1	Introcution		
Chaoter 2	Theoretical background		
Chaoter 3	Theoretical framework		
Chaoter 4	Research methodology		
Chaoter 5	Results	5.2	**SRQ1:** Which practices are performed in circular material hubs to reintroduce secondary building components into the material cycle and make them available for reuse?
		5.2	**SRQ2:** Which practices performed in circular material hubs facilitate the reuse of building components in circular designs?
		5.2	**SRQ3:** Which different building component scouting practices are there in connection to circular material hubs?
		5.2	**SRQ4:** What are opportunities, challenges, and potential future developments of circular material hubs in the Netherlands?
Chaoter 6	Discussion		
Chaoter 7	Conclusion		

Table 1.1 Overview of the study outline and the sub-research questions.

2. THEORETICAL BACKGROUND

The Theoretical background chapter provides an overview of concepts related to the circular construction industry which are necessary to understand why a transition towards more circularity is needed and how this supports national and international efforts of climate protection. First, the current state of our economy will be described, including different types of economies and material loops. Second, advantages of a circular economy will be highlighted and its importance for the environment, society and economy are described. Following this, an explanation of the R-ladder, one of the ways to measure the degree of circularity, will be provided. This is important to provide the reader with a tool to distinguish different stages of circular progress. This also helps to categorize the various processing practices for secondary building components in circular material hubs later in this study. Subsequently, the focus will be placed on the circular built environment and circular construction industry. This part of the chapter is especially important for the present study to understand the context of the research as it also focuses on circular material hubs.

2.1. Linear and circular economy

Currently, the linear economy (LE) is still the predominant economic concept when it comes to the use and management of resources. It is characterized by a take-make-consume-dispose mentality where natural resources are extracted, turned into goods to generate profit, and disposed when they are not needed anymore (Sariatli, 2017). The circular economy (CE) is the antithesis to the LE and provides a concept which is considered a key strategy for enhancing sustainability (Preston, 2012 & Lieder and Rashid, 2016 & Ghisellini et al., 2018, as cited in Osobajo et al., 2020). Potting et al. (2017, p.4) state that „as a rule of thumb, more circularity equals more environmental benefits“. The CE aims at a reduction of natural resource and material consumption, while minimizing waste production, decreasing the release of pollutants into the soil, water, and air, and retaining value over a longer period (Potting et al., 2017; Morseletto, 2020). Instead of disposing products once they reach their end-of-life phase, they are returned to the system (Ogunmakinde, 2022). There is a broad concept of what a CE is, including certain characteristics and aspects. However, there is no commonly accepted definition of a CE yet (Kirchherr, 2017; Yamaguchi, 2022). In 2017, a study by Kirchherr et al. found 114 definitions of a circular economy. Only a couple of years later, in 2023, Kirchherr et al. published a follow up study which included the analysis of 221 CE definitions that were published after 2017. This shows that there are a large number of CE definitions. Some definitions that can be found in literature are primarily concerned with material resources and waste, while others argue for a transformation of the entire economic system (Rizos et ak., 2017). Geissdoerfer et al. (2017) found that the majority of authors do not consider the three dimensions of sustainability (social, economic, environmental) comprehensively, but primarily look at the environmental performance enhancement that can be achieved through a CE. Furthermore, social wellbeing is only covered marginally by most CE authors, leading to many CE concepts that “appear to exclude large parts of the social dimension” (Geissdoerfer et al., 2017, p. 766). According to Jaeger-Erben (2021) this lack of attention to social sustainability

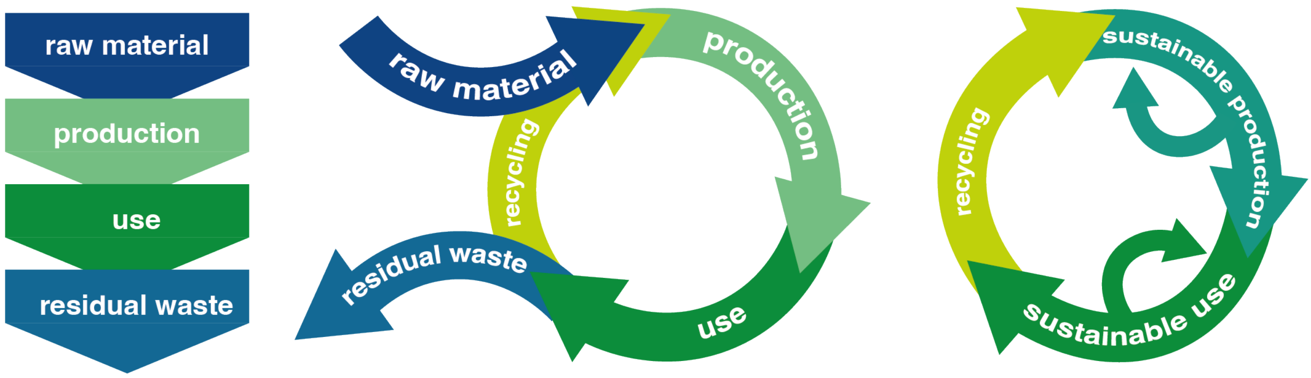

Figure 2.1 Comparison of linear economy, recycling economy, and circular economy, visualizing the handling of resources. Adapted from Council for the Environment and Infrastructure, 2015, p. 60.

and social change has been reason for criticism. In 2023 (p. 6), Kirchherr et al. found that social issues such as "human health, well-being, and development, 'just' transitions, and the concept of a circular society" are also dealt with throughout the sample of definitions that were published recently (e.g. Schröder et al., 2020; Friante et al., 2020; Jaeger-Erben et al., 2021)).

The present study is also in favor of a CE definition that does not only combine economic benefits with necessary environmental efforts, meaning that the current linear behavior is replaced by a circular behavior while still supporting the underlying mechanisms that characterize the linear system today. Hence, this research aims for a CE definition that rethinks the system and considers social aspects as well. Based on the CE definition provided by Geissdoerfer et al. (2017, p. 759), Schröder's et al. (2020, p. 5) attempt to define a CE including a focus on human development is as follows: The CE is a

> *„human-centred regenerative and restorative socio-economic system which increases human choices and builds human capabilities by recapturing value of materials and waste for people through slowing, closing, and narrowing material and energy loops that minimise resource inputs and waste, emissions, and energy leakage. This can be achieved by empowering workers, enabling social inclusion and fostering sustainable lifestyles through applying practices and policies for long-lasting human-centred design, maintenance, ensuring rights to repair, reusing and sharing, remanufacturing, refurbishing, and recycling."*

The definition provided by Schröder et al. (2020) is also the one used in this research.

2.2. Material loops in different economies

One of the main differences between different economic concepts such as the LE and CE is the way resource use is handled. Since nothing is black and white, there are also concepts which are positioned between LE and CE, for example the economy with feedback loops, which is also known as recycling economy (RE) (Council for the Environment and Infrastructure, 2015). Figure 2.1 shows a graphic from the Council for the Environment and Infrastructure (2015) which depicts the differences in resource use between LE, RE and CE. LE does not consider reusing and recycling materials and products at all. As already mentioned before, this economy is solely focused on a single life span of a product. One step further is the so-called recycling economy, where materials are recycled, but raw materials are still added, and waste is generated. This means that although a cycle already exists, it is not completely closed yet, and the focus is on recycling and recovery (rather than reuse). In a CE, however, the loops are fully closed, and materials and products are reused repeatedly (Council for the Environment and Infrastructure, 2015). A circular approach to managing the use of resources would mean that materials and products stay in the chain as long as possible and are used again after a product is disposed, ideally maintaining their initial quality (Potting et al., 2017). Despite all circularity efforts, it must be emphasized that it is not possible to close the material loop 100% due to additional materials that must be added to keep the original ones in the cycle (Eberhardt et al., 2019, as cited in Benachio et al., 2020).

2.3. Environmental, social, and economic advantages of a circular economy

According to van Buren et al. (2016), shifting towards a CE creates economic, social, and environmental value and Ghisellini et al. (2018, as cited in Osobajo et al., 2022) state that material reuse provides both environmental as well as economic advantages. The Dutch government claims that a transition towards a CE is required to meet their climate targets and creates new economic opportunities such as new markets, new income streams and more collaboration but also stresses that new economic structures must be developed for these opportunities to arise (Ministry of Infrastructure and Water Management, 2021).

The following three benefits were found by van Buren et al. (2016):

1. Less dependency on other countries for importing natural resources to produce goods.
2. Employment generation due to an increased need for regional reuse, repair, remanufacturing, and reclamation activities. These activities were traditionally outsourced to countries with lower wages but are recently relocated closer to the place the end products are sold. Additionally, more jobs are created in industries which offer innovative expertise, advanced technologies and services for circular production-consumption chains and protection of the environment.
3. Possibility of an immediate and substantial decrease of environmental impact.

In this context, the question arises whether circular business models per se are enough to facilitate a transition towards a CE. Hart et al. (2019, p. 620) argue that, despite circular business models often being seen "as enablers and facets of CE", it depends on the context whether they are enablers or barriers. When it comes to alternative ownership models, for example, a performance contract on its own is not enough. As an example, Hart et al. (2019) refer to the pay-per-lux model for lighting. Instead of solely providing the luminaires, it is crucial to consider future dismantling, disassembly, and upgrading. Additionally, Maitre-Ekern (2021) stresses the importance of producer responsibility for repair and so-called take-back schemes. This means that they must produce products that can be used for as long as possible, with materials that can be used for as long as possible. If producers must take back their products at the end of their life cycle, either to prepare the product for another use time or to use use its components for another product, it is an incentive to (1) produce products that can be disassembled, and (2) use materials that are of good quality to reduce economic losses. Producers "must plan for waste avoidance, not waste management" (Maitre-Ekern, 2021, p. 10)

A factor that also plays a role in the question of extending the life cycle and usage time of materials is of financial nature. Rau and Oberhuber (2022, Write down, not off section) provide an example about furniture use duration in hotels. According to them, furniture in big hotel groups is changed after five to seven years. Even if the furniture was still in good condition, it would be replaced due to the financial depreciation period. This example shows that materials or products can still work perfectly fine, even after they reach their first end-of-life phase. It is therefore important to ensure that discarded materials and products are reused to reduce excessive and unnecessary use of primary raw materials.

2.4. The R-ladder, measuring circularity

The R-ladder or R-list is a hierarchy of strategies to achieve more circularity and a useful way to talk about or measure the degree of circularity. There are various ways to assess the degree of circularity. This research uses the concept of the R-ladder, as it is also part of EU policies and the Waste Framework Directive, a concept which targets the basic waste management principles and defines what waste is (European Commission, 2008).

The R-ladder has its origin in the „Ladder of Lansink" („Ladder van Lansink" in Dutch), a concept for waste management and resource protection introduced by the Dutch politician Ad Lansink in 1979. Other names for the „Ladder of Lansink" are „Waste Hierarchy" or „Hierarchy of Waste Management" (Recycling.com, 2021). There are several advantages associated with the implementation of a waste hierarchy, including reduced energy consumption, decreased harmful substances, protection of resources, encouragement of green technologies and prevention of hazardous GHG emissions (Recycling.com, 2021).

Over time, different variations of R-ladders were developed, which differ mostly in the number of circular strategies (i.e. numbers of Rs on the ladder). While the original „Ladder of Lansink" consists of six steps, namely reduce, reuse, recycling energy recover, incineration and landfill (Recycling.com, 2021), there are versions with

Figure 2.2 Waste hierarchy of the EU, visualizing the preferred hierarchy from prevention to disposal, from EC, 2008.

up to ten circular strategies (R0 - R9), including recover, recycle, repurpose, remanufacture, refurbish, repair, re-use, reduce, rethink and refuse (Potting et al., 2017). Even though there is also an R-ladder specifically designed for the construction industry, the so-called Delft Ladder, which is based on “prevention, construction reuse, element reuse, material reuse, useful application, immobilization with useful application (recycling, composting, anaerobic digestion), immobilization, incineration with energy recovery, incineration and landfill”. (Zhang et al., 2021; Hendriks & Dorsthorst, 2001), this study will use a five-step waste hierarchy provided by the EU which consists of prevention, preparing for reuse, recycling, other recovery, and disposal (EC, 2008). Figure 2.2 shows the EU waste hierarchy. Regardless of which R-ladder is chosen, the following applies to all: the lower the R-number, the higher the degree of circularity (PBL Netherlands Environmental Assessment Agency, 2018).

The CE also works with R-based principles, also called a 3R rule, namely reduce, reuse, and recycle (Zhang et al., 2022). Comparing the Rs used in the CE framework to the Rs used in the waste hierarchy, one can see that the former does not include disposal, while the latter does (Zhang et al., 2022). According to Zhang et al., (2022), another similarity is, that both the CE and the waste hierarchy take the entire life phase of a product into account, which means that they consider the pre-use (prevention), use (preparing for reuse), and post use (recycling, other recovery, disposal) phase of a product.

Figure 2.3 Explanation of the concepts used in the five-step waste hierarchy from the EU, illustrated by the author.

The decision to work with the waste hierarchy of the EU was made to directly link the present research to the targets of the EU. Furthermore, not all strategies included in larger R-ladders such as the one with ten steps are important for this research, as the focus is on strategies to extend the life cycle of building components and keep them in the loop for longer. To understand the used R-ladder or five step waste hierarchy better, Figure 2.3 provides a definition of all concepts included according to the definitions provided by the EU (EC, 2008).

2.5. The circular built environment

Before discussing a circular construction industry, it is necessary to address the circular built environment. To do so, the term built environment must be defined, as this definition provides the basis for a conversation about a circular built environment.

The built environment

There is no commonly accepted definition of the built environment (Ancapi et al., 2022). While some scholars refer to construction elements or infrastructure, others focus on multiple levels within the urban scale. The EC defines the built environment as "everything people live in and around, such as housing, transport infrastructure, services networks or public spaces" (European Parliament, n.d., para. 2). Bolton et al. (2018, p. 27) provide a similar but more detailed definition: „All forms of buildings (residential, industrial, commercial, hospitals, schools), all economic infrastructure (above and below ground) and the urban space and landscape between and around buildings and infrastructure". This study defines the term as follows:

> *The built environment is everything in our daily living space that is made by humans, not only those parts which are evidently created by people, such as buildings or streets, but also those that intend to bring a sense of nature into a city, for example, parks and green spaces, also including humans themselves as inhabitants of the built environment.*

The inclusion of humans in the definition of a build environment can be argued as follows: First, they play a crucial and leading role in the construction of the built environment, namely as initiators and builders of, for example, new construction projects. Second, they can and do intervene in nature and the built environment according to their wishes. If they want to seal an area or remove trees to build there, they can do so, if permission is granted. Therefore, humans are considered part of the built environment, too. This means that everything that would not be there without human intervention, including humans themselves, can be summed up as built environment in this study.

The circular built environment

The circular built environment, in turn, is about implementing the concept of CE in the built environment and applying CE characteristics to reduce its environmental impact. According to Ogunmakinde et al. (2022, p. 2) „the World Green Building Council acknowledged the CE as one of the innovations that could enable the built environment contribute to sustainable development". This notion is also supported by Schröder et al. (2020) who state that sustainable urban transitions need an incorporation of CE principles into the built environment. Similarly, Joensuu and Saari (2018) state that, due to its large environmental impact, a circular built environment could lead to a reduction of many issues regarding sustainability. Furthermore, they note that it is not only about physical aspects of the built environment, such as the construction of buildings and infrastructure, but also about the way they are „operated, maintained and used for different purposes" (Joensuu and Saari, 2018, p. 3). The approach of not only including physical constructions, but also humans and their interactions with the built environment, is also supported by other authors and organizations. Based on Schröder et al. (2020) and Korhonen et al. (2018), Ancapi et al. (2022, p. 1) state that "political, social, economic and behavioural aspects, which are known to present essential barriers and drivers to systemic change" are not considered when it comes to the circular built environment. Ancapi et al. (2022, p. 2) provide a summary of the understanding of the circular built environment by the Ellen MacArthur Foundation in 2018, which does not only refer to buildings and construction, but must

> *„(1) support human-wellbeing and natural systems; (2) be guided by system thinking; (3) be leveraged by digital technology; (4) implement holistic urban planning; (5) foster continuous material cycles; (6) design for maintenance and deconstruction; (7) provide flexible productive buildings; and (8) combine integrated infrastructure systems."*

This study also adopts the view that humans are part of the circular built environment. If the CE concept is implemented in the built environment, and, according to the definition of a CE provided in chapter 2.1., humans and society must be considered in a CE, they inherently also must be part of the circular built environment. Therefore, the definition of a circular built environment by the Ellen MacArthur Foundation, as provided above, is also applicable to this research.

2.6. The circular construction industry

In the context of the construction industry, the CE concept translates into a more responsible use of materials and building components and regarding C&D waste as a source for new building components. This means that a circular construction industry focuses on recycling and reusing the industry's waste (Lieder and Rashid, 2016 & Schroeder et al., 2019 & Tukker, 2015 & One et al., 2015, as cited in Osobajo et al., 2020). Therefore, the handling of buildings and building components at their end-of-life phase is crucial. The importance of a shift towards a more circular construction industry is highlighted by Kootstra et al. (2019, p. 3) who state that „even a ‚less linear' economy could create large impact, since the construction sector accounts for large resource consumption, greenhouse gas emissions and waste production."

Construction and demolition waste

A comparison of the C&D waste management practices of the EU member states (note: EU28) showed that the Netherlands is the country with the best C&D waste management (Zhang et al., 2022).

The construction industry uses 50% of all the raw materials that are minded globally every per year (de Wit et al., 2018, as cited by Anastasiades et al., 2021). While in 1960 approximately 21 billion tonnes of raw material were extracted, the number quadrupled, leading to roughly 84 billion tonnes of extracted raw materials today (de Wit et al., 2018, as cited by Anastasiades et al., 2021). According to Zhang et al., (2021), C&D waste is the main waste stream of gross waste production in our society nowadays. According to Reike et al. (2018), as cited in Anastasiades et al. (2021), from the 95% of C&D waste that can be recycled, most is downcycled and used for the foundation in road construction. The large quantities of C&D waste can be partly attributed to the fact that the construction industry still operates on a linear model, where natural resources are extracted, turned into building components and assembled in such a way that they cannot be deconstructed and therefore must be sent to landfills or incinerated (Ellen MacArthur Foundation, 2015 & Mangialardo and Micelli, 2018, as cited in Benachio et al., 2020).

C&D waste is not only made up by waste produced during the C&D phase of a building, but also during renovation. While demolition only accounts for 8% of all building activities, it produces, depending on the source, 55% to 70% of C&D waste. New construction, on the other hand, produces 16% of C&D waste while being responsible for 52% of all building activities. Renovation accounts for 29% of C&D waste while making up 40% of building activities (Koutamanis et al., 2018).

According to Kibert (2016, as cited in Osobajo et al., 2020), more than 50% and thus most of the C&D waste is generated during the end-of-life phase of a building and the demolition process. Nevertheless, is important to keep in mind that C&D waste is generated throughout the entire life cycle of a building, which implies that waste is not generated only when a building is demolished or deconstructed. C&D waste can already be prevented during the design process when designers are aware of decisions that can be taken to reduce waste (Esa et al., 2016, as cited in Benachio et al., 2020). According to Adams et al., 2017, as cited by Hart et al., 2019, how circular each stage of a building's life-cycle can be is influenced by

> *„legislation and policy; awareness and understanding; manufacture of construction products (design for end-of-life); designing and operating buildings (design for disassembly, adaptability etc.); recovery of materials and products (market mechanisms); business (Circular Business Models - CBMs, contracts, metrics); economic (the financial case for CE)".*

The production and sources of waste differ based on construction activity, site, and process (Jones & Greenwood, 2003, as cited in Ogunmakinde, 2019). Ogunmakinde (2019) reviewed different studies to find significant factors which contribute to the generation of C&D waste. As part of this, Ogunmakinde (2019, p. 25) noted the following causes for C&D waste:

„inadequate storage facilities, off-cuts of materials, improper handling of materials, poor site management practices, material spillage and left over, poor supply chain management, contractors' inexperience, mistakes, rework, and inadequate scheduling".

According to Ghisellini (2008, as cited in Donkers, 2020), the environmental impact can be reduced by reusing construction elements in their initial form instead of recycling them first. The material stock available within the urban fabric and built environment can provide resources for future construction projects once a building reaches its end-of-life phase (Gorgolewski, 2019).

Building component categories

For this research, four different categories of building components are important, depending on how and for what they can be used. In other words, some products can be used to create new materials, while others can be directly reused in the same way they were used in the past. A distinction can be made between secondary raw materials, structural elements, non-structural elements, and interior (Figure 2.4). A differentiation between the four categories is important as this research is also concerned with the category of building components offered by a circular material hub. Below, a description of each category including some examples is given:

I. Secondary raw materials: Secondary raw materials are those materials which are returned to the economy and material chain as new raw materials, e.g. by recycling waste or end-of-life products (Polidori, 2021). Examples for secondary raw materials are wood in various forms, paper, glass, metals, or plastics (PPC Group, 2022). According to the Dutch Ministry of General Affairs (2023), "in a circular economy, waste is the new raw material".

II. Structural elements: Structural elements include all elements or building components that can resist forces and therefore help to prevent a building structure from collapsing. This includes, amongst others, foundations, beams, columns, structural and load-bearing walls, slabs, or roofs (Law Insider, n.d.).

III. Non-structural elements: Non-structural elements comprise all building components that are non-load-bearing and do not directly absorb forces but are attached to a building or can be found within a building. These include, amongst others, windows, doors, (false) ceilings or panels (Humanity Development Library 2.0, n.d.; Murty, C.V.R., n.d.).

IV. Interior: Even though furniture such as tables, chairs, shelves, or cupboards, which are necessary for the operational use of a building, are also part of the non-structural elements, they are assigned to the Interior category in the present study due to their significantly different nature than non-structural elements.

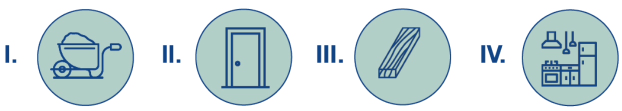

Figure 2.4 Overview of the building component categories. Visualized by the author.

2.7. Circular material hubs

Before discussing circular material hubs, the concept of material hubs must be explained. This forms the basis to understand the emergence of circular material hubs,

Material hubs

A material, construction or logistics hub is a facility that supports the logistics of construction projects by providing a central location outside of cities from where building components can be distributed. Building components are brought to the material hub in large quantities, stored there and then transported directly to the construction site in smaller quantities (van Hoogdalem, 2022). By organizing and making the logistics for construction projects more efficient, material hubs contribute to reduced pressure on the construction site surrounding, less congestion, improved air quality and decreased CO_2 emissions (Metabolic, n.d.; van Hoogdalem, 2022). Material hubs, however, do not aim at facilitating more circularity within the construction industry, as they do not focus on secondary building components (Metabolic, n.d.).

Circular material hubs

In comparison to material hubs, circular material hubs focus on the provision and logistics for reused building components. Due to a possible discrepancy between supply and demand, both in terms of time, location, quantity, and quality, it is necessary that materials can be stored temporarily (Metabolic, n.d.). This is where circular material hubs can help. A study provided by Tsui et al. (2023, p.4) found that there are two understandings of circular material hubs, namely

"as industrial hubs or clusters, where circular companies are close to one another in order to share and exchange resources and knowledge, or as urban mining hubs, where materials are collected, stored, processed, and re-distributed."

From this, is can be concluded that circular material hubs are characterized either by the co-location of companies with a circular mindset or by the provision of secondary building components. The present study focuses on the second definition of circular material hubs as spaces to store recovered building materials and components temporarily, verify their condition and quality, process them, and prepare them for reuse before passing them on. Tsui et al. (2023) further differ between four categories of circular material hubs, as seen in Figure 2.5, based on their regional scale, industry perspective, local scale, and logistics perspective. In the following, a description for each category is given, as provided by Tsui et al. (2023).

a) Circular industry hubs work on a large scale (national, provincial) and process bulk building materials, e.g. asphalt, concrete, sand, gravel, or topsoil.

b) Urban mining hubs handle building components which do not need "processing before redistribution" through sorting, storing and distribution, e.g. bricks or doors. There is potentially one bigger hub connected to smaller so-called satellite hubs.

c) Circular craft centers and local material banks together form the category of craft hubs.

a. Circular craft centers work on a more regional scale and produce small scale products from residue construction flows, e.g. furniture or retail areas.

b. Local material banks are often connected to circular craft centers because they are at the same location or run by the company. They process residue flows which are not interesting for larger companies and often work together with people with a distance from the labor market.

The present study focuses on circular material hubs which fall in the category of urban mining hubs. These circular material hubs focus on

> *"housing and offices (…) because they often have standardized materials, and require regular renovations … [and] [g]overnment buildings (…) [because they] are backed by the governmental circular public procurement strategies, which allow for more centralized coordination of construction and demolition" (Tsui et al., 2023, p. 14).*

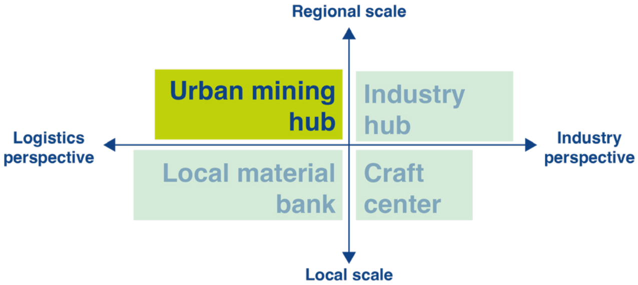

Figure 2.5 Different types of circular material hubs. Adapted from from Tsui et al., 2023, p. 10.

The main activities in circular material hubs are "inspection, sorting, upcycling, preparation for reuse/recycle, reuse or storage" (Karamanou, 2019, p. 10)

As shown above, different terms are used in academic literature and in practice to describe circular materials hubs. Therefore, it is important to mention that the similarities between the underlying concepts described in various publications on this topic are important rather than a conformity in names (e.g. circular building hub, circular material hub, circular construction hub, or urban mining hub). To conclude, this study understands circular material hubs as hubs which, by processing and supplying secondary building components, help to enable more building components to be reused in the construction industry. They contribute to improved logistics for and facilitate the use of secondary building components by bridging the gap between various actors in the material cycle.

Materials offered in circular material hubs

Harvesting secondary materials can be supported by, among other actors, demolition or salvage companies (Gorgolewski and Ergun, 2013, as cited in Ditte et al., 2021). For circular material hubs, especially those building components with a long life cycle are important, since they can be reused and therefore offered at those hubs (Leising et al., 2018, as cited in Ditte et al., 2021). According to Ogunmakinde et al. (2022), a significant proportion of construction materials can be reused and recycled. In some cases, reusing a material is the preferred option, while in others recycling is the better choice. Ogunmakinde et al. (2022) cite information provided by different scholars on materials which are preferably reused or recycled. For windows and doors, reuse is preferred, while wall and roof structures are suitable for both reuse and recycling, concrete and steel are preferably recycled and an entire building can be reused (Ng and Chau, 2015, Yellishetty et al., 2011 & Al-Obaidi et al., 2017, as cited in Ogunmakinde et al., 2022).

Contribution towards a more circular construction industry

The demand for building components cannot be met with what becomes available through deconstruction (Shan 2023). Nevertheless, circular material hubs have positive effects on minimizing demolition waste and increasing both material efficiency and the proportion of secondary material used in a project (Shan, 2023). Next to promoting material reuse, they can also contribute to a greater stakeholder awareness (CIRCLE Economy & Metabolic, 2022, Economy, 2020, as cited in Shan, 2023). Shan (2023) states that circular material hubs can be understood as a supporting factor in the transition towards more circularity, but that matching supply and demand is just one piece of the puzzle in the entire transformation.

2.8. Reuse in the construction industry

> *„Architect Jeanne Gang suggests that ‚[b]y proposing a building made from materials at hand, the project introduces an entirely new paradigm for a project delivery process that has not changed substantially in the last fifty years. It radically alters the way a building is both conceived and made: form follows availability' (Gang & Gang, 2010, as cited in Gorgolewski, 2019, p. 2).“*

The design phase has been found to be the most The design phase has been found to be the most favorable time to decrease C&D waste (Ekanayake and Ofori, 2004, as cited by Akanbi et al., 2019). According to Anastasiades et al. (2021), it is necessary to improve more than just the environmental performance of materials and the construction of newly built projects, as it is also crucial to optimize the design and how it is built. In line with this, Ditte et al. (2021), who are citing Johansen and Wilson (2006) and Kibert (2013), stress the importance of incorporating circularity at the beginning of a construction project by stating that the pre-phase of a project might be even more decisive when it comes to an effective implementation of circular strategies. Steps which become important during the end-of-life phase of a building, such as dismantling, reuse or recycling, must already be considered during the first phases, when a project is initiated, prepared, and designed (Ditte et al., 2021). Next to this, Kooter et al. (2021) state that a more conceptual level of designing is needed to cope with the unpredictable supply of building components. This indicates that designers need to change the approach to a design project and incorporate a circular way of thinking already at the planning stage.

Literature shows that designing with secondary building components requires additional skills. Kozminska (2019, p. 7), for example, states that architects who are designing with secondary building components need more and more expertise in navigating "between often contradicting circumstances without compromising the quality of created sustainable architecture." According to Hosseini et al. (2015), designers are often not concerned with meeting the requirements of deconstruction due to the linear thinking they are used to. While designers learn how to design with primary building components during their education and practice, designing with secondary building components is often not included in their education (Kozminska, 2019). Gorgolewski (2020) states that a shift in the design process may occur when there is a better understanding of the use of secondary building components and when they become more available. This means that, next to knowing how to design with secondary building components, it is also important to know where to find the necessary information about them. When designing with primary building components, information about these components can be acquired from resources such as catalogues, brochures, websites, or experts (Kozminska, 2019). This is more complicated when it comes to designing with reused building components, as information regarding their availability, location and characteristics is not always available (Kozminska, 2019).

Reuse in the construction industry - challenges

By using secondary building components instead of primary ones, the environmental impact can be reduced by two to twelve times (Deweerdt & Mertens, 2020). In line with this, Anastasiades et al. (2021) state that building component reuse is better for the environment than simply recycling materials. However, the decision which secondary building components to use is accompanied by the assessment of a range of technical, aesthetic, economic and social aspects, which potentially results in "a longer and more expensive design and construction process" (Kozminska, 2019, p. 2). In addition to the aspects mentioned above, designing with secondary building components has infrastructural, legal, and environmental challenges (Kozminska, 2019). These challenges or additional requirements also include the provision of guarantees. While certifications are traditionally provided by the producer, the use of secondary building components often requires designers to obtain the required permits and certificates (Kozminska, 2019).

Next to the challenges mentioned before, the stakeholders themselves can also sometimes be considered a barrier. Hosseini et al. (2015) state that even though designers need to take the lead in the transition, the duty and function of other stakeholders (builders, demolition-subcontractors, and policy makers) must be revised as well. Here, it should be added that designers, clients, and subcontractors are the most critical players who are not aware enough of the importance of

CE (Adams et al., 2017, as cited by Anastasiades et al., 2021). Kozminska (2019) emphasizes a need for early collaboration of stakeholders in the concept development stage of a design process. This facilitates an understanding of both design priorities and decisions that are made along the way. Nevertheless, awareness is not an assurance that secondary materials will be used in new construction projects. The mindset of professionals working in the construction industry and especially the one of architects can be considered a barrier to including secondary building components in new design since they consider reusing materials in terms of time, cost, quality as a risk to a successful project (Kernan, 2002 & Sassi, 2004, as cited in Hosseini et al., 2015). In line with this, Gorgolewski (2020, p. 2) states that the active integration of secondary building components is not only dependent on design choices and awareness, but also on factors such as „availability, supply chain, ownership, detailing, codes and standards, acceptability, and availability of information".

Especially when it comes to the drivers and barriers of a circular built environment, a focus must be on the multidisciplinary and complex characteristics of the field. Hart et al. (2019) found that, besides challenges related to technology or regulations, those connected to culture, finance or market are more outstanding and hindering in the transition towards a circular built environment.

Reuse in the construction industry - facilitators

For the direct reuse of building components, it is important to know what exactly happened to a building during its use time, including all the changes that were made to the building to know the potential impact they had on the building components (Anastasiades et al., 2021).

Another contributor to easier building component reuse and adaptability, next to the provision of detailed information as mentioned above, is "the standardization of dimensions, components, connections and the compatibility with other construction systems, both dimensionally and functionally" (International Organisation for Standardisation, 2020, as cited by Anastasiades et al., 2021, p. 3). This is also supported by Zhang et al. (2022) who state that building component reuse can be enhanced through innovation, certification, and standardization. However, according to Anastasiades et al. (2021), designers tend to not design with standardized sizes due to the availability of a great variety of sizes and connections. To counteract this, they suggest that lengths, heights, and connections of building components should be standardized, while still making sure that architects have enough freedom in their designs.

A possible design approach is, for example, Design for Disassembly. As the name suggests, building components are not fixed permanently, but can be disassembled when needed due to the use of reversible connections. Due to the possibility to disassemble building components, individual components can be replaced easier when they reach the end of their life-cycle. Additionally, it allows dismantling once a building reaches its end-of-life phase and the dismantled building components can be directly reused in another project (Anastasiades et al., 2021).

3. THEORETICAL FRAMEWORK

The Theoretical framework chapter describes the theory that was used to explore the problem discussed in the present research. The theory applied is the Social Practice Theory (SPT). One can therefore say, that SPT is the lens through which the topic is viewed. The structure of the chapter is designed to help readers to understand the concept of SPT and its potential to apply it to the (circular) construction industry. First, the fundamental idea of SPT and some approaches from different scholars are presented. This is to emphasize that SPT does not have a single definition but can be understood in different ways. After establishing a basic understanding of SPT, a more detailed description of the approach utilized, and the definition of a practice used in this study follows. A special focus is also placed on the understanding of bundles of practices and the systems of practices, as this is fundamental to the present research.

3.1. Introduction to Social Practice Theory

To investigate the system of circular material hubs in the Netherlands, the concept of SPT is applied. In SPT, the focus lies on practices instead of individual persons (Svennevik et al., 2021). „To understand practice theory, it is important to realise that it represents a particular way of understanding society: a way that takes practices as the fundamental and smallest unit of social analysis“ (Kuijer, 2014, p. 24). Practices can be seen as tools to comprehend why people act in a certain way (Smagacz-Poziemska et al. 2021). The way people act, however, is not determined by factors such as their attitude, but by the social practices they are surrounded by and by what they consider to be ‘normal‘ in their lives (Warde, 2005 & Shove, 2004, as cited in Hargreaves, 2011). Kuijer (2014, p. 30) states that „in practice theory it is awkward to speak about someone’s practice, (…) no one has ‘complete’ agency or authority over a practice“. Individuals are therefore just the carriers of practices (Hui et al., 2017).

For this study, SPT was chosen because of its emphasis on practices instead of human beings. The study does not deal with individuals and why they, for example, decide to engage in circular activities. The focus is rather on practices that contribute towards more circularity and the relation between different practices within a bigger system. The emphasis is not on actions which are influenced by a person’s attitude, but on practices which are influenced by what these individuals perceive as normal. For this research, the transition towards more circularity shall not be influenced by personal beliefs or motivations, as every human being is unique and motives are different. Therefore, the spotlight is on practices which support the transition towards more circularity and not on certain individuals who are interested in it.

SPT application in research

In research, SPT is often applied to end-users. Practices of this kind are characterized by their observable features such as “regularity, habitual nature, repetitiveness, recursivity“ (Bourdieu, 1990; Giddens, 1984; T. R. Schatzki, 2002; Reckwitz, 2002 as cited in Smagacz-Poziemska et al., 2020, p. 66). These observable features allow us to understand the implicit aspects of practices. Everyday practices that meet these criteria and have already been researched with SPT are for example cycling (Spotswood et al., 2015), “cooking and eating (House, 2019; Twine, 2018), using a laundry (Mylan and Southerton (2018), ballet dancing (Müller, 2017) or even practices of parental involvement (Freeman, 2004) or walking for pleasure with sticks, that is Nordic Walking (Shove & Pantzar, 2005)" (Smagacz-Poziemska et al., 2020, p. 66). According to Schatzki (2016), a focus on practices like the ones mentioned are also cause for criticism of practice theories. Practice theories are criticized for being well applicable to "local or small phenomena such as cooking, Nordic walking, and professional practices but badly to large social matters such as markets, international federations, the military-industrial complex, and the Catholic Church" (Schatzki, 2016, para. 5). By implication, this criticism would suggest that SPT can only be applied to a limited extent, and only to those phenomena that are local or small. The present study, however, does not look at practices performed by a specific group of end-users or everyday practices which are performed solely in a local context. Rather, it looks at a bigger picture of practices which are performed within the construction industry, specifically within the system of circular material hubs. Therefore, it does not support the view that SPT is only applicable to local or small phenomena. The reasons for this view and the understanding of a system of practices, i.e. the application of SPT to a larger phenomenon, are explained in chapter 3.7. Due to the focus of this study on the system of circular material hubs in the Netherlands, the context for this specific study can be understood as local. Here, it is argued that the local context can be attributed to the exploratory nature of the research. What has been explained above is one of the main differentiators to many other studies performed under the application of SPT. Nevertheless, SPT has already been applied to urban studies and studies regarding the construction industry, e.g. by Smagacz-Poziemska et al., (2020), Gherardi et al. (1998), and Löwstedt (2015).

3.2. Different understandings of practices

As described above, this study explores practices which are performed within the system of circular material hubs. To describe these practices, it is necessary to dive deeper into SPT and understand which approaches there are and what a practice can be.

Schatzki (Cetina et al., 2005) states that there is no uniform guide for practices, which can partially be explained by the fact that the concept of practices is used in various fields such as philosophy, history, sociology, science, and technology. Since SPT is applied in many areas of research and life, and, as mentioned before, is also applicable to larger phenomena, it is also suitable for research concerning the transition towards a circular construction industry. The lack of a unified definition leads to different approaches within SPT and different practitioners advocate for different approaches. To give some examples: While some practitioners emphasis elements (e.g. Shove or Reckwitz), others focus on the relationships between elements (e.g. Schatzki or Warde) or the role of practices in linking individuals and sociotechnical systems (e.g. Spaargaren or Van Vliet) (Hargreaves, 2011). At this point it must be noted that there are many different approaches to SPT apart from the three mentioned above. Naming a few of these approaches is intended to show how diverse SPT is. There is not one single approach to SPT, hence the right approach is the one that fits the individual study best.

Similarly to the various approaches in SPT, different scholars define elements of a practice differently. Four different definitions are provided here: (1) For Reckwitz, elements of practices are defined as bodily and mental activities, objects or materials and shared competences, knowledge and skills; (2) Shove divides them in three categories, namely material, meanings and competences; (3) Warde argues for understandings, procedures and engagement; (4) Schatzki links elements of a practice though practical understanding, rules, teleoaffective structure, general understanding and social memories (Hui et al., 2017).

3.3. The approach of Shove et al. (2012)

For the present study, the theoretical approach proposed by Shove et al. (2012) is utilized as its approach to defining practices and the interplay between different practices fits this research. Additionally, materials as defined in this approach play an important role in the topic studied in this research. Therefore, it appeared suitable to choose this approach. Moreover, the approach of Shove et al. is the most frequently cited one in SPT (Higginson et al., 2015), which allows finding inspiration by and parallels or differences to topics which were already explored through this SPT approach. This approach is subsequently used to develop the definition of a practice in this study.

Meanings, materials, and competences

Shove et al. (2012) propose that a practice is de-

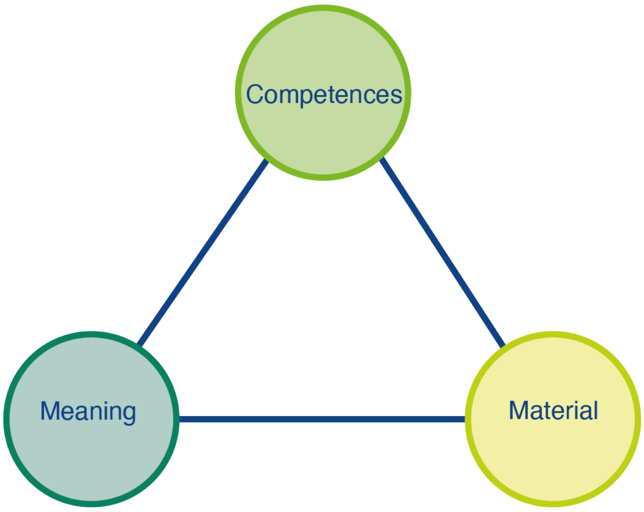

Figure 3.1 Model of a practice. Adapted from Shove et al., 2012, p. 14.

fined through the interdependency between the elements materials, meanings and competences. The division of a practice into these three elements is shown in Figure 3.1. To understand what these elements represent, Shove et al. (2012, p. 14) provide the following explanation:

•„materials - including things, technologies, tangible physical entities, and the stuff of which objects are made;
• competences - which encompass skill, know-how and technique; and
• meanings - in which we include symbolic meanings, ideas, and aspirations."

The understanding of the three above explained elements in this study is almost identical to the definition provided by Shove et al. (2012). However, to give the reader a better understanding of what each element refers to in the context of this study, they will be connected to the example of an architectural practice in the context of a circular construction industry (circular design practice). This research interprets material as something that can either be touched physically or that is needed to perform a certain task. This could include having access to material hubs, secondary building components, material banks or material passports as well as knowing which materials are available. Competence encompasses the skills, knowledge, experience etc. that are needed to perform a practice. The competences in an architectural practice could be knowing how to design with reused materials and what to pay attention to when designing with secondary building components instead of new ones. The term meaning covers why certain practices are performed, including the meaning behind it and the reasoning for it. Meaning could therefore be reducing the resource consumption of the construction industry and contributing towards a more circular construction industry.

The definitions provided above form the basis for understanding practices under the application of the approach of Shove et al. (2012).

Changing elements over time

Shove et al. (2012) propose that a change in one of the elements would lead to the following two possibilities: „one is that relevant elements exist but without being linked (proto-practice); the second is that practices disintegrate when links are no longer sustained". On the one hand, elements are interdependent and on the other hand, they also shape each other. Sometimes, elements can link practices. If this is the case, a change in one of the practices also influences the other one (Shove et al., 2012). Additionally, some practices rely on the reproduction of others (Shove et al., 2012). Applying this to the acquisition of secondary building components by employees in circular material hubs could mean that they rely on construction workers and demolition companies to dismantle buildings in such a way that materials are not damaged but can be harvested and prepared for reuse.

In this context it is important to mention that Shove et al. (2012, p. 21) state „that practices emerge, persist and disappear as links between their defining elements are made and broken". This highlights the role of connections or links between elements. Additionally, it is important to remark that elements do not strictly have one fixed place, but they can change their position within one practice or move between different practices (Shove et al., 2012). This change of elements over time can be seen in Figure 3.2, where the shift in position is visualized.

3.4. Understanding of practices in this research

For this research, the theoretical approach proposed by Shove et al. (2012) is utilized to define a practice. However, defining a practice is not done by defining solely it's elements, namely materials, meanings, and competences, as it is not clear yet where a practice starts, ends, or changes. This part of the Theoretical framework chapter therefore provides a description of how the present study understands a practice.

The practices that will be defined during this research have one thing in common: they can be connected to the transition towards a circular

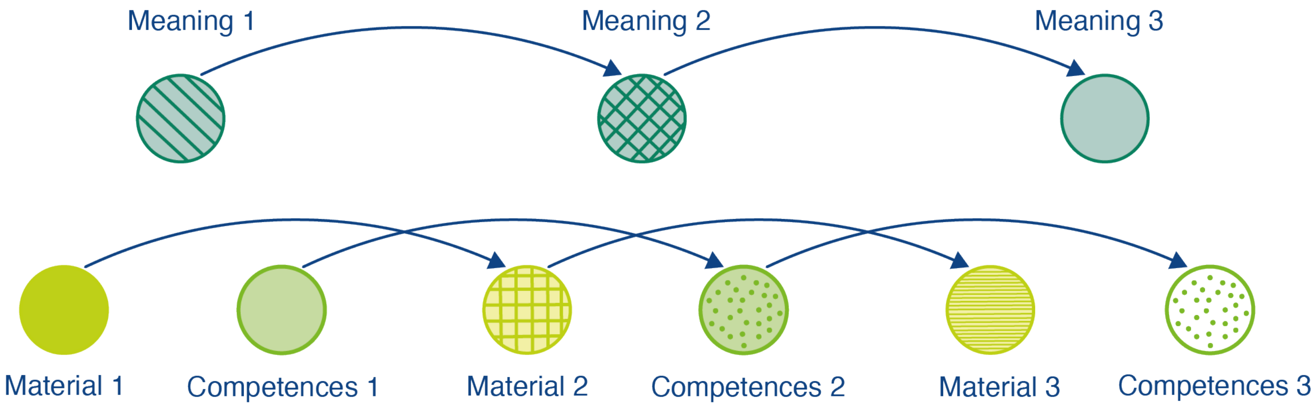

Figure 3.2 The change of elements of a practice over time. Adapted from Shove et al, 2012, p. 33.

economy and aim at the reuse of building components. Therefore, the practices which this research wants to detect facilitate the use secondary building components in one way or another. This does not mean that a practice must directly result in a higher reuse of building components, but that the practice through its connection to other practices leads to an increase of secondary building component use in construction projects.

Although people „do not have practices“ (Kuijer, 2014, p. 30), but only perform them, the question is still which practices are performed by practitioners active within the system of circular material hubs, e.g. by circular material hub employees or architects. Therefore, even though this study talks about practices performed in circular material hubs, by architects, by material scouts, etc., this does not mean that only these groups can perform the respective practices. The reason for this wording is to avoid misunderstandings and specify who performed a certain practice within the studied context.

Changing practices

In the process of defining what a practice is, the question arose whether a change in one, two or all three elements leads to change of an entire practice. Arguing that a new practice emerges as soon as one element changes or when at least two of the elements change may sound applicable at first. However, applying this to some test scenarios shows that a change of a practice cannot be detected that easily. Even when all elements change, the outcome can still be the same and the practice itself, based on its understanding in this research, does not have to change. In this context, one must differ between practices which are similar but still different, and varieties of the same practice (Kuijer, 2014, p. 62). This will be explained using the example of designing a floorplan for a building which uses secondary building components. To discuss this practice, it is assumed that the architect must visualize the floor plan to be able to present it to the client. Furthermore, the architect needs to know how to visualize building components which are typically part of a floor plan, e.g. walls, windows, doors, or furniture. Finally, the role of circularity must be considered as well. Why a change in all three elements does not necessarily lead to a new practice, but just to a different performance, is visualized in Figure 3.3. At this point, it must be emphasized that the assumption that a change in elements does not necessarily lead to a new practice applies only to the present study and is no more than one possible interpretation and application of SPT.

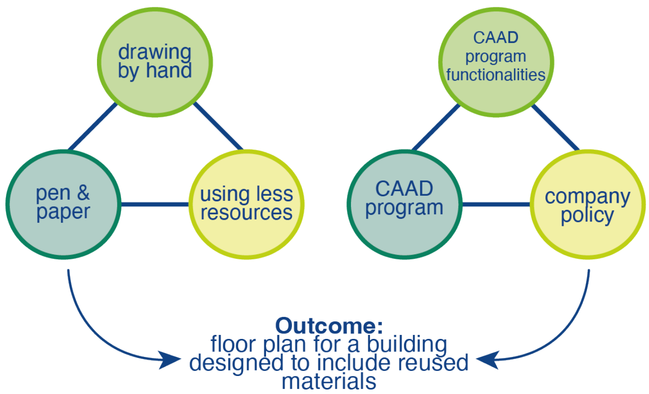

Figure 3.3 Output of a change in elements, which does not lead to a different practice. Visualized by the author.

Variation A:

• Materials: Pen, paper, and a ruler are utilized to draw a floor plan.

• Meanings: Reused building components are incorporated to decrease resource consumption and contribute to combatting climate change.

• Competences: Knowledge on how to design a floor plan for a design which incorporates secondary building components; Knowledge on how to draw a floor plan by hand.

Variation B:

• Materials: A CAAD program is used to visualize the floor plan.

• Meanings: Reused building components are incorporated to fulfill the company policy which expects employees to decrease the amount of primary raw materials.

• Competences: Knowledge on how to design a floor plan for a design which incorporates secondary building components; Knowledge on the handling of a CAAD program.

Materials, meanings, and competences are different in Variation A and Variation B. The outcome, however, is the same. This is to illustrate why changing the elements for this work does not result in a new practice. The focus here is on whether changing the elements affects the result. Since the result in the example given is the representation of a floorplan for a building designed to include secondary building components, despite different materials, meanings, and competences, it is not assumed here that it is a different practice. It can be argued that both performed a variety of the same practice, namely the practice of designing a floor plan. It does not make a difference whether the floor plan is drawn by hand or with a CAAD program and what the meaning behind using secondary building components is. Even though all three elements changed, the practice itself is still the same and both Variation A and Variation B are just variations or different performances of the same practice, i.e. different practice-as-performance. In the end, both performances (practice-as-performance) belong to the same circular design practice (practice-as-entity). Therefore, it can be concluded that a change in one of the elements does not automatically lead to a new practice. Additionally, as this study focuses more on practices-as-entities rather than practices-as-performance, defining practices based on a change in elements and therefore performances does not match the research focus and does not provide the insights this study aims at. Different practices-as-performance can have different elements while still belonging to the same practice-as-entity (see explanation above and Figure 3.5). Watson (2012) argues that practices can change through a change in elements, a change of the carriers, or how practices are bundled together. For the purpose of this research, practices change if their outcome or result is fundamentally different. This research recognizes that this definition can be too loose in certain cases, which means that it is sometimes necessary to decide on a case-by-case basis, depending on the given context, whether it is a different practice. However, as this research focuses on the bigger picture of practices performed within the system of circular material hubs, defining practices according to the end result they lead to fits the purpose.

3.5. Practice bundles and complexes

As mentioned in chapter 3.3., elements are interdependent and have the potential to link different practices. The question how practices can be linked is especially interesting for the present study since it focuses on different practices performed by different practitioners within one system.

When talking about the interdependency of elements and practices, Shove et al. (2012) introduce bundles and complexes into the discussion. These terms are defined by Shove et al. (2012, 81) as followed: „Bundles are loose-knit patterns based on the colocation and co-existence of practices. Complexes represent stickier and more integrated combinations, some so dense that they constitute new entities in their own right." From this, it can be concluded that, firstly, practices which depend on each other form complexes and secondly, bundles can evolve into complexes. This means that multiple practices can be linked to create bundles or complexes. Therefore, a multitude of practices can be found within bundles or complexes.

An interesting aspect of studying practice bundles is that they can be extended out in time, both spatially and temporally, while their extension can be explored by switching between close and increasingly distant views (Lamers et al., 2016). Within SPT, there are different approaches and concepts to refer to practice-arrangement bundles (e.g. "pairs, chains, nexuses, compounds, complexes, circuits, constellations, networks or configurations of social practices" (Lamers et al., 2016, p. 234), depending on the individual scholars' understanding of connections between practices.

While elements from different practices can be interlinked (Shove et al., 2012), practices can also reinforce each other (Smagacz-Poziemska et al., 2021). This implies that practices performed within the system of circular material hubs, i.e. directly in circular material hubs or by practitioners whose practice can be linked to circular mate-

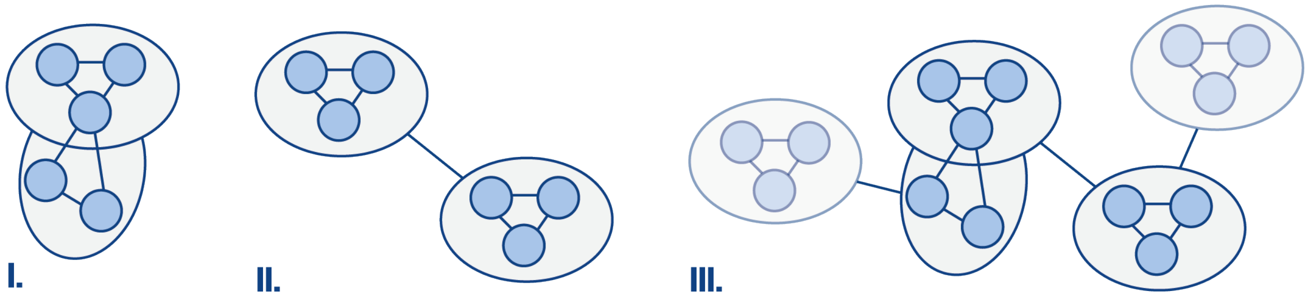

Figure 3.4 Relationships between practices which are interesting for this study. Practices are linked because they share one element (I.), influence each other (II.) or due to a combination of both (III.). Visualized by the author.

rial hubs might amplify or at least influence each other. So far, however, no further research has been carried out into what the system of circular material hubs consists of and how the practices performed within it relate, which effect they have on each other and whether they reinforce each other.

Figure 3.4. visualizes the scenarios interesting for the present study.

I. Practices are linked by sharing one element. This, potentially, could also be extended to sharing two elements, which means that two different practices that only differ from each other in one element.

II. Practices are linked because they influence each other, for example because they are dependent on each other.

III. A constellation of practices which includes I. and II. In this scenario, multiple practices are linked because some share the same element, while others are dependent on them. This scenario, additionally, also includes practices which are not directly interesting for the study because they are not related to circularity, but somehow still influence some of the practices studied (these ones are represented in light blue).

3.6. Practice-as-entity and practice-as-performance

When talking about practices, one can differ between practice-as-entity and practice-as-performance. Practice-as-entity understands „the practices as a structured organization (…) [which relies on] (…) repeated performances to remain alive“ (Kuijer, 2014, p. 28). This means that these practices are performed in a certain way. In comparison, practice-as-performance describes practices whose performance always differs a little bit (Kuijer, 2014). Practice-as-entity and practice-as-performance can be related and somewhat need each other. Kuijer (2014) states that entity provides a leading framework for performance and orders it, while it also emerges from the same performance. Ordering performances, however, does not imply that differences are not possible, as performances can vary within the leading framework. „A dialectical relationship exists between entities and performances because, whilst practices as entities may guide performances, it is through these performances that entities are (re)produced and either stabilised or changed“ (Higginson et al., 2015, p. 953). Multiple different practice-as-performance lead to a practice-as-entity, which can be understood as the idealized version of a practice. Practice-as-entity „exist over time and space, even if they are not currently enacted“ (Higginson et al., 2015, p.956), while practice-as-performance are particular for each point in time. Figure 3.5 visualizes the concept of practice-as-entity (on the left) versus practice-as-performance (in the middle and on the right). The two practice-as-performance differ in their elements (dots) and connections (lines). The configuration of elements differs, represented by different configurations of dots and dot sizes, and links are varying in strength or importance, indicated by different line widths. The figure also shows that the practice-as-entity is formed by combining the two practice-as-performance.

The question arises whether practice-as-entity or practice-as-performance is more important for this research. According to Spurling et al. (2013, p. 8), focusing on practices-as-entity helps to avoid that the focus in social change is placed too much on individual behavior, as “individual behaviours are, primarily, performances of social practices”. This study is mainly interested in practice-as-entities. Practices which are already performed but potentially not yet fully established in the construction industry and the connections between those practices that need to be further developed to meet the future needs of the in-

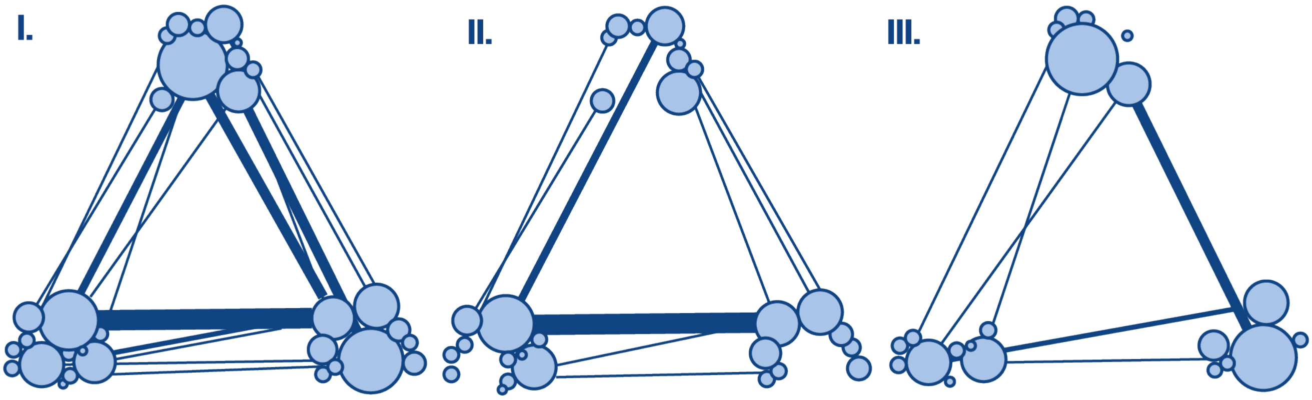

Figure 3.5 Practices-as-entities (I.) and practices-as-performance (II. and III.). Adapted from Higginson et al., 2015, p. 954, based on Kuijer, 2014, p. 53.

dustry are expected to be detected by focusing on practices-as-entities. However, the “context specificity, adaptability and variety” (Higginson et al., 2015, 953) of practices-as-performance is important as well.

Looking at practices more from a distance (practices-as-entities), i.e. zoomed out, rather than close up (practice-as-performance), i.e. zoomed in, allows to understand the relationships between practices performed within the context of circular material hubs (Higginson et al., 2015). Therefore, a combination of zooming out and in will be applied. By zooming out, it allows to understand the connections between different practices and their allocation within one system. By zooming in, different practices, whose performances are considered essential for understanding the system, can be better understood.

3.7. System of practices

As already indicated, this study is not only interested in one single practice-as-entity and its configuration though different practices-as-performance. The study focus is rather on a multitude of practices that are performed within a system of practices that are connected to each other. To understand this, it is necessary to explain what a system of practices is and why it is important for this research.

As mentioned before, the focus in SPT is on the practice that are performed by a carrier rather than the carrier itself. This leads to the understanding that, whenever someone does something, it is a performance of a practice (Watson, 2012). According to Watson (2012, p. 488), it is “this understanding which gives the link between changes in what people do and the rest of any socio-technical system”. This can be explained by the view that practices are to some extent formed by the socio-technical systems in which they are embedded, while their performance also contributes to its constitution and sustenance (Watson, 2012). If practices are part of the constitution and sustenance of a system, this in turn implies that a system changes if the practices it contains change, keeping in mind that practices are transformed by their performances (Watson, 2012). Watson (2012, p. 493) states:

> *„The concept of systems of practice aims to capture, simultaneously, how far practices are embedded in systemic relations constituted first by relations with other practices; and second also through the systemic elements – including infrastructures, technologies, rules, norms and meanings – which those practices constitute and sustain.”*

Regarding the idea that systems can change through changes of practices, Watson (2012) further elaborates that these changes can happen at any level. In an article about the transition to a decarbonized transport system, Watson provides an example where the impact of peak oil, which can be understood as a change on the landscape level, can lead to a change in attitude towards cycling. To provide a hypothetical example which translates the example by Watson to the context of the construction industry and the transition towards a circular construction industry, it could be that the depletion of river sand reserves (e.g. Jiang et al., 2022) and the resulting impact on the concrete production could lead to alternative production methods and potentially greater building component reuse. This example and the idea that an entire system can change due to changing practices is interesting for this study as a transition towards more building component reuse, especially as part of a transition towards a circular construction industry, is needed. Understanding how systems are constituted and the links with the system can help to find potential areas for positive intervention (Watson, 2012).

In this study, the system of circular material hubs is not limited to the circular material hub as a location itself. Rather, it is seen as a connection or a series of connections of practices that are performed within the system. This means that, to study the system of circular material hubs, it is not enough to focus on those practices that are performed at the circular material hub location. Much more important is to research which practices are performed in the system and how these are connected to each other, so that it can be determined where, for example, intervention could be made to facilitate a transition towards a circular construction industry. Important for this understanding is also a more zoomed out view on practices to understand the bundles which are formed by the practices within the system.

Due to the contextualization of this research in a transition towards a circular construction industry, it is important to talk about the impact of policy on system change. Rip (2006, as cited by Watson, 2012) state that policy is part of the system rather than a factor outside of this system which determines how it is developing. Instead, past interventions form the basis for what is needed for current interventions of policy.

3.8. Conclusion

To conclude, it can be said that one of the most important notions of this chapter is that this study focuses on the system of practices, i.e. the zoomed-out totality of practices rather than a single practice. The system itself can be understood as a connection or series of connections of practices. The practices that are performed within the system constitute the system. This, in turn, means that a change in system is initiated by a change of the practices it is constituted by. Due to the understanding that the system is constituted by a multitude of practices and their connections, the focus of this study is on a variety of practices-as-entities rather than one single practice-as-entity and the practices-as-performance it is constituted by. However, where necessary, practices-as-performance will be studied as well.

4. RESEARCH METHODOLOGY

The Research methodology chapter introduces the methods applied in the present research and the research design. To address the main research question, four sub-questions were formulated. The sub-questions were framed in such a way that they contribute towards answering the main research question and provide information relevant to the research. The system of circular material has not yet been researched in detail yet. Hence an exploratory research approach was chosen to gain fundamental knowledge on this topic and understand its importance in the transition towards more material reuse in the construction industry. The data was gathered through literature review and fourteen semi-structured interviews with participants who are familiar with the topic of circularity in the construction industry, either because they work in a circular material hub, architectural office, deconstruction company or as a researcher. This enabled them to provide relevant information on building component reuse in the Dutch construction industry with a focus on practices performed in circular material hubs as well as design and scouting practices. The names of the interview partners and companies were anonymized to protect the information shared from being traced back to the participants. Instead, descriptive pseudonyms are used to give the reader a better understanding of the interviewee. In the first part of this chapter, the data collection method is described. This includes a description semi-structured interviews, participants, and criteria for the selection of circular material hubs. Afterwards, the data analysis is described. This includes information on the transcription and coding of the interviews as well as the identification of the main themes that emerged from the interviews and how they are prepared for the presentation of the results that follows in the next chapter.

4.1. Data collection

During this research, data was collected through: (1) text analysis of secondary data, policy documents, EU regulations, architectural project descriptions, academic articles, research papers and theses; (2) semi-structured interviews with practitioners active in the construction industry; and (3) semi-structured interviews with experts. These resources together helped to gather information about the system of circular material hubs and the practices performed within it. This includes:

I. practices performed in circular material hubs which aim at reintroducing secondary building components into the material cycle. This includes (1) where circular material hubs receive secondary building components from; (2) how they process secondary building components directly at the circular material hub location; (3) whether there are different processing practices performed within the same hub and what they depend on; (4) to whom circular material hubs sell secondary building components; (5) where they sell them, e.g. online or offline, shop or marketplace (hereinafter referred to as communication channel); (6) how the target group affects the choice of communication channel, and (7) how the target groups affects the building components they handle.

II. practices performed in circular material hubs which directly influence the material reuse amongst architects. Here, the focus was specifically on practices and activities which facilitate the reuse possibilities for practitioners performing a circular design practice, i.e. how easy it is to include secondary building components in a circular design practice. This includes (1) whether there even is a connection between architects and circular material hub providers, (2) who takes over the scouting of secondary building components, (3) where the scouting of secondary building components takes place, (4) the view of architects on circular material hubs, (5) the communication between architects and circular material hubs, (6) what architects wish they would receive from circular material hubs, especially in terms of information, and (7) what circular material hubs need from architects to be able to facilitate their wishes.

III. practices performed by architects which are directly related material reuse. This includes (1) skills that are needed to design with reused materials, (2) where architects scout secondary building components, (3) how they are supported in using secondary building components, (4) what challenges they face when designing with secondary building components.

IV. opportunities, challenges, and potential future developments of circular material hubs.

4.1.1. Interviews

According to DiCicco-Bloom and Crabtree (2006, as cited in Kallio et al., 2016) semi-structured interviews are the most applied interview method when conducting qualitative research. They are characterized by being “versatile and flexible” (Kallio et al., 2016, p. 2955), which can be attributed to the fact that they allow the interviewer to prepare questions beforehand, while leaving open the possibility of asking other questions that come up during the interview. By providing a structure which can be followed during each interview, they additionally prevent the interviewer from forgetting to ask important questions during the interview. Semi-structured interviews were chosen for multiple reasons. First, preparing a set of questions provides a guideline which can be followed throughout all interviews. Second, they allow the interviewer to ask questions which were not prepared beforehand as a response to what the interviewee said. Third, interviewees can express themselves and reply in the way they want (Hardon et al. 2004, Rubin & Rubin 2005, Polit & Beck 2010, Robert Wood Johnson Foundation, 2008, as cited in Kallio et al., 2016).

Smagacz-Poziemska et al. (2021, p. 70) state „that conducting an interview in terms of social practices requires a special skill: authentic wonderment that gives the obvious and the ordinary the status of unobvious, interesting and important matters“. This shows that conducting interviews with the aim to get to know more about peoples' practices requires the interviewer to be intentional about their questioning style. Therefore, particular attention was paid to the way the questions were asked. The aim was to precisely understand the practices performed by the interviewees. This was achieved by conducting detailed interviews about the practices performed by the interview partners. It was important that the interviewees described exactly how they perform a practice and why they perform them in exactly this way. After each interview, the interviewer had to have an accurate picture of how the practices are performed, even without being present during the performance of the practices themselves.

Participants

For this research, fourteen interviews were conducted. Table 4.1 presents an overview of all interviews, including a description of the organization as well as the function of the interviewee. The interviews are split into practitioners' interviews and expert interviews. While practitioner interviews aimed at identifying practices performed by the interviewees, expert interviews were conducted to validate the information gathered through literature review and practitioner interviews.

Practitioner interviews

Eleven interviews were conducted with practitioners working in the construction industry, six of them with five different representatives of four different circular material hubs, four with architects from different architectural offices and one with a representative of Insert. The practitioner interviews served to gain a thorough understanding of the practices performed within the system of circular material hubs. Therefore, the interviewees were chosen according to their field of work and experience.

Expert interviews

Additionally, three interviews were conducted with experts on the topic of a circular construction industry. One specialized in construction logistics and (circular) material hubs, the second specialized in the circular construction industry, circular material hubs, and designing with secondary building components, and the third specialized in the circular construction industry, designing with secondary building components, and the circular economy. The purpose of these expert interviews was to (1) validate the information collected during the interviews with practitioners and (2) gain additional knowledge regarding circular material hubs and the transition towards a circular construction industry. The interviews with practitioners revealed opportunities, challenges, and potential future developments, as they are perceived by the practitioners. The expert interviews served to validate and complete this information. As some of the experts work in research institutions, it was therefore also examined how the results found through practitioner interviews correspond to the findings of research.

Overview of conducted interviews		
Pseudonym interviewee	**Description of the organization**	**Function within the organization**
The rejuvenating hub [inteviewed twice]	A circular material hub that uses many of its harvested elements to produce new furniture.	Circular material hub manager
The B2B hub	A circular material hub that uses many of its harvested elements to produce new furniture.	Circular material hub manager
The all-rounder hub 1	A circular material hub that offers a variety of services at its location, from storage over processing to advising.	Circular material hub manager
The all-rounder hub 2	A circular material hub that offers a variety of services at its location, from storage over processing to advising.	Circular material hub manager
The all-rounder hub 2	A circular material hub that offers a variety of services at its location, from storage over processing to advising.	Director recycling department
The ambitious hub	A circular material hub that aims at connecting all parties in the circular chain to improve the deconstruction process.	Circular material hub manager
The aware architect	An architectural firm that pays particular attention in its work to the fact that people only live on earth temporarily.	Architect
The thoughtful architect	An architectural firm that beliefs that a sustainable design must take both environment as well as humans and their comfort into account.	Architect
The visionary architect	An architectural firm that does not shy away from unconventional application scenarios when designing with secondary materials or elements.	Architect
The pioneering architect	An architectural firm that has can be seen as a pioneering office when it comes to sustainable and circular design.	Architect
The circular economy expert [conducted in German]	An architect and pioneer in circular thinking who focuses on what is needed in the future and thinks beyond the construction sector.	Architect and circular economy expert

Overview of conducted interviews		
Pseudonym interviewee	**Description of the organization**	**Function within the organization**
The circular architecture expert	An architect who creates future oriented alternatives for the construction sector.	Architect and circular construction industry expert
The circular logistics expert	An expert in construction logistics who studies material hubs as well as circular material hubs.	Researcher
Insert [no synonym]	A foundation which offers both an online market place for secondary materials and elements as well as other services connected to the transition towards a circular construction industry.	Manager of Insert

Table 4.1 Overview of criteria for the selection of circular material hubs.

Interview guide

The interviews centered on practices which are performed within the system of circular material hubs, including practices performed in circular material hubs or those related to them, as well as circular design practices performed by architects. The common characteristic is that they are related to material reuse in the construction industry. To achieve the best possible outcome and collect trustworthy and valuable information, a semi-structured interview guide was developed according to the five steps presented by Kallio et al. (2016, p. 2953): „(1) identifying the prerequisites for using semi-structured interviews; (2) retrieving and using previous knowledge; (3) formulating the preliminary semi-structured interview guide; (4) pilot testing the interview guide; and (5) presenting the complete semistructured interview guide."

The interview guide consisted out of a list of open-ended questions which were slightly adapted to each interviewee and their field of expertise and work. The set of questions was divided into those regarding the main topic, which aim at collecting information regarding the primary research subject, and follow-up questions, which are intended to provide the interviewer with an even greater knowledge on the topic researched (Kallio et al., 2016; Turner, 2010, as cited in Kallio et al., 2016). The primary research subject was to identify practices performed in circular material hubs and by architects. In addition to identifying practices which are performed within the system of circular material hubs, the interviews also aimed at identifying opportunities, challenges and potential future developments of circular material hubs and building component reuse in the construction industry. These questions were not specifically focused on practices performed by the interviews, but on their experiences, opinions, and ideas. However, as the practitioners were chosen due to the practice they perform, they are also expected to influence the opportunities, challenges and potential future developments communicated by the interviewees.

The expert interviews did not follow the same interview guide as the interviews which were conducted with practitioners, as they had a different purpose and focus. While the interviews conducted with practitioners aimed at identifying and understanding the practices performed by them, the expert interviews were conducted for validation purpose.

4.1.2. Participant selection

In a first step, circular material hub providers and architects were contacted. Participants were found through internet research and the first contact was made by email.

The circular material hubs were chosen according to a set of pre-defined criteria (Table 4.2).

Architects were chosen based on their previous experience in working with reused materials. Initially, the plan was to choose architects who are collaborating with one of the circular material hubs under investigation. However, finding architects in this way turned out to be more difficult than originally assumed as the selected circular material hubs are rarely in direct contact with architects. It was therefore decided to select architects who already perform a circular design practice and therefore have experience with material reuse.

In addition to practitioners (circular material hub providers and architects), experts in the field of circular economy, circular construction industry and construction logistics were contacted.

For reasons of anonymity, interviewees as well as the organizations they work at are anonymized. Instead, pseudonyms are chosen to describe the interviewees or the organizations they work for. To avoid confusion, the pseudonyms are descriptive and inspired by the characteristics of the respective interview partner or organization. It is assumed that it is easier to connect different but descriptive pseudonyms and the information provided by them rather than very similar pseudonyms that do not reveal any information about the individual interview partners or organizations. Therefore, the chosen pseudonyms are not circular material hub 1 or circular material hub 2, etc., but e.g. The B2B hub or The all-rounder hub.

Criteria for circular material hubs

The circular material hubs were selected based on previously defined criteria. Table 4.2. provides an overview of all criteria, including the category they can be allocated to as well as an explanation and reasoning behind it. The criteria were defined according to characteristics of circular material hubs found in literature review and characteristics which were expected to be important for this study. To elaborate: Criteria I. and II. can be attributed to the focus of the research. As this study explores the system of circular material hubs in the Netherlands, it was important to only include those circular material hubs which are located in the Netherlands rather than abroad (Criteria I.). As this study deals with the current system of circular material hubs and not with a hypothetical future system, it was important that the circular material hubs investigated are already active rather than in the planning stage (Criteria II.).

Criteria IV. and V. are based on the different types of circular material hubs (circular industry hub, urban mining hub, circular craft center, local material bank) described by Tsui et al. (2023) (see chapter 3.7). The allocation of a circular material hub to one of the categories mainly depends on their spatial scale (regional or local), their main activity (processing or redistributing), the type of materials they handle (secondary raw materials, structural elements etc.), who they sell to (e.g. residents), and where they get their building components from (e.g. from construction projects, residents etc.). This study focuses on circular material hubs which can be allocated to the category of urban mining hubs. Therefore, the circular material hubs investigated in this study must be able to supply secondary building components for construction projects rather than small scale projects of residents. Additionally, as this study also focuses on the connection of circular material hubs and architects designing with reused materials, the circular material hubs must provide secondary building components which can be categorized as structural elements, non-structural elements, or interior rather than secondary raw materials.

Overview of criteria for the selection of circular material hubs			
Nr.	Criteria	Category	Explanation
I.	Located in the Netherlands	Location	The circular material hub must be in the Netherlands. This criterion ensures that the circumstances within which the hubs are located are similar and comparable. It is not necessary that all material hubs are in the same region.
II.	Already active entity	Existance	The circular material hub must already be active and in use. Circular material hubs which are still in the planning phase but do not operate yet do not qualify. It is necessary that the practices investigated are already being performed in circular material hubs rather than being hypothetical practices which could potentially be performed.
III.	Collection by the circular material hub or external parties	Collection	The collection of building components handled in the circular material hubs can be done by (1) the circular material hub itself or by (2) external parties the which collaborate with the circular material hub.

Overview of criteria for the selection of circular material hubs			
Nr.	Criteria	Category	Explanation
IV.	Processing in the circular material hub	Processing	The processing of building components must take place at the circular material hub. Circular material hubs that either (1) collect and distribute building components, but do not process them themselves or (2) sell building comments that were not processed by themselves do not qualify for this study.
V.	High quantity of available materials	Availability	The circular material hub must be able to provide building components not only for private use but for commercial use such as new building projects. This ensures that the circular material hub is big enough to supply construction projects and not only small scale, private renovations. This, however, does not mean that the circular material hub (1) must provide all materials needed for a single construction project and (2) cannot supply private individuals.
VI.	Provision of ready to use building components	Provision	The circular material hub must provide ready to use building components such as beams, columns, floors, tiles, toilets etc. Circular material hubs which are specialized on raw materials or little processed materials such as different concrete components do not qualify. This ensures that the circular material hub provides building components which are interesting and in the decision area of those performing a harvesting or design practice.

Table 4.2 Overview of conducted interviews, including pseudonyms, organization description and function within the organization.

By choosing circular material hubs according to the set of criteria, it was possible to study hubs that do not operate completely the same way but are to a certain extent similar and comparable. In fact, it was even desirable to choose hubs that were not identical to allow the diversity that exists within the system to be represented. As the aim of this research is to explore the system of circular material hubs in the Netherlands, the focus was to select circular material hubs that represent multiple aspects of the system as good as possible, hence represent a great variety. However, this does not mean that this research claims to include all possible forms of circular material hubs that exist within the system. One reason for this is that only circular material hubs that process ready to use building components are included. Circular material hubs which process secondary raw materials are not included in the research (e.g. circular material hubs which handle crushed concrete).

4.2. Data analysis

A total of fourteen semi-structured interviews were conducted.

The interviews were recorded and transcribed (step 1), coded (step 2), and analyzed (step 3). Afterwards, the main themes were identified (step 4), which formed the basis to decide on a structure to present the results (step 5). In the following, a description of each step is provided.

Step 1: Recording and transcription

All interviews were either only audio or audio and video recorded by using a voice recording smart phone application or the recording function integrated in MS Teams. Depending on the availability and location of the interviewee, interviews were conducted in person or online. For interviews conducted online via MS Teams, the software's own transcription function was used. For interviews conducted in person, the audio files were uploaded to Microsoft Word where the software's automated transcription function transcribed the interviews. Even though both options save time for the initial transcription, compared to transcribing everything manually, it was still necessary to listen to all interviews again to correct errors.

As the interview guide consisted exclusively of open questions, the answers were transcribed verbatim. This means that the answers were transcribed the way the respondent gave them instead of summarizing them. The transcripts were cleaned up and word repetitions or filler words were deleted to facilitate reading and coding. Here, particular attention was paid to removing only repetitions and filler words, but not words or entire parts of sentences that would change its meaning.

Step 2: Coding

The information obtained through the interviews is qualitative and descriptive in nature. "Coding is the process of labeling and organizing your qualitative data to identify different themes and the relationships between them" (Medelyan, 2024). This means that coding helps to understand the previously collected data.

In this research, the interview transcripts were coded using the computer-aided qualitative data analysis software ATLAS.ti. The coding itself was done manually rather than automated by using a thematic coding approach.

There are different possibilities to develop the codes that are applied to the data. Deductive or concept-driven coding, on the one hand, is a top-down approach characterized by developing codes before the coding process starts (Delve, 2022; Medelyan, 2024). Inductive or open coding, on the other hand, is a bottom-up approach where codes are created from the data (Delve, 2022; Medelyan, 2024). This allows to create codes which are less biased and more corresponding to the collected set of data (Medelyan, 2024).

For this research, a combination of both deductive and inductive coding was chosen. This allowed the researcher to follow a more structured approach and look for certain information within the data while also providing the freedom to create new codes throughout the process. Prior to starting the coding process, the codebook was developed based on both theory and research questions. Within the code book, two different categories of codes were developed. (1) Codes which are applied to data that help to identify practices and (2) codes which are applied to data that describes opportunities, challenges, and potential future developments of circular material hubs. Within each category, different, more specific codes were developed. Here, special attention was paid to grouping similar topics under one code and not using several codes for very similar topics.

An overview of the codes applied during the data analysis are provided in Table 4.3.

Example coding
Client
Building component
Material scouting
Material scouting: meaning
Material scouting: material
Material scouting: competence
Circular design
Circular design: meaning
Circular design: material
Circular design: competence
Processing
Processing: material
Processing: meaning
Processing: competence
Communication channel: online
Communication channel: offline
Challenge
Challenge: guarantee
Challenge: regulation
Challenge: uncertainty
Challenge: collaboration
Challenge: costs
Opportunity
Opportunity: regulation
Opportunity: collaboration
Opportunity: information & knowledge
Future development

Table 4.3 Codes used for coding the interviews.

Step 4: Identification of main themes

In a first step, the main themes that occurred throughout the interviews were identified to provide a structure that leads the presentation of the results. This was done in multiple rounds. In a first round, the broad themes were created from the recollection of the interviewer. In the second round, these themes were specified, adapted, or exchanged by an initial review of the interview transcripts. In the third round, the themes were finalized by comparing them to the frequency of the codes applied to the transcripts and the most frequently occurring topics. As a major part of this research focuses on the practices performed within the system of circular material hubs, the identified practice-as-entities can be understood as the main themes. The sub-themes are then equivalent to the identified practices-as-performance. However, as the research also identified challenges, opportunities and possible future developments of circular material hubs, the main themes also emerged from these findings, even though they do not represent practices.

Step 5: Presentation of results

Once steps one to four had been completed, a decision had to be made on how to communicate the results. It was decided that the results are presented according to the main themes that emerged in the interviews. This means that the text was structured according to the (1) identified practices (first part of the chapter) and (2) challenges, opportunities, and potential future developments (second part of the chapter). The textual representation is supported by the integration of verbatim responses, i.e. quotes from the interviews. Quotes from the interviews are used to support both argumentation and storyline. They are used where it is considered important to provide the interviewee's exact wording.

The order in which the practices are presented is based on the path that a secondary building component must follow, from the demolished building to a new owner or project. First, the secondary building component must be dismantled and taken to a circular material hub. There it must be processed and prepared for reuse before it can be sold to a customer. The secondary building component must then be scoutd by a customer. In the construction industry, however, first a design needs to be created in which secondary building components are installed. This is a simplified description of the practices and steps that a secondary building component must go through. It just aims at creating a picture of how the results are structured. A more detailed description, including possible differences, diversions etc., can be found in chapter 5, Results.

4.3. Conclusion

IIn this methodology chapter, research methodology and data analysis are explained. A qualitative exploratory research approach was chosen to explore the topic of circular material hubs and provide the basis for future qualitative and quantitative research. Semi-structured interviews with practitioners and experts built the foundation for data collection. Practitioner interviews followed an interview guide that was specifically designed to understand the practices performed by the interviewees and to be able to identify which practices are performed within the system of circular material hubs in the Netherlands. The expert interviews followed a set of questions specifically designed for the respective interviewee, as the expertise of all experts depended on their field of work.

Additionally, opportunities, challenges, and potential future developments of the system of circular material hubs were identified through both practitioner and expert interviews.

A combination of deductive and inductive coding allowed to create new codes during the coding process next to the codes that were pre-defined before the coding started. This allowed more flexibility when the codes already available turned out to be unsuitable.

5. RESULTS

In this chapter, the results of the qualitative, exploratory research on the system of circular material hubs in the Netherlands are presented. At the beginning of each sub-chapter, a short summary of the main finding is provided. Following this summary, an in-depth description of the results is given. At the end of the chapter, a summary of all results will be provided. The first part of the chapter (5.1) is structured around the five main practices discovered during the data collection, namely acquisition practice (5.1.1), processing practice (5.1.2), sales practice (5.1.3), circular design practice (5.1.4), and building component scouting practice (5.1.5). It is shown what the system of circular material hubs in the Netherlands looks like and which practices performed within this system facilitate material reuse in the Dutch construction industry. The first part of the chapter ends with a conclusion on the practices identified during the study, with a special focus on the practices-as-performance. The second part of the chapter (5.2) focuses on challenges (5.2.1), opportunities (5.2.2), and possible future developments (5.2.3) as communicated by the interviewees are presented. The chapter ends with a conclusion which summarizes the findings.

5.1. Practices bundles

Hereinafter, the practice bundles identified during this research are presented. Each practice bundle consists of different practices-as-entities.

5.1.1. Practice bundle I: acquisition practices

The interviews showed that all circular material hubs under investigation acquire their secondary building components in a similar way, either from the demolition department within the same company or from an external party. To acquire materials, different practices are performed. All these practices are part of practice bundle I – acquisition bundle. While some of the practices are performed in a certain sequence or temporal order, others are optional or do not need a temporal order. The acquisition bundle contains multiple practices that potentially influence each other or are influenced by practices from another bundles. Part of the acquisition bundle are practices which help to get an overview of what is becoming available during a deconstruction process or which materials and elements can potentially be acquired from an external party, calculate their value, and decide whether they match with the circular material hub's offer. In some cases, clients are sought even before the materials or elements have been dismantled. Building components that are accepted must correspond to the circular material hub's general range and be of interest to customers so that they can be sold quickly and in most cases be old, as old wood is for example more popular than new wood.

All four circular material hubs included in the study are part of a larger company that also has a demolition department. This direct connection to a demolition department also influences where the circular material hubs source their building components from. All representatives stated that they receive building components from the company they are part of. Those building components come either from a deconstruction or construction site. The former if the demolition department was commissioned with the deconstruction of a building. The latter if a new building was completed and the demolition department was responsible for the deconstruction of the building that previously stood on the site. One major difference, for example, is that secondary building components acquired from deconstruction projects have at least one life cycle behind them, while those acquired from new construction projects have not yet been used. Whether and to what extent this has an impact on other practices in this bundle was outside of the scope of this study. There were differences as to whether the connected demolition department is the only source of supply. Only one out of the four circular material hubs sources its supply exclusively from its own operations, i.e. from the connected demolition department. The other three circular material hubs also receive and accept building components from external parties. In this case it has been shown that the circular material hubs are contacted by the external parties when they have suitable building components and not the other way around.

Within the acquisition bundle, different practices-as-entities were found. These are creation of an inventory list (hereinafter referred to as inventory practice), calculation of building component value (hereinafter referred to as value calculation practice), price calculation for the deconstruction of a building (hereinafter referred to as price calculation practice) and deciding whether building components match the circular material hub's offer and are accepted or declined (hereinafter referred to as accepting/declining practice). These practices partly influence each other and are also partly influenced by practices that are not part of the acquisition bundle. In the following, all practices including their influential potential will be described.

At this point, it must be mentioned that there are other practices which also must or can be performed before building components can be processed at the circular material hub. Examples are the actual deconstruction or the transportation from the deconstruction site to the circular material hub location. These practices can be attributed to a bundle of practices that has not been within the scope of this study. As this research focuses on the system of circular material hubs within the Netherlands, the focus is on practices or bundles which potentially influence the entire system instead of just one step within the path of building components, from dismantling to re-introduction into the material cycle.

5.1.1.1. Practice I.I: Inventory practice

When building components are acquired from a deconstruction site, a so-called circular advisor visits the deconstruction site and creates an inventory list of building components that will be released during dismantling. The circular advisor walks through the building and writes down all materials and elements that become available. Creating an inventory list is important for multiple reasons. First, it provides an overview of what and how much is available. Second, it allows further calculations regarding the value of the available building components. Third, it allows to calculate the price that is asked for the deconstruction process. Fourth, it can be used to decide which materials and elements match the offer of the respective circular material hub. Fifth, buyers can be sought even before the dismantling took place, which reduces the amount of building components that need to be transported, processed, and stored in a circular material hub.

Connections: The inventory practice is connected to other practices performed within the acquisition bundle. It directly influences the value calculation practice (see chapter 5.1.1.2.), the client search practice (see chapter 5.1.1.3) and indirectly the decision making practice (see 5.1.1.5).

5.1.1.2. Practice I.II: Value caluclation practice

The value of all available building components is calculated to estimate how much money can be generated by the sale of acquired building components at a later stage. The basis for calculating the value of available building components is an inventory list. The monetary value is influenced by the popularity of the respective building component amongst clients. Based on experience from previous business activities, circular material hub employees know which building components are especially popular and sell well (e.g. old wood). Hence, knowledge about what the clients of the respective circular material hub want is needed to decide whether a building component can be sold and how much money can be asked. The monetary value is influenced by the condition and certain characteristics of the building component.

Connections: The value calculation practice is connected to the inventory practice (see chapter 5.1.1) and the price calculation practice (see chapter 5.1.4). The former because an inventory list is necessary to have an overview of all building components and the latter because it has an influence on the calculated price.

5.1.1.3. Practice I.III: Client search practice

It is possible that building components are sold before they get dismantled. One circular material hub representative reported that for 60 to 70% of the building components a new owner can be found before the deconstruction starts, which results in the materials and elements never being transported to the hub. In this case, the buyers are mostly specialized trade companies instead of end users. When searching for clients, it is crucial to know which materials become available to look for potential buyers. In turn, when building components get sold and do not have to be transported to and stored in a hub, it also influences which process activities must be performed in a circular material hub, since less components mean less processing (see chapter 5.1.1.2.). Therefore, selling building components before the deconstruction process starts leads to less material transportation, processing, and storing at the hub.

Connections: The client search practice is directly influenced by the inventory practice (see chapter 5.1.1.1), since it is crucial to know which materials become available to look for potential buyers. At the same time, it influences the processing practice. When materials are sold before they get to the circular material hub, they do not have to be processed there. To a certain degree, this also indirectly influences the scouting practice. If building components are sold before they get to a circular material hub, it only targets those carriers of a scouting practice who decide to scout building components directly from deconstruction projects and not from online marketplaces or at the circular material hub.

5.1.1.4. Practice I.IV: Price calculation practice

Which price a demolition company asks for the deconstruction of a building depends on the project as well as the building components that get available during deconstruction. They typically have standardized contracts and prices depending on the task and whether all, most or no building components shall be deconstructed or demolished. During this research it was found that the contract typically includes that the demolition company can keep all the building components that get dismantled. The price calculated for the deconstruction of a building minus the monetary value of the building components that can be dismantled results in the price that is asked for the deconstruction of a building.

Connections: The price calculation practice for calculating how much the demolition company asks for deconstructing a building is connected to the value calculation practice, since the asking price is made up of the demolition price minus calculated value of all building components released (see chapter 5.1.1.2.).

5.1.1.5. Practice I.V: Decision making practice

A circular material hub must decide whether to accept or decline building components that get offered by an external party. To decide, it is necessary to have an overview of the building components on offer and their condition as well as enough experience to know whether these components can be sold quickly or not. The price a circular material hub pays for building components that get offered by an external party depend on certain characteristics. For example, the more nails there are within one meter of wooden plank, the lower the price will be since more holes result in less quality due to less load-bearing and less processable wood. Accepting materials from external parties is not always equivalent to paying for these materials, as one hub stated that external partners can hand over the materials or elements to them, but only in some cases they pay a fee when they are sold. Typically, building components from external parties are only accepted if they match the circular material hub's range. There are two different ways to get an overview of what is available and to support the decision-making process. The first one is that a circular advisor or employee of the circular material hub visits the building in person, walks through it and compiles a list of building components that suit the offer of the circular material hub. This option was pointed out to be particularly suitable for larger projects. The second one is to not visit the deconstruction site in person, but instead ask for pictures, a video chat and detailed information of the available building components. By asking questions which are specific enough to understand the building components on offer, essential information for the further handling can be collected.

> *"… how are the planks connected, what do they look like when they come loose, what will they look like, are there nails in the planks, is there material left over on the planks." (The rejuvenating hub)*

This method is chosen if there is no time to view the materials in person or if the project is too far away. As one interviewee (The rejuvenating hub) stated, the reasoning behind checking all materials and elements is that "I don't want a surprise at my door step with materials I don't want." Once the basic information explained above is obtained, the final intake of the building components depends on storage capacity, demand and potential to find buyers: "We are always checking if there is enough in store and enough demand, we don't want to have the things on the shelf for too long." (The rejuvenating hub). Several representatives from circular material hubs explained that old or rare items sell particularly well, and that old wood is especially popular amongst clients. This illustrates the market insights the material hubs require to make a qualified decision on whether to accept a building component or not.

Connections: The decision making practice is connected to the inventory practice (see chapter 5.1.1.1) and the sales practice (see chapter 5.1.1.3.). Knowledge about which building components are on offer forms the foundation for decision making. Additionally, it is crucial to know whether the building components subsequently can be sold, which in turn is influenced by the preferences of potential clients.

5.1.2. Practice bundle II: Processing

When the building components get to the circular material hub, processing practices, i.e. practices that are combined in a processing practice bundle, can be performed to prepare the building components for reuse. Building components offered in circular material hubs can be grouped into the categories secondary raw materials, structural elements, non-structural elements, and furniture. The practices in this bundle arecleaning practice, repurposing practice, remanufacturing practice, separating practice, and recycling practice.

Once the building components have been accepted, they are taken to the circular material hub. There, they are processed and prepared for reintroduction into the material cycle. Processing, here, refers to all the practices performed in the circular material hub to prepare the materials for a new life cycle. There are various practices within the processing practice. Depending on which materials or elements are offered in the circular material hub, different practices were identified that are performed by the employees before they can re-enter the material cycle. These practices are cleaning, repurposing, remanufacturing, separating, and recycling. Which practices are performed in a circular material hub depend on the offer of the respective hub, their focus in terms of material (e.g. wood) and building component handling (e.g. mostly non-structural elements), and the building component at hand. Below, a classification of the different building component categories is given, followed by description of and an example for each practice.

Building component categories

It is difficult to say exactly what is offered in a circular material hub. The range is constantly changing and always depends on what becomes available during dismantling projects. This is also made clear by the statement of one interviewee who said: "Our assortment is changing all the time, it is not like in a supermarket, we are dependent on what is coming in" (The rejuvenating hub). It is, however, possible to determine a basic range of elements or materials based on the usual supply. The interviews showed that the circular material hubs under investigation mostly sell structural elements, non-structural elements, and interor.

Examples of secondary building components of each category sold in circular material hubs are:

- Secondary raw materials: Wood, concrete
- Structural elements: Beams, planks, columns, concrete stairs
- Non-structural elements: Insulation, doors, windows, locks, panels,
- Interior: Toilets, sinks, cabinets, kitchen, tables, chairs

In terms of materials, a tendency towards wood materials was identified. Half of the hubs surveyed have their own wood saw and process wood products. This also matches with the findings from this study showing that wood and especially old wood is particularly popular amongst clients. As the circular material hubs under investigation were chosen according to the building component categories they sell (namely mainly structural elements, non-structural elements, and interior), secondary raw materials apart from wood are little to not handled. In one example, secondary raw materials such as concrete are processed (broken, crushed, washed, sived) by the associated recycling department, but not by the circular material hub department.

5.1.2.1. Practice II.I: Cleaning

Before being able to sell building components, cleaning of the component in question is sometimes needed, and therefore one of the practices performed at circular material hubs. An example is the cleaning of toilets which was performed in one of the circular material hubs under investigation. Since performing a cleaning practice specifically for toilets is not a regular practice performed at the circular material hub in question, a small wash box in which the toilets can be cleaned had to be built first. The reason for this was that a customer no longer wanted to use new materials for the project. To be able to reuse the toilets, it was necessary to clean them. This required the toilets that need to be cleaned, the employees that performed the practice, a suitable washing facility, the knowledge of how to clean them and a client who wanted to reuse building components. Additionally, circular material hub employees who are willing to perform a practice they normally do not perform and even build a tool necessary for performing this practice were needed.

5.1.2.2. Practice II.II: Repurposing

Within the sample population of four circular material hubs, one makes completely new items from secondary building components that no longer correspond to the original use. For example, doors are repurposed as tabletops, windows are repurposed as doors for cupboards and cupboards are repurposed as parts of kitchen islands or kitchen counters. To perform this practice, handicraft knowledge, tools, creative thinking, and a suitable workplace are required. Additionally, it needs knowledge about certain building standards such as conventional table heights, top depths etc.

5.1.2.3. Practice II.IV: Separating

Before being able to reuse, remanufacture, repurpose, or recycle components, the different building components (e.g. concrete, wood, bricks, or roof tiles) must be separated, (1) from each other or (2) according to their quality. Wood, for example, is separated according to its quality into A-wood, B-wood, and C-wood, which can then further not only be recycled, but also reused, remanufactured, or repurposed.

5.1.2.4. Practice II.V: Recycling

Interestingly, circular material hubs do not use the secondary raw materials themselves. Instead, they work together with producers and pass the secondary raw materials on to them so they can make new products out of it.

> *"We need producers because we need to make the raw materials and the producers can use it for circular products." (The all-rounder hub 2)*

Another option is to pass them on to the recycling department within the same company. When it comes to the circular material hubs under investigation, wood is the material that is recycled the most. Those circular material hubs which have a wood saw cut wooden beams into new building components with different dimensions or make pressed wood out of it. Other activities such as crushing, washing, grinding, or shredding, which are for example necessary to recycle concrete, are not performed within the circular material hub, but rather by a recycling department within the same company.

5.1.3. Practice bundle III: Sales

The sales practice bundle describes different practices that are performed in a sequence or temporal order to sell the building components offered by a circular material hub. Building components are sold through different communication channels and to different clients. Clients of circular material hubs can be grouped into four main target groups: private customers, businesses or wholesale, fixed partners or producers, and public customers. Communication channels were identified as the intersection between the circular material hub and the customer. The five main communication channels identified during the study are the Insert marketplace, Marktplaats, a web shop, a physical shop as well as contacting potential clients directly (e.g. by phone). Depending on the client, different communication channels are preferred by the representatives of the circular material hubs.

Multiple reasons were found why circular material hubs do what they do, i.e. why they collect or accept, process, and then sell building components. Building components that are treated in a circular material hub are returned to the cycle by selling them to different parties. By doing this, they remain part of the material cycle. This return to the material cycle is one of the first motivating factors. The representatives report that they see it as their task and duty to help ensure that more resources are reused in the construction industry. The awareness that primary raw resources cannot be used indefinitely, and that the construction sector contributes to a large part of the environmental damage is the reason why they are active in this area. Additionally, the vision of the Dutch government to become circular and climate neutral by 2050 was mentioned to be a reason for the company the respective circular material hub is part of to operate such a department. In a circular economy, reusing secondary building components will be a fundamental part, hence offering those is seen as a "… need in the future" (The all-rounder hub 2).

It must be noted that the practice of selling secondary building components is an economic activity which is connected to money, profit, and turnover, as one representative stated: "I'm also a businessman. I always have to look on return on investment" (The all-rounder hub 2). Despite turnover being important, it was found that profit is not the main motivation behind running a circular material hub, as they do not generate a lot of revenue.

"It's not the most profitable part for our organization. So everything we do here we do because we have and want to do something with old materials from our projects. It's not really a big part of our revenue." (The B2B hub)

As indicated in the introduction of this section, the practices of choosing a client and communication channel are crucial for the sales bundle. Those practices are described below.

5.1.3.1. Practice III.I: Choosing a client practice

In a first step, the practice of choosing a client or target group must be performed. Five main target groups of circular material hubs were identified. These are private customers, wholesale, fixed partners or producers and public organizations.

Clients depend on (1) the building components that are sold, (2) for which target group they are relevant, (3) who is willing to buy secondary building components and (5) an active decision of the circular material hub providers for or against a specific target group. To reach different target groups and potential clients, different communication channels are used. Therefore, performing the practice of choosing a client informs the practice of choosing a communication channel. In the following, all target groups are described. This description forms the basis for the chosen communication channel, as described in chapter 5.3.1.2 and 5.3.1.3.

Target group I: Private customers

Private customers are an important target group for circular material hubs and for some even the most important one. Even though "consumers are very wide, if you look at the target group (…) most (…) customers are private customers who buy things for themselves" (The rejuvenating hub). However, it was found that private customers are not important for every circular material hub, as a representative of one hub specifically mentioned that they actively try to avoid private customers:

> *"We try to stay away from that. Because it's very low volume and they need a lot of attention." (THE B2B HUB)*

A concern mentioned in the context of selling to private customers is that they not always realize that the circular material hub does not give a guarantee on secondary materials and elements. Hence, it is the responsibility of the private customer to check the quality. Despite attempts to avoid private customers, they cannot always be prevented when advertising online.

Target group II: Wholesale

Selling to wholesale was found to be attractive for circular material hubs as it is easier and more efficient than other ways of selling.

> *"We try to sell as much as possible to wholesale because it is easier." (THE B2B HUB)*

It is easier as the circular material hub does not have to look for buyers, but already knows that the wholesale partner will very likely buy the building components. What needs to be done is to inform the client about available building components and offer a price. Selling to wholesale is more efficient and less expensive for the circular material hub operator compared to having an entire logistical network and warehouse. Additionally, it was found to be as close to the procedure nowadays considered as standard as possible, which in turn makes it attractive for other users such as building companies.

Target group III: Fixed partners and producers

Selling to fixed partners was found to be useful as it eliminates the need to search for potential customers every time. It was found that some circular material hubs work together with fixed partners to which they bring back certain building components. Within the category of fixed partners, two different target groups were mentioned. Fixed partners can either be companies such as construction companies, warehouses, or producers. Within the group of producers, a distinction can be made between the original producer of the respective building component and producers who create new products from secondary building components but are not the original producer. One representative stated: "For all the mainstream materials we have fixed buyers" (The B2B Hub). Building components mentioned in this context were concrete and wood which are turned into new concrete or new wooden panels. A reason that was given by one representative for not bringing back the materials to the original producer was that the circular material hub does not know who the original producer was. A lack of information regarding who the original producer is as well as a collaboration with the original producer are needed to be able to bring the building components back.

Target group IV: Public organizations

Targeting public organizations such as schools or libraries was reported as beneficial by one circular material hub.

> *"… one of the possibilities to make more turnover is to look at those libraries or schools, because the government or government branches are more interested in reusing materials." (The rejuvenating hub)*

According to the interviewee, this can be attributed to the circumstance that the municipality has an interest in making the construction process more circular, also because of the government's goal of becoming climate-neutral and circular. The municipality therefore does not necessarily select the cheapest offer, but also pays attention to its circular efforts, whereby more money is invested in secondary building components.

Target group V: Construction sector

A close connection between circular material hubs and architects could not be detected. According to the representatives of the circular material hubs under investigation, architects are not part of the main target group. Statements such as "we don't see them a lot in our hub" (The all-rounder hub 1), "we talk to architects now more and more" (The B2B hub) and "we have a separate department which works together with architects, but it is at the beginning of the process and not that far yet" (The rejuvenating hub) show that architects are not yet part of the regular clientele. From the perspective of circular material hub representatives, architects are interested in reusing materials, but due to the unpredictable supply of materials and elements that are offered at a circular material hub, they think it is difficult for architects to design with them.

The same applies to contractors or constructors, as these are, in contrast to architects, seen as a target group, but are not the main purchasers of building components sold at circular material hubs.

> *"Sometimes there are also companies like small constructors which [buy building components that] are already on stock, like old doors or concrete stairs, that are also a target groups of us, but these companies are very small in terms of total turnover." (The rejuvenating hub)*

5.1.3.2. Practice III.III: Online sales practice

It was found that circular material hubs sell secondary building components both online and offline. Therefore, two sales practices were identified, an online sales practice and an offline sales practice. For both practices, different performances were investigated. In case of online and offline sales practices, zooming in to different performances provides important insights into the differences that occur when a practice is performed in different settings or to reach different target groups. To be more precise, the performances differ in where the building components are sold and are directly connected to the desired target group. The options for selling materials and elements are subsequently referred to as communication channels, as they are a means of bringing circular material hubs and clients together. As such, they can be assigned to the material category. Through these channels, (1) circular material hubs can offer their building components and (2) customers can find building components. This means that the communication channels function bidirectionally and are beneficial both for circular material hubs, which represent the selling party, and for customers, who represent the buying or searching (scouting) party.

Five different communication channels were identified. These are the Insert marketplace, Marktplaats, an individual, company owned online shop, a physical shop or by contacting the potential client directly. Which communication channel is used depends on the offer as well as the target group. In the following, the two different sales practices identified in this research and different performances of these practices are explained.

Performance III.III.I: Selling on the Insert marketplace

The Insert marketplace was found to be one of the most important players when it comes to connecting circular material hubs and potential clients. The Insert marketplace is an online platform operated by the Insert foundation where building components offered by different suppliers can be found. One interviewee stated: "We have our own web shop but we also use Marktplaats" (The B2B hub). After further investigation, it turned out that the web shop the interviewee referred to was not a company owned web shop, but the Insert marketplace. This shows that the Insert marketplace is not just seen as a marketplace by many, but as a company's own store. This can also be observed from the fact that the Insert marketplace can be filtered according to the various suppliers, so that only those building components offered by a single company are displayed on one page. As a result, the impression can be conveyed that it is indeed a company owned online store. The Insert marketplace is intended to be a business to business (B2B) marketplace which targets players within the construction industry and not private customers. This is also evident from the structure of the platform, as it is possible to filter all building components according to STABU and RAW codes (note from the author: STABU and RAW are systems for providing codes in the construction industry. RAW is used for residential and non-residential construction (Ketenstandaard Bouw en Techniek, 2022), and RAW is used for civil engineering construction (Dreschler, 2009)).

When selling on the Insert marketplace, the following information must be provided: pictures, material specifications (availability, quantity, dimensions, material location), project information (provider, project, location), additional information (technical quality, aesthetic quality, raw material, type of connection) as well as additional descriptions or information that could be interesting for a potential client. The price does not have to be provided, however, the representative of Insert stated that providing a price is beneficial as this is what clients are interested in. To sell on insert, an employee of the circular material hub must take pictures of the building components and put all the information into the system. Additionally, the circular material hub must have an Insert subscription. While building components can be searched even without an Insert membership, placing building components in the web shop is only possible with the standard or pro subscription. As mentioned above, clients can get the impression of visiting the web shop of the circular material hub, even if it is the Insert Marketplace. This is where the different memberships come into play once again, as it is also possible to embed a widget on the website of the circular material hub with the Pro membership.

The main target groups reached via the Insert marketplace are architects and other actors within the construction sector.

Performance III.III.II: Selling on Marktplaats

It was found that the circular material hubs are not relying on Marktplaats to sell building components. Even though Marktplaats is used, it is not used intensively and can be understood as a communication channel of secondary importance. Marktplaats tends to be used for smaller quantities of materials or in addition to other online or offline marketplaces. To sell on Marktplaats, pictures and information about the building component must be put into the system as well. On Marktplaats it is not mandatory to provide as much information as on the Insert marketplace. When analyzing the posts on Marktplaats, it can be seen that this lack of required data results in

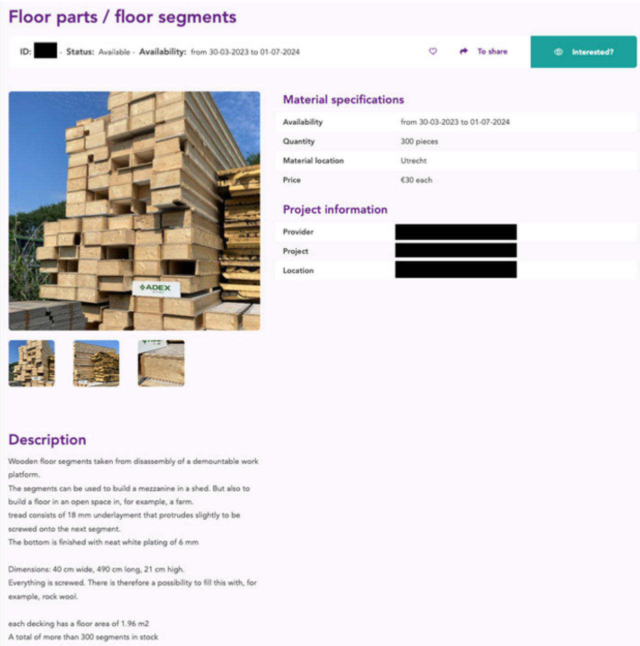

Figure 5.1 Exemplary screenshot of the Insert online marketplace.

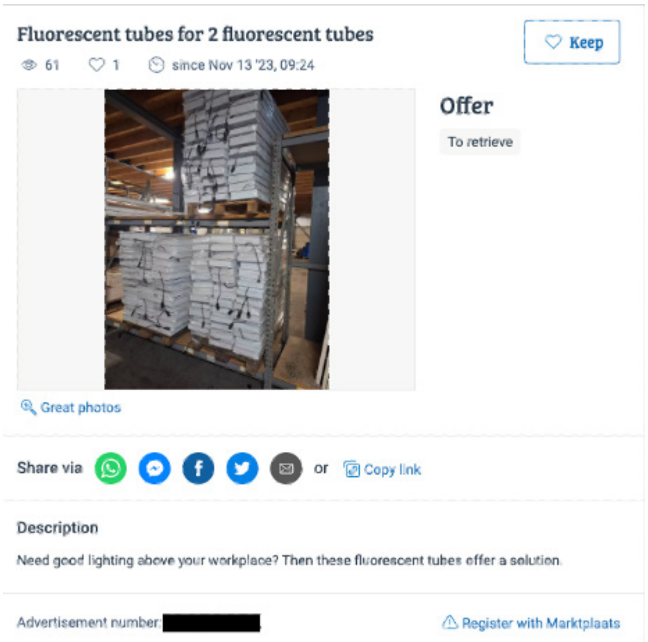

Figure 5.2 Exemplary screenshot of the Marktplaats online marketplace.

less information being provided. On Marktplaats, mostly private customers or end-users are targeted.

Performance III.III.III: Selling in web shop

It was found that circular material hubs typically do not operate their own web shop but use the Insert marketplace or Marktplaats for their online presence. However, as mentioned before, circular material hubs can embed an Insert widget on their website. From the four material hubs under investigation, one has a web shop which is run by its own company. All other circular material hubs offer their building components on a marketplace run by an external operator (Insert or Marktplaats) since this is easier. One representative even stated that selling elements or furniture in a web shop cause too much distance to the customer. Here, it must be mentioned that this circular material hub produces furniture from secondary building components, which needs consultation with the client to understand their wishes. They are unique pieces that are only made when there is a buyer for them. In this case, a web store would prevent the customer‘s needs and ideas from being precisely understood and implemented. A company owned web shop targets different groups of clients.

5.1.3.3. Practice III.II: Offline sales practice

Performance III.II.I: Selling in a physical shop

It is not usual for building components to be offered in a physical shop or showroom. Selling building components directly at the location of the circular material hub, without there being a dedicated shop for this purpose, is not an essential part of the sales practice, even though customers sometimes do visit to check the building components before they buy them. One of the four circular material hubs under investigation operates a physical store which is open to the public. In the store, structural elements such as doors, windows and stairs are displayed next to non-structural elements such as door handles, furniture such as tables and refurbished furniture such as doors, tables, chairs, cupboards, or kitchens. The argument for running a physical store was that it allows close contact with customers and exclusivity. This close contact was found to be especially important for exactly this hub since it produces furniture from secondary building components. A task which requires close connection to clients to produce a piece of furniture which meets the expectations and needs of the customers.

> *"… we try to connect with the customer, take them by the hand and go through the progress with them (…)." (The rejuvenating hub)*

In a physical shop, customers can be advised individually, and it is possible to find out exactly what they want, for what purpose, and what ideas they have. Additionally, clients who come to the shop to purchase a specific element or piece of furniture might get convinced to buy something else as well.

> *"The main attraction are the old doors, they attract and if they come in, we try to get them in on the weekend and if they look at the showroom and then they get interest in more and more." (The rejuvenating hub)*

Selling secondary building components in a physical shop targets mostly private customers and small businesses. To conclude, performing an offline sales practice in a physical shop is beneficial when a close connection to clients is desired or required.

Figure 5.3 Exemplary picture of a physical shop operated by a circular material hub.

Performance III.II.I: Direct selling

Another performance of an offline sales practice is characterized by selling secondary building components to fixed partners. The building components do not have to be offered online or in a physical shop but can be offered directly to potential customers, e.g. by calling them. When contacting the potential client, a circular material hub employee provides information on which building component is on offer, the amount and the asking sales price. The potential customer then only has to accept or reject the offer. This establishes a certain regularity in the sales process, and it avoids the need to look for other customers. A direct sales practice targets mostly wholesale, producers or other fixed partners the circular material hub collaborates with.

5.1.4. Practice IV: Circular design practice

A circular design practice can be performed in multiple ways, i.e. have different performances. Decisive factors are whether the design or knowledge about reusable materials and elements is first, which materials can be scouted, how the building components available for reuse can be found and the partners that are part of the project team, meaning whether they support material reuse or not. Competences that are important for a circular design process are flexibility and creativity. In the following, a circular design practice-as-entity is described.

It was found that there are two ways of approaching a design including secondary building components.

> *"Either you look for what's there and make a design with that or you design a building and then see how you can fit." (The visionary architect)*

The first option or performance is to identify which building components are available and afterwards start a design with the knowledge about current availabilities. The second option or performance is to create a design and afterwards look for secondary building components that are available that could fit the project and design. Whether the knowledge on available building components or the design comes first depends on the project, as in some cases building components from a donor building or deconstruction project are available. One reason given for creating a design first and then searching for secondary building components was the strict requirements and regulations that must be fulfilled. This, however, does not mean that the entire design must be finished before the search for building components can start. If a design just includes openings and square meters but no materials specification, it allows to have enough knowledge on what could fit the project without taking the possibility to change the design according to the building components that are available. One expert, however, does not agree with this way of designing and states:

> *"It's a disaster that we make designs and then look afterwards to see how we can actually put the thing together." (The circular economy expert, translated)*

Designing with secondary building components is a skill that needs to be learned, just as designing with virgin materials requires certain competences.

> *"I think you can learn to work with reuse materials." (The visionary architect)*

It has been shown that architects have generally a positive attitude and think that other architects either already know how to design circularly or can at least learn to do so.

> *"Many architects, they are willing, they want it, they know how to do it because all it takes is creativity and the will to do it … " (The visionary architect)*

Two skills mentioned by several architects that are essential when designing with secondary building components are flexibility and creativity. Flexibility here refers to the knowledge that changes may be necessary in the final design stages. To stay flexible, the final design stage should be dynamic instead of static. This allows the architect to adapt the design according to the materials and elements that are available. As a result, unforeseeable changes or changes at short notice can be accommodated.

> *"I think what is really important is the (…) creative view on how can we find a way to reuse this building, all these materials …" (The visionary architect)*

Creativity, on the other side, stands for the ability to rethink the design process. Whereas in a traditional design process any materials can be selected, a circular design process relies on either the selected materials already being available or at least being able to be found.

> *"… it requires a way of thinking and sort of flexibility that enables you to design with reuse materials and some architects, I think, they just don't want it or they feel bounded by, for example, availability or quality …" (The visionary architect)*

Flexibility and creativity are also seen as a potential reason why architects do not design with secondary building components.

> *"I think architects and designers are visually,*

they need visuals." (The visionary architect)

Due to designers responding to visual stimuli, it was found to be especially helpful if they get an in-depth understanding of the state of a building material or element and what it looks like. This also reduces the risk of creativity, or missing creativity, being a decisive factor in the choice not to use secondary building components. The needed understanding of and information about certain building components is hard to obtain while they are still installed, as it is not clear whether and how they can be taken apart or how they are attached to each other. This understanding, however, is necessary to include a certain building component in a design. One argument given was that it is easier to imagine a reuse scenario if the building components have already been dismantled rather than still being installed in a building. In this context, direct online access to circular material hub offers was identified as support. It allows them to decide whether it is worth spending time on visiting the circular material hub and looking at the available building components or not.

As mentioned above, it depends whether the knowledge about available secondary building components or the design comes first. Even though the performance differs for the two options, both, in the end, require secondary building components that are available for reuse. The difference is, at which stage of the design process the knowledge about the available materials is needed.

Another factor are the partners that participate in a project. It was found that the project team can be dependent on whether a design includes reused materials or not. Being supported by a team, client, contractor, and advisory partner is necessary to enable reuse among architects.

"… if everyone is against you and actually nobody wants it … then it's impossible." (The visionary architect)

According to one architect, using secondary building components is not always more expensive and sometimes even cheaper. However, what makes it more expensive is the work that is accompanying the scouting process. When designing in the traditional way, building components can be found and selected in a construction shop. In comparison, when designing with secondary building components, more time is spent finding the materials and checking their condition. This extra work leads to higher costs.

In some performances of circular design practices secondary building components are preferred to look like they are reused, while in others they are preferred to look like new, even though they are reused. It was found that these differences depend on the taste of the carrier of the practice, i.e. the taste of the designing architect or client. One architect stated that showing exactly where a material came from "can be an interesting aspect to a design" (The visionary architect).

5.1.5. Practice V: Building component scouting

Building components can be scouted offline or online. Offline, building component can be scouted from donor buildings, circular material hubs or physical shops operated by circular material hub providers. Online building component scouting can make use of online marketplaces shared by multiple providers or online shops operated by a single provider. The scouting practice itself can be performed by different carriers, namely architects, material scouts, contractors, clients, or employees of the Insert Foundation. The Insert Foundation does not only play a crucial role in the scouting process by providing an online marketplace which can be used by those performing a building component scouting practice, but also by offering a scouting service to look for specifically required materials.

When it comes to scouting secondary building components which can be used in a construction project, two main performances of this practice were found. The difference between those performances is mainly where the building components are scouted, i.e online or offline. Scouting building components offline can be performed by visiting (1) a donor building or (2) a circular material hub or a physical shop operated by the circular material hub. A donor building can for example be a building that currently stands on the site the new one is planned for or another building that is currently being or planned to be deconstructed. Scouting building components online typically includes visiting (1) online marketplaces, where building components from multiple suppliers are offered, or (2) an online shop operated by a single circular material hub. While an offline scouting practice requires the person who performs the practice to physically go to the location where the secondary building components can be scouted or harvested, an online scouting practice can be performed virtually anywhere. Within one project, one or both performances can be performed. This means that secondary building components can either only be scouted online, only offline or both online and offline.

Carriers of a scouting practice

Even though the focus is on the practice itself rather than the carrier, this research does not want to neglect who potentially performs the practice, as there are certain characteristics related to each carrier that can significantly influence the respective performance. Below, an overview of carriers who can perform the practice of scouting secondary building components is provided.

Practice performed by architects

Whether building components are mainly scouted by architects and other employees of an architectural firm or by an external carrier depends on the project, but also on the architectural firm. Architects can look for secondary building components either offline or online. Especially when special secondary building components are incorporated in a design, the practice is performed by architects. Special building components are those that are significant for the design, and often especially for the appearance. However, in most of the architectural firms under investigation, building components are scouted not mainly by the designing architects themselves, but by other employees who are assigned specifically to this task. These employees are hereinafter referred to as material scouts.

Practice performed by material scouts

Material scouts are typically not designing but only scouting secondary building components or developing technical details which are influenced by decisions connected to circularity. While looking for building components that fit the designs provided by the architects, material scouts are in contact with other parties that are part of the circular loop, and they are responsible for making the contract with the provider once they found suitable building components.

Practice performed by contractors

It was found that contractors play an important role when it comes to building component reuse in a construction project. They are not always the party performing the scouting practice, but due to their big network involving them in the process was found to be helpful. The contractors' big networks were also found to be useful when in need of a storage space for building components that can be scouted and harvested early on in a project but only be used in a later stage of the process. Therefore, through providing the network, they also contribute by facilitating the scouting practice performed by other carriers. Only one interviewee stated specifically that scouting belongs to the tasks of a contractor. Nevertheless, even in this case it was mentioned that architects can also look for building components themselves, especially when special building components are involved.

Practice performed by clients

It has been found that clients can also perform the scouting practice, or at least influence it. The former when they harvest building components and therefore actively participate in looking for building components, and the latter if they provide a donor building, deconstruction project or already harvested building components.

Practice performed by the Insert Foundation

It has been shown that the Insert Foundation is not only important for circular material hub providers by operating an online marketplace, but also for those who are performing a scouting practice. The Insert marketplace is also important for material scouting by providing a common online platform where secondary building components from multiple providers are sold. Furthermore, the Insert Foundation offers a material scouting service and looks for special secondary building components that are requested by clients. In case the required building components can be scouted before the construction project starts, the network of the Insert Foundation also helps them in finding temporary storage possibilities. Additionally, the Insert Foundation can also create an in-depth inventory of the building components that will become available during the redevelopment or deconstruction of a (donor) building.

One architect states:

> *"… we collaborate with them quite a lot, especially for the past couple of months. And for us, that worked really well …" (The visionary architect)*

5.1.5.1. Performance V.I: Scouting building components offline

It was found that it depends on the project whether materials and elements are scouted and harvested from a donor building, from a circular material hub directly or from one of the online platforms available.

Scouting building components from donor buildings

Donor buildings tend to be used when they belong to the same contractor or client. However, buildings that are known to be demolished during a project can also be used as donor buildings. Scouting all building components needed for a new project from one single donor building was found to be rather unlikely. Therefore, it is often necessary to search for the required building components elsewhere, i.e. different deconstruction projects, material hubs or marketplaces. In this case, it is also possible to combine an online and offline performed scouting practice. If building components are scouted from a donor building, either material scouts or architects visit the building to make an inventory of what can potentially be used. The scouting process itself can be performed in multiple rounds, as visiting the same building multiple times is not unusual. It allows different impressions to be gathered and means that the inventory list does not have to be compiled during the first visit. If architects are the ones performing the material scouting practice, visiting a donor building multiple times has the advantage that the first visit can take place completely without pressure. They can get an overview of everything that is available, let the materials take effect on them and potentially help them to come up with first ideas of how certain building components could be included in a new design. Additional tools such as a decision tree chart can also be used in the process of deciding whether a building component from a donor building can be reused or not. Questions that are raised during this process are (1) whether the building components can be disassembled, (2) how the connections work, (3) whether they can be reused exactly the way they are or if they must be altered or used for a different purpose and (4) if they are safe to reuse.

An issue that has been reported with using building components from a donor building is that it is difficult to know what exactly they will look like before they get dismantled. If building components are still installed, the size cannot be measured exactly, and it is not possible to know in detail how they were installed and connected. This is a problem as an in-depth understanding of the building components, their condition, and the way their connection works is crucial for both the scouting and design process. Even if it is not known yet what the building component looks like, both in terms of measures and color, knowing how it is connected allows to anticipate how it can be used. Therefore, information on the connection of building components is crucial for those performing a scouting practice.

Scouting building components from circular material hubs

Visiting circular material hubs to scout secondary building components without previously checking online whether the required building components are available has been found to be less preferred. One representative stated that visiting a circular material hub without knowing whether there are building components available that match the search criteria can take away time that could be spent differently. To avoid this, it is preferred to first check online which building components are available if possible. The argument that specific knowledge is required to scout building components directly from circular material hubs is complemented, although in a different respect, by another interviewee. This interviewee mentioned that elements such as window frames or doors, for example, are known to always be available, but the question is where. Circular material hubs can help with this, as they are known to sell certain building components. However, a temporal level is added, as it is not certain whether specific building components will be available at a given time.

Scouting building components through the Insert Foundation

Secondary building components can also be scouted by commissioning the Insert Foundation and making use of their scouting service. In this case, an employee of the Insert Foundation performs the harvesting practice. This option is chosen, for example, when those performing a design practice require a large number of a particular building component. They approach the Insert service and ask if they think they can find the required building components. If Insert says no, the design is adapted. Otherwise, Insert is commissioned with the task of scouting the required building components.Additionally, Insert has a large network and access to its own marketplace, which enables a larger search radius.

Scouting building components from non-traditional sources

It has been found that building components can also be scouted from other suppliers which are traditionally not within the supply source of construction projects. One architect, for example, prefers industrial waste as a source for material scouting. Reasons given for this preference were that industrial waste usually comes from one source and is available in the same quantities at the same time. This allows to make more reliable appointments compared to materials and elements that are scouted from deconstruction projects.

5.1.5.2. Performance V.II: Scouting building components online

An online scouting practice is typically performed by using online marketplaces or online shops. While online marketplaces such as the Insert marketplace or Marktplaats provide secondary building components from multiple suppliers, online shops operated by a single circular material hub provider only offer secondary building components from one supplier. As a result, the range of secondary building components on offer on online marketplaces is generally larger than in individual online shops. This is beneficial for those performing a scouting practice, as they do not have to check the online shops from a variety of suppliers. When it comes to online marketplaces, the Insert marketplace was mentioned by the majority of the interviewees. Only one interviewee did not know what Insert is. It was found that, even though Marktplaats is also known as a platform where building components can be found, the Insert marketplace tends to be used more often. Because new and old items are offered on Marktplaats and the platform is consumer oriented, it was reported to be more difficult to find building components that suit the respective project. For this reason, platforms that are business to business are preferred. This gives the Insert marketplace an advantage over Marktplaats. Insert allows to find building components from different suppliers on the same website, whereby it is clear that these are business suppliers and not private sellers. Additionally, the Insert marketplace can be filtered by the so called STABU and RAW codes which are systems for providing product information in the Netherlands (STABU is used for residential and non-residential construction (Ketenstandaard Bouw en Techniek, 2022), while RAW is used for civil engineering construction (Dreschler, 2009)). The use of a generalized code system facilitates the scouting practice as those who are looking for secondary building components are very likely familiar with the systems and how they work.

5.2. Challenges, opportunities, and possible future developments

Next to the practices which were identified during this research and presented in chapter 6.1., the interviewees also shared information on challenges and opportunities that either relate directly to the practices they perform or to the system in which they are performed. Additionally, potential future developments connected to the current system of circular material hubs in the Netherlands were identified. In the following, these challenges, opportunities, and potential future developments are presented. This information is considered essential to understand the potentials of circular material hubs, certain limitations that potentially hinder or opportunities that support the development of the entire system in the context of a necessary transition towards a more circular construction industry. Additionally, this information also plays a key role in shaping recommendations for government and practitioners.

5.2.1. Challenges

This section describes the challenges identified by the interviewees. These can be challenges expressed by architects, circular material hub representatives or experts. Uncertainty, the need to be flexible throughout the entire design process, the status of guidelines and regulations, missing collaborations between all parties involved in the project, costs, and the question of who is providing the guarantee for secondary building components are the main challenges which have been named by both architects as well as circular material hub representatives.

5.2.1.1. Challenge I: Uncertainty, irregular assortment and flexibility

Uncertainty can be one of the challenges practitioners have to face during a circular design practice, specifically during the process of scouting or harvesting building components.

> *"In the world of reusing materials (…) anything can happen and you never know if something turns out differently than you expected, usually it does" (The visionary architect).*

This uncertainty is also exacerbated by the irregular assortment of circular material hubs. The fact that the offer of circular material hubs depends on deconstruction projects and the building components that get available reinforces uncertainty and the need for more flexibility. It cannot be guaranteed that certain building components will be available in a certain amount or dimension at a certain time. For practitioners performing a circular design practice, in turn, this uncertainty makes it harder to include secondary building components in their design. However, there is not only uncertainty when it comes to the offer available at circular material hubs, but also to the building components that can be harvested from deconstruction projects. Questions such as whether the quality is as expected, how a still built-in building component is connected, whether it can be deconstructed without damage and if all safety regulations can be met with the intended building component after its deconstruction lead to a certain degree of uncertainty that needs to be taken in to account. This in turn needs flexibility to adapt the design to possible changes, even at a later stage in the project, potentially even during the construction phase.

It has been shown that these uncertainties lead to projects starting ambitiously, only to realize at the end that the result is far from the ambitious goal planned at the beginning. Reasons for unforeseeable changes may be that materials have been damaged during dismantling, that the quality of the building components do not meet expectations, that regulations cannot be met with what is available, that the desired building component cannot be found or that is different from what was originally assumed. The last case can occur when building components are scouted from a donor building. In some cases, it can happen that only after the deconstruction it is it discovered that the building component is different from what was assumed when it was still built in.

5.2.1.2. Challenge II: Missing collaboration

A problem mentioned by multiple interviewees is the timeline when different parties get involved in a project. The consensus is that the earlier all parties get involved, the better. This means that

> *"… incorporate us as early as possible and put us on the same table as the architect." (The B2B hub)*

Involved partners starting to work on a project one after the other instead of at the same time was considered as a disadvantage. If partners only become part of the project one after the other, it may only emerge at a later stage that one of the partners is unable to perform one of the previously decided tasks, for example due to a lack of knowledge and skills. This means that changes must be made that could have been avoided if all partners had been on board from the start.

Whether or not it is a good idea to have contractors involved at the start of the design is judged differently depending on the architect.

> *"…as long as it fits our design. We don't mind if they [the contractors] also look for materials." (The visionary architect)*

The advantage mentioned was that circular design decisions regarding the choice of materials or elements can be made without the contractor being able to reject them from the outset, as they only get involved in a project at a later stage when most parts of the design were already developed. As a result, contractors might be convinced to reuse more building components. However, this same argument was also mentioned as a disadvantage by another interviewee. If circular proposals are made and contractors only become part of the team later, it may only become apparent at an advanced stage of the design process that the contractor is not able or does not have the experience to build with the desired secondary building components.

5.2.1.3. Challenge III: Guidelines and regulations

A major hurdle to reusing building components is the current guidelines that the construction sector must adhere to. For example, old doors are available in large quantities, but their measures do not match the current regulations. A similar problem was found with windows which are also available in high volumes, but the quality of the glass does not meet the current requirements. Building components which were produced during a time with different regulations can potentially not be used in a project nowadays due to deviating measurements, even if they would be safe to use. This challenge has been named by both architects as well as circular material hub representatives.

5.2.1.4. Challenge IV: Costs

Another challenge is the financial factor that comes with reusing building components, which in some cases even prevents their use.

> *"Everybody who thinks linear doesn't go over to the circular economy, only if it costs less." (The all-rounder hub 2)*

One representative from a circular material hub stated that secondary raw materials are more expensive than virgin materials. The costs for virgin raw materials are too low compared to the costs of secondary raw materials, which means that it would not be an advantage for clients to use the latter. An increased effort and workload in the logistics process also results in additional costs. Workers who need to be trained for deconstruction, the transport to the storage location and afterwards to the new construction site, preparation for further use and storage costs lead to increasing additional costs.

According to different interviewees, low costs are, however, the biggest incentive for decisions made by clients. That means that clients typically go for the cheapest option, and if secondary raw materials are more expensive than virgin raw materials, material and element reuse is not an attractive alternative. One architect reported a case in which they suggested reusing the existing toilet bowl and only replacing the tiles. However, the client ultimately decided to have new toilets installed as the contractor calculated that this would be cheaper than building around the existing toilets. This shows that clients have the decision-making power to opt for secondary building components, but that a decision for reusing is more likely when it also provides (financial) advantages for them.

5.2.1.5. Challenge V: Guarantee

Depending on the interviewee different answers were given to the questions who bears the risk of reusing building components and whether the issue of providing a guarantee is seen as a problem. The answer also differed from architectural firm to architectural firm and circular material hub to circular material hub. The shared opinion among architects, circular material hub providers and experts is that common sense and knowledge can be used to decide whether a building component can be reused or not. A common opinion of experts and circular material hub representatives is that the original producer has the best possibilities for providing a guarantee for secondary building components.

In terms of the entire building, the contractor is giving a guarantee to the client. For the load-bearing structure, structural engineers are the ones giving the guarantee that the materials and elements used can carry the weight. Next to this, architects were found to have certain ways of finding out whether a material or element can be used or not. One option is to commission a research institute with the certification of the material or element that is intended to be used. An additional possibility is to certify that the material or element that is used complies with the current regulations without obtaining a proper certification.

Circular material hubs sometimes, but not always provide a guarantee for the building components they sell. They do not provide such guarantees as on the one hand, they were not produced, built in, or maintained by them, and on the other hand, because of missing tools or financial reasons.

5.2.2. Opportunities

Four opportunities for the future of both building component reuse and the further development of the system of circular material hubs have been found. These opportunities are connected to decisions the government can make to stipulate reuse, the collaboration of all parties involved in a project from an early moment onwards, the provision of information regarding building components on an online platform and the further development of the Insert marketplace.

5.2.2.1. Opportunity I: Governmental decisions

It was found that the common opinion amongst the interviewees is that the government has the power to change the current system by introducing the right laws and regulations.

> *"So first of all, the legislator must become much more active, i.e. the market does what is possible and the state must organize what is necessary" (The circular economy expert)*

Architects, representatives from circular material hubs and experts agree that change not only can but must be initiated by the government by stipulating material and element reuse.

5.2.2.2. Opportunity II: Early collaborations

It was found to be beneficial if all parties get involved in a project as early as possible as good collaboration can foster the reuse of building components.

> *"Trust and working together are two main things to be successful in in the circular economy…" (Insert)*

One architect reported that more building components could be reused in one of the company's projects because all parties involved worked closely together.

> *"There was a short line between the different actors which allowed for this high amount of reused materials." (The visionary architect)*

One representative of a circular material hub stated that bringing together client, demolition or deconstruction company, architect, contractor, and construction company at the beginning of a project allows to develop a common plan that takes the abilities of all parties involved into account. To give an example: Clients can demand that building components are dismantled by deconstruction companies in such a way that they can be reused. Architects then already know which building components are available before they start the design process and contractors can communicate at the beginning of the project whether they are able to build with secondary building components or not.

5.2.2.3. Opportunity III: Information and knowledge

It has been found that an online inventory of the building components that are currently available in a circular material hub is considered helpful and even crucial. Checking online what is available before going to the physical location ensures that the desired materials are available. Additionally, it also saves time as there is no need to visit a circular material hub that does not offer the required materials. This aspect of saving time also corresponds with the information that scouting takes a lot of time. To facilitate a scouting practice, as much information about the available building components as possible should be provided by the supplier. At a minimum, the following questions should be answered:

• What is the state of the building component?

• What are the dimensions of the building component?

• Does the building component meet the current regulations (e.g. building physics or safety requirements)?

It was found that seeing different building component and variations of one building component at one place can be inspiring for architects and potentially lead to a change in the choice of building component towards a more circular option. Additionally, it was found that both architects as well as circular material hub representatives think that knowing from which building components were harvested can be beneficial. While a representative from a circular material hub stated that it can contribute to the sales strategy, an architect described it as adding an interesting aspect to a design.

5.2.2.4. Opportunity IV: A shared and targeted online marketplace OR:

An online marketplace that is used by multiple providers of secondary building components and therefore offers a greater variety of components showed to be preferred over an online marketplace operated by a single provider. In this context, Insert has proven to be particularly popular, as this B2B platform is specifically designed to meet the needs of the construction industry and offers secondary building components from a range of suppliers. To improve their service and provide the users with what they really want, Insert is asking for feedback from their users. This is especially important as different target and user groups, e.g. architects or building companies, have different needs. Insights into what is working on the platform and what is not are crucial for the development. Therefore, the ones who perform or influence the scouting practice can contribute to an improvement of the system by communicating what they are missing or needing to establish building component reuse in their organization and projects.

5.2.3. Possible future development

According to circular material hub providers and experts who participated in this study, there are two main shifts expected in the system of secondary building component provision. The first one is that circular material hubs and marketplaces for secondary building components will not exist in the form they do now. The second one is that data about buildings, building components and their expected deconstruction will become more and more important and significantly influence decision-making.

According to one representative, circular material hubs will not exist in the future the way they currently do. One representative of a circular material hub even thinks that they "will become a moving company and bring the products back to the producer" (The B2B hub). This can be associated with the expected greater importance of producers. It has also been noted that the current system serves little purpose as it is not very efficient. As this study has shown, circular material hubs are currently mainly operated by construction companies that deconstruct the buildings and then process the harvested building components. This requires certain tools, such as wood saws, as well as specially trained employees. Multiple interviewees agree that the original producers, in comparison, have most knowledge about a certain building component. It is therefore assumed that the producers can process the building component more efficiently. Another reasoning for the expected increase in the importance of original producers is the following: by producing new building components from secondary building components, the raw material consumption decreases, which in turn is beneficial for lowering the environmental impact of the construction industry. Additionally, it is expected that producers are able to provide a guarantee on the building component, facilitating the reuse of secondary building components due to the removal of guarantee issues.

Corresponding with this, the representative of Insert believes that in a decade from now, there will not be a marketplace anymore.

> *"The system will then have changed so much that it will regulate itself without a marketplace." (Insert)*

The reason given for this is that there are expected to be specialized companies that trade building components for a circular economy. Examples include producing doors from old doors and windows from old windows. In combination with the forecast that "the biobased markets will collapse (…) in a positive way (…) [,] they will explode …", the representative of Insert expects a shift in the entire system of providing secondary building components.

> *"So that might be a nice idea for the transition during the transformation, but the hubs don't belong in the new system." (The circular economy expert, translated)*

According to an architect and circularity expert, every building becomes a material hub when data on all the materials and elements present in the building is collected. This means that as soon as it becomes known that a building will be dismantled at a certain point in time and that the materials and elements become available, architects can design with them. This eliminates the circular material hub's task of physically collecting and providing the materials, as these are already documented and organized online so that interested parties can find them more easily, along with all the important information, an bring them directly to the new construction site. Data is seen as the basis for decision making and will allow actors to have an overview of all materials and elements that are already and will become available.

5.3. Conclusion

Conclusion practices

To conclude this chapter, it must be said that the practices found are mainly practices-as-entity, although a closer look was also taken at practices-as-performance, depending on the practice. This interplay of close (practices-as-performance) and distant (practices-as-entity) analysis made it possible to take a closer look where it has become apparent that a more detailed analysis would be informative. However, for the understanding of the system, an understanding of the practices-as-entities was considered more important. Those practices whose connection can be further defined, beyond the obvious connection through their constituent roles in the system, have been grouped into bundles. This allowed to detect the connections between the acquisition practice bundle the processing practice bundle, the sales practice bundle, a circular design practice, and the building component scouting practice. The building component scouting practice, for example, influences the acquisition practice bundle, as it is already necessary to consider at this stage which secondary building components are regularly scouted. This shows the potential for positive interventions due to the connection and influence of the constituent practices.

Conclusion challenges, opportunities and potential future developments

A variety of challenges and opportunities were identified. Information about both contributes to informing future changes. For example, when circular material hub providers are aware of how important detailed information on available secondary building components is for those performing a circular design practice or scouting practice, they are potentially more likely to put more effort into providing this information. The same applies to the early cooperation required by all interviewees for construction projects. What is currently a challenge can also be an opportunity for positive future changes. A lack of cooperation in a project is currently a challenge that needs to be overcome. At the same time, early collaboration between all parties and the early involvement of circular material hub providers is an opportunity to increase the reuse of building components.

Some representatives from circular material hubs and experts believe that circular material hubs will not exist in the future in the way they do now. This does not mean that circular material hubs will not exist at all, but it implies that they potentially must undergo a transformation and find a new business case and area of work. Additionally, some participants of this study believe that circular material hubs and online marketplaces will not exist at all. The focus of this study was not to examine whether circular material hubs will still exist in the future. Nevertheless, the results can draw attention to the fact that representatives of circular material hubs and marketplaces themselves see the possibility that the companies they operate may no longer be needed in a circular construction industry. This indication and the potential that practitioners active in the construction industry see for the future development of circular material hubs can form a basis for future research, decision making and conversations among practitioners. This is discussed further in the Conclusion chapter of this research (chapter 7).

Synthesis of practices, challenges and opportunities

As explained above, the system of circular material hubs is constituted by a number of practices which also form practice-bundles together with other constituent practices. Figure 5.4 visualizes this system and indicates where challenges and opportunities provide the basis for potential intervention. However, interventions are not solely based on challenges and opportunities, but derive mainly from the connection between practices.

Even before the acquisition practice starts, a potential challenge, but also opportunity can be identified. While missing collaborations potentially minder the reuse potential in projects, early collaborations at the same time facilitate a successful reuse story. This can be explained by the finding that it is beneficial if all parties involved in a project patriciate in discussions from the beginning onwards to clarify what they can or cannot do. They can share right at the beginning their experiences with building component reuse, which in turn decreases the risk of unexpected changed later in the project. In this stage of the project, when building components are acquired, scouting practices performed by material scouts, architects or other actors in the construction industry influence which building components are accepted. Between the processing and scouting practice, another challenge can be identified when circular material hubs do not provide any guarantees. However, as circular material hubs often do not provide any guarantees, those affected by this challenge already work with other partners to obtain guarantees. Most of the influences, however, can be identified between sales, design, and scouting practice. Those influences are both challenges and opportunities. On the one hand, challenges such as potentially higher costs, and uncertainty in terms of assortment impact the design and building component scouting practice. However, there are also two opportunities here. Both practices can be influenced by shared online marketplaces and sufficient information provided by circular material hubs and thus by the sales practice performed by circular material hub employees. A circular design practice can further be challenged by current regulations, which potentially influence that secondary building components that are available cannot be used. However, at this stage, a change in regulations and more flexibility from a regulatory perspective also be an opportunity for increased building component reuse. Lastly, potentially higher costs due to longer scouting practices, or due to building component costs, potentially influence the circular design practice. If building components are not scouted because of financial reasons, they cannot be included in a design.

The visualization shows that there are challenges and opportunities which originate outside of the system of circular material hubs. However, due to the impact the have on the system, they are considered crucial for the development of the system. Nevertheless, most opportunities and challenges can be identified through the connection between practices that constitute the system. This provides insight into potential intervention possibilities and shows the close, multidirectional connection between practices and practice-bundles within the system of circular material hubs.

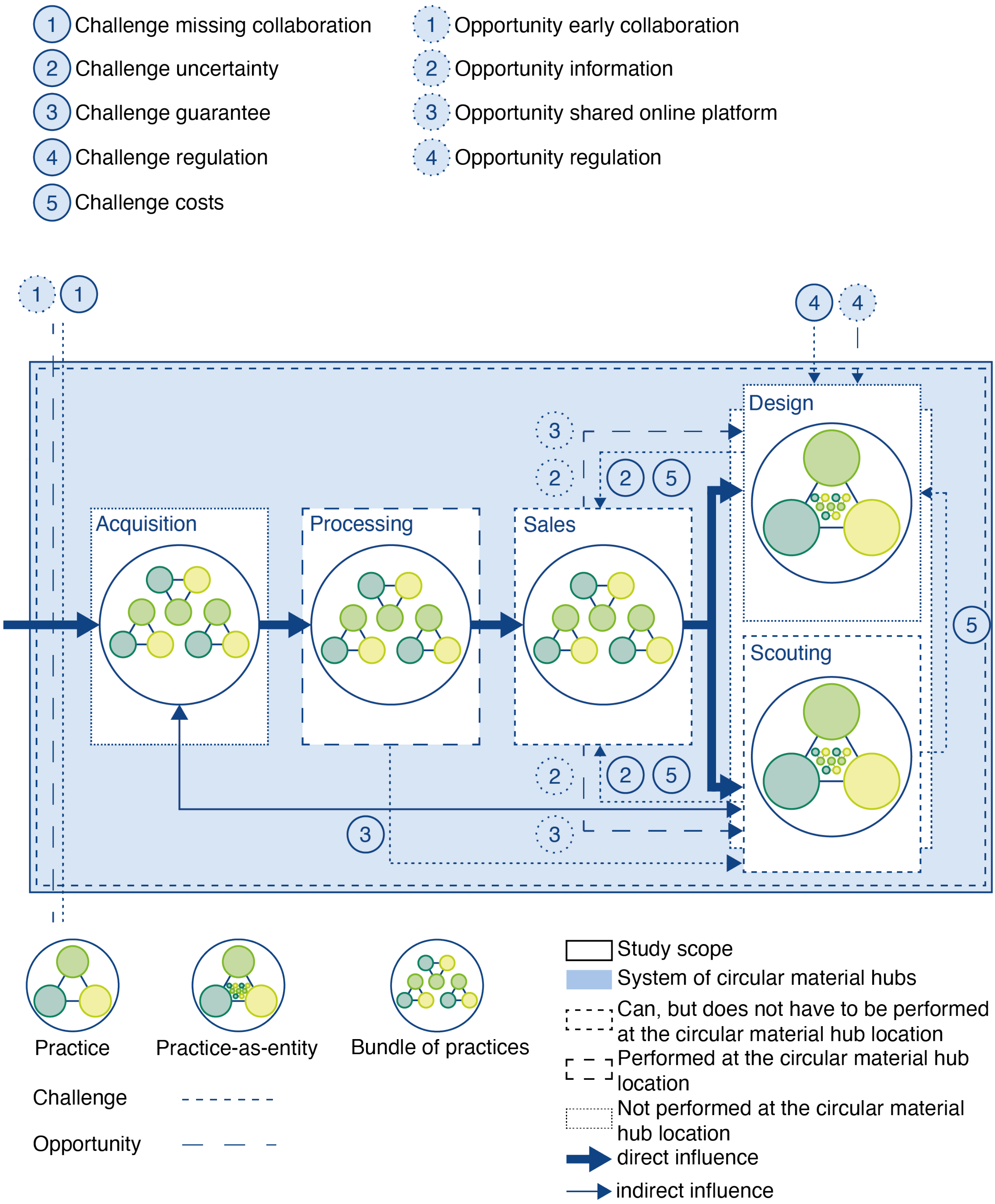

Figure 5.4 Visualization of the system of circular material hubs. Visualized by the author.

6. DISCUSSION

This chapter discusses the main findings of the present research which aimed at discovering what the system of circular material hubs in the Netherlands consists of. In the first part of the chapter, a synthesis of the results presented in chapter 5 is provided. While the results in chapter 5 are presented in a linear approach, one after the other, the synthesis provides a more comprehensive look at the findings. Afterwards, the results will be reflected upon and put in relation to findings from literature review. In this part of the chapter, the contribution of the research is examined as well. This exploratory qualitative research on the system of circular material hubs viewed through the lens of SPT provides useful information for both academia as well as practitioners who are working in the field as it attempts to provide a first overview of the system of circular material hubs and the connections within the system. For certain aspects, such as the question of barriers, opportunities, and possible future developments, the SPT lens was not applied as SPT cannot provide an answer to those questions. This is therefore not research conducted entirely with SPT.

6.1. Synthesis of the findings

Understanding of the system of circular material hubs

Through the identification of practice performed within the system of circular material hubs in the Netherlands, a comprehensive view on the extent of the system was possible, due to the understanding of a system as a connection of practices. The research has shown that the system of circular material hubs is not limited to the location of the circular material hub or the company it is run by. Looking at the system through the lens of SPT allowed us to understand the complexity of the system by analyzing the interconnectedness between different practices which constitute the system. Allocating those practices-as-entities in practice bundles allowed insights into the complex structure. In addition, the interplay of zooming out (practice-as-entities) and zooming in (practice-as-performance) allowed a closer look at those practices that have been shown to have significant impacts on the rest of the system through their different performances.

The practices that are part of the researched system are not determined by whether they are performed directly in the circular material hub or by one of its employees. The system can therefore be defined by the multitude of practices that are interconnected with or influenced by practices performed in circular material hubs. Understanding that the system is not limited to the location and does not necessarily have to have a direct company affiliation is important to understand the potentials that it creates. This also suggests that circular material hubs and the system they are embedded in have the potential to facilitate a necessary transition towards more circularity by connecting practitioners through shared links and bundles of practices.

Identified practices

Different practices-as-entity and practices-as-performance identified within this system are interconnected and influence each other or are part of the same practice bundle. There are certain practices and bundles of practices which are performed at the circular material hub (e.g. practice bundle II: processing practice). There are practices which are performed by an employee of a circular material hub, but not necessarily at the location of the circular material hub (e.g. practice bundle I: acquisition practice, which can be performed in a building that is deconstructed). There are practices which are potentially performed at the circular material hub location, but not by an employee of a circular material hub (e.g. a material harvesting practice performed in a physical shop). Finally, there are also those practices that are not typically performed at the circular material hub location (e.g. a circular design practice performed in an architectural office) or do not have to be performed there (e.g. a material scouting practice performed online).

This means that practices that constitute the system of circular material hubs do not necessarily have to be performed directly in circular material hubs.

Connection between different practices and practice bundles

Circular material hubs are often part of larger companies which also run a demolition or deconstruction department. This results in a potential close and direct connection between circular material hubs and deconstruction projects. Employees of circular material hubs do not only perform practices directly at the circular material hub location, but also at other locations, e.g. when creating an inventory list at a deconstruction site as part of the acquisition practice bundle. Which building components are acquired during the acquisition practice influences which building components are available to be scouted by other actors in the construction industry during the material scouting practice. The material scouting practice, in turn, also influences the acquisition practices, as the circular material hubs takes wishes and preferences of their clients into account. All practices which are (potentially) performed as part of the acquisition practice bundle are a first indication that the system of circular material hubs is not limited to the location of the circular material hub itself. After the building components have been processed in the circular material hub, they need to be sold. The question arises who potential clients could be and how they can be reached. These questions are targeted by practices performed as part of the sales practice bundle. The preferred communication channel is influenced by the target group, which in turn is influenced by the building component that needs to be sold. Building components are only rarely sold directly at the physical location of the circular material hub but are more likely to be sold via other communication channels. One of the most important communication channels is the online marketplace operated by the Insert Foundation. It is used by most of the circular material hubs and architects under investigation as it provides an intermediary platform between the ones performing a sales practice and the ones performing a scouting practice. The sales practice bundle is therefore characterized by two practices:

(1) The practice of choosing a client: Depending on the building component, different customer groups are targeted. Circular material hubs can actively decide which target group to focus on, depending on their preferred way to sell building components. Clients can range from warehouses to private individuals.

(2) Choosing a communication channel: Different customer groups, which are, as mentioned before, influenced by the secondary building component at hand, can be targeted through different communication channels. Warehouses, for example, are targeted by direct communication through phone calls, while material scouts from the construction industry can be targeted through Insert.

The communication channel chosen by the circular material hub employees as element of the sales practice, in turn, influences the material scouting practice performed by an actor in the construction industry. This also influences the circular design practice performed by architects. Where secondary building components can be found and how much data is available about them are decisive factors for the performance of a circular design and material scouting practice. However, whether secondary building components are included in a project does not depend solely on the carriers of a circular design practice, but also on clients, contractors, and the entire teams around them. This means that architects can take secondary building components into account in their designs, but the actual implementation is influenced by other factors and players. Crucial are also how much experience the respective parties, and especially the contractors have and how the use of secondary building components affects the costs of the project, as it has been shown that money is often still a decisive factor when it comes to the reuse of building components.

6.2. Comparison and contribution to literature

In academic literature, few studies can be found on circular material hubs. Research that has been done on circular material hubs often focuses on spatial parameters and locational preferences (e.g. Tsui et al.,2023; Yang et al., 2023; Duarte et al., 2023). However, insights into the entire context or system they are embedded in are limited. This study takes a different approach and looks at the entire system of circular material hubs through an interplay of close and distant perspectives that allow a new understanding of the topic under investigation. It shows where it is important to zoom in, where it is necessary to pay more attention to and what differences there are in practices between and within circular material hubs. By exploring challenges, opportunities, and potential future developments of the system of circular material hubs, the view of those active in the sector and their opinions, based on what they experience in their daily work, indicates where interventions might be needed and where they potentially benefit the system.

In this section of the Discussion chapter, the results of the present study, as presented in chapter 5, are put in relation to previous studies and academic literature. Along with a comparison to existing literature, this section also contains the contributions of this research to the current state of literature. The chapter is organized according to three themes. First, a look is taken at the CE (6.2.1), followed by the circular construction industry (6.2.2), and finally the application of SPT (6.2.3).

6.2.3.1. The circular economy

Economic opportunities

During the interviews conducted for this research, it emerged that some interviewees believe that circular material hubs will no longer exist in the future as we know them today. From this finding, the question arises how circular material hubs can potentially develop and which role they can play in a further advanced transition towards a CE. Scholars such as van Buren et al. (2016) and Ghisellini et al. (2018, as cited in Osobajo et al., 2022) state that the transition towards a CE economy can create economic advantages. In line with this, the Dutch government also claims that a CE creates new economic opportunities, e.g. new markets and income streams (Ministry of Infrastructure and Water Management, 2021). This suggests that circular material hubs can potentially take on other responsibilities in a changing economy and construction industry. However, the extent to which circular material hubs change or need to change is not within the scope of this research and therefore not discussed here.

One argument for a decreasing importance of circular material hubs, as found in this study, is an expected increasing importance of the original producers of building components. Hart et a. (2019), for example, state that producers who work with alternative ownership models where they sell a performance contracts instead of a building components also need to consider future dismantling, disassembly and upgrading. This implies that producers are not only responsible for a product at the beginning of its life-cycle or use time, but also at the end. This new responsibility attributed to producers is also in line with claims that can be found in academic literature. Maitre-Ekern (2021), for example, states that EU policy regulation must make sure that producers (1) are responsible for their products at their end-of-life and (2) are only allowed to bring durable, reparable, and more and more sustainable products on the market. If we take a closer look at (1), this raises the question of how the building components are returned to the producers at the end of their life. Even though, compared to material hubs, circular material hubs are more concerned with the provision of secondary building components than with pure logistics, they are, depending on the circular material hub, still experienced in logistics (Tsui et al., 2022). Circular material hubs could, for example, take on the task based on their experience in logistics and the handling of secondary building components and established connections with other actors in the construction industry. This suggestion was made by a representative of a circular material hub who could imagine the company becoming a pure moving company that takes dismantled building components back to the producers.

It can be questioned, however, whether circular material hubs could possibly only be of diminishing importance in the context of a (circular) construction industry, but not when it comes to supporting building component reuse outside this context. This means that the circular construction industry might benefit more from a system of secondary building component provision that is closer to the current linear one. Circular material hubs can continue to be important or potentially even gain in importance for smaller projects, for example for private use.

6.2.1. The circular construction industry

Circular material hubs

According to literature review, the main activities in circular material hubs are “inspection, sorting, upcycling, preparation for reuse/recycle, reuse or storage" (Karamanou, 2019, p. 10). This mainly corresponds with the practices that were defined as part of the processing practice bundle in this research (cleaning, repurposing, separating, recycling). However, this study also identified other practices and activities which are carried out in circular material hubs, by employees of circular material hubs, or within the system of circular material hubs. This can mainly be attributed to the fact that the present study focused not only on those practices that are carried out directly in the circular material hub, but also on those that are not necessarily carried out at the location. This perspective can be explained by the understanding of practices as constituting parts of systems, which is fundamental to this study. As a result, the system of circular material hubs is not limited to the location and the practices that take place there but is constituted by a multitude of connected practices (see Watson, 2012 or Schatzki, 2016). The study therefore proposes to expand the abovementioned list of activities that take place in a circular material hub with practices and bundles of practices that constitute the system of circular material hubs to gain a more comprehensive understanding. The proposed additions are: (1) acquisition practice bundle (inventory practice, value calculation practice, client search practice, price calculation practice, decision making practice), (2) sales practice bundle (activity of choosing a client, online sales practice, offline sales practice), (3) circular design practice, and (4) building component scouting practice. While (1) and (2) are typically performed by employees of circular material hubs, (3) and (4) are generally not performed by employees of circular material hubs, but by architects or designers, material scouts or other actors in the construction industry such as contractors or clients. Additionally, it can be said that (1), (2), and (4) can, but do not have to be performed at the location of the circular material hub, while (3) is typically never performed at the circular material hub itself. The understanding of the system of circular material hubs as a connection of practices which do not necessarily have to be performed at the circular material hub itself allows to identify a wider range of practices which are crucial for the development of circular material hubs in the context of the transition towards a circular construction industry and potential points or practices for intervention.

Online marketplaces

Circular material hubs such as the B2B hub investigated in this study actively choose to establish closer cooperation with warehouses or producers to avoid private individuals. To target clients from the construction industry, the Insert marketplace provides an effective solution as it is a B2B platform. If this result is put in relation to the information from the literature, it is possible to argued why. Literature review has shown that designers typically acquire information about the primary building components they intent to use through catalogues, brochures, websites, or experts (Kozminska, 2019). The importance of available information is also supported by Gorgolewski (2000, p.2) who states that „availability, supply chain, ownership, detailing, codes and standards, acceptability, and availability of information" are crucial for decision making. This suggests that the designers generally know where to find the information they are looking for when it comes to primary building components, e.g. on websites or in brochures (Kozminska, 2019). But when it comes to secondary building components, it is not as easy (Kozminska, 2019). The present study can support this finding from Kozminska (2019). On the one hand, it is unclear where exactly to search for the building components and which ones are available where they can be found. Additionally, and here it is important to mention that this was one of the main requirements from the interviewees, enough information on the building components must be communicated by the providers. The importance of accurate information about the available building components is also supported by a study from Deweert and Mertens (2020). Deweert and Mertens (2020, p. 55) state that the more information is provided, the easier it is for clients to "envisage an effective reuse opportunity". In line with Deweert and Mertens (2020), the present study also found that providing more information equals more work, as all the characteristics such as dimensions etc. must be compiled, photos taken and then uploaded. However, knowing that this information is crucial for those performing a material scouting practice, it can be argued that the additional effort potentially leads to a higher chance of attracting new customers, selling more building components, and therefore increasing building component reuse.

When looking at material offers on different online platforms, it becomes clear that on some platforms there is considerably less information available than on others. While on Marktplaats, for example, only the information that the provider wants to communicate needs to be made available, the Insert marketplace requires a whole range of information that is specifically designed to provide customers from the construction industry with as much information as possible. In line with Deweert and Mertens (2020), this study found that next to the basic information such as dimensions, material and amount, connection, scratch resistance, translucency, RAW color, number of colored layers and maintenance are also interesting for those performing a scouting or circular design practice. Deweert and Mertens (2020), however, even go one step further and include the environmental impact and disassembly recommendations in their list. This additional information could, for example, be also interesting for future developments of the Insert platform or of any other online marketplace where secondary building components are offered.

Early collaboration

Shan (2023) states that material reuse and greater stakeholder awareness can be promoted by circular material hubs. This study has found that projects may start with high ambitions, but in the end, it is often not possible to fully implement the ambitious plans. The realization can be hindered by a lack of or late collaboration, building component availability, knowledge gaps, financial aspects and problems obtaining guarantees. Hart et al. (2019) defined categories of barriers and enablers of a CE based on the example of a circular construction industry. According to this categorization, enablers and barriers are of cultural, regulatory, financial, and sectorial nature. This duality can be explained by the fact that a lack of enablers results in a barrier. This ambiguity can also be seen to some extent, if not exactly as in Hart el at. (2019), in the present study. While a lack of collaboration is currently a challenge, close collaboration between all project partners at the beginning of a project is equally an opportunity to enable more circularity. Knowing which barriers to building component reuse there are, in turn, means that there is great potential for changing the situation as it can be seen as a starting point for change. Hence, knowing why certain actors in the construction industry do not facilitate building component reuse yet is a first step to target them and get them on board to scout secondary building components from circular material hubs. Hart et al. (2019, p. 624) state:

> *"A consensus appears to be emerging that while many technical and regulatory challenges remain, the real obstacles to a more circular built environment are the cultural and financial / market issues…"*

This statement partly corresponds with the findings from the present study. All interviewees working in the construction industry stressed the importance of early collaboration. Involving circular material hubs from the start is particularly important, as they often have close links to deconstruction companies, logistics knowledge and connections to other actors in the construction industry. Additionally, it has been found that the willingness to, and experience with reuse is crucial. Contractors have a noteworthy influence on how circular a construction project is. This influence of contractors also aligns with findings from Ogunmakinde (2019). Little experience with building component reuse and the focus on financial matters can lead to decisions against circular solutions.

Legal restrictions

Literature on a circular construction industry and building component provision has shown that there is a gap between availability and demand, as the amount of building components needed for new construction projects is significantly greater than the supply of secondary building components (Shan, 2023). Literature review has shown that, depending on the building component, reuse or recycling is the preferred option. According to Ogunmakinde et al. (2022), for example, for windows and doors, reuse is preferred. Finding from this research also show that doors and windows are amongst the most popular products for some of the circular material hubs under investigation. However, even though windows and doors are most of the time available according to representatives from circular material hubs, it does not mean that those who are scouting building components find what they need solely because of their availability. Leaving out the design parameter and the question, whether the building component fulfills all aesthetic requirements, legal requirements potentially hinder their reuse, as the measures sometimes do not match the current regulations. This suggests that supply and demand may exist, but if the current regulations sometimes hinder the necessary flexibility. Hence, the positive aspirations cannot be put into practice.

6.2.1.1. Circular design

The results of this study suggest that the performance of a circular design practice itself, while being very important and in need of further research, does not appear to be the biggest barrier to increased building component reuse, at least not amongst designers who are willing to change their design practice. Literature review has shown that designers do not learn how to perform a circular design practice during their education or in practice (Kozminska, 2019). As this study has found that a circular design practice requires certain skills which are different from the ones that are needed for the traditional linear design practice, it becomes evident that these skills must be taught in education.

Two of the most important skills are creativity and flexibility. Creativity, on the one hand, allows to rethink the design process. It refers for example to the questions: What can be achieved and done with already available building components. How can a design be created that does not start from zero, but that starts form the secondary building components that are available? How can secondary building components at hand be reused in a different setting or with a different purpose? Flexibility, on the other hand, allows to adapt to the uncertainty that comes with designing with secondary building components. It allows to make the changes that are necessary to continue a project even when unforeseeable interruptions occur. If all phases and especially the final design phases are viewed dynamically, flexibility is inherently considered throughout the entire project. Flexibility can be, for example, to create a basic spatial concept with open spaces and openings without defining the exact opening sizes or materials from the outset. A need for those skills aligns with a call from literature for a more conceptual level of designing to cope with the unpredictable supply of building components (Kooter et al., 2021).

6.2.2. Social practice theory

The novelty of this study is to relate practices performed within the construction industry to the system of circular material hubs, instead of viewing circular material hubs as a phenomenon limited to its location. The study aimed at investigating the system of circular material hubs in the Netherlands by detecting practices which are performed within this system through a partial application of SPT. This means that, compared to more traditional studies performed applying SPT, there was not one predefined practice, e.g. using a laundry (e.g. Mylan and Southerton (2018)), under investigation. Instead, different practices performed within the same system were identified and studied. Additionally, even though applying SPT to the construction industry or an urban context is not completely new (e.g. Smagacz-Poziemska et al., 2020; Gherardi et al., 1998; Löwstedt, 2015), it is also not a fully established field of application yet. Therefore, by studying a construction related topic through the lens of SPT, this study contributed to a greater establishment of the application of SPT in construction industry research.

Applying SPT allowed to investigate a topic that can be considered part of a more technical field or nature, not merely from a technical nor merely from a sociological perspective. By focusing on practices and the connections between them, and especially through the identification of their elements (materials, meanings, and competences), it was possible to take a socio-technical perspective on the phenomenon. This means that it was possible to identify the motivation behind the performance of a practice (meaning), while also identifying the skills and competences (competences) and the mostly but not exclusively physical things that are needed for the performance (materials). By focusing neither on the merely organizational characteristics of circular material hubs (e.g. spatial parameters and factors influencing site selection, e.g. Tsui et al.,2023; Yang et al., 2023; Duarte et al., 2023) nor on their typological differences (e.g. Nieuwhoff, 2022), but rather on the entire system they are embedded in, allowed to extend the view on circular material hubs beyond their location.

While SPT is sometimes criticized for only being applicable to local or small phenomena, this opinion is not held by some scholars (e.g. Schatzki, 2016; Watson, 2012) and the present study also contributes to demonstrating that larger phenomena can indeed be investigated using SPT by viewing practices as part of larger systems. Several authors explore practices that are small or local phenomena, e.g. cycling (Spotswood et al., 2015), cooking and eating (House, 2019; Twine, 2018), using a laundry (Mylan and Southerton (2018), ballet dancing (Müller, 2017), or Nordic Walking (Shove & Pantzar, 2005). That SPT is well applicable those small or local phenomena, can be argued by certain observable features such as “regularity, habitual nature, repetitiveness, (and) recursivity“ (Bourdieu, 1990; Giddens, 1984; T. R. Schatzki, 2002; Reckwitz, 2002 as cited in Smagacz-Poziemska et al., 2020, p. 66). However, it can also be argued that viewing practices as constituent parts of systems allows to explore larger social phenomena (e.g. Watson, 2012; Schatzki, 2016).

Therefore, instead of viewing circular material hubs purely as a location where secondary building components are processed, stored, and prepared for reuse, they are considered part of a bigger system. Similarly, although in a different field of research, Watson (2012) has looked at how SPT can support a socio-technical transition through a systems of practice approach. Watson (2012, p. 495) argues that the identification of “the complex constituents within practices, (…) and the ways in which they bundle one with another, it is possible to identify intervention points which have the potential to initiate or add momentum to positive feedback processes, not only at the level of everyday travel practices, but affecting practices throughout the socio-technical system.” This study supports the approach of Watson (2012) and argues that a comprehensive understanding and consideration of the influences between practices performed at circular material hubs and other practices which are connected to building component reuse (e.g. circular design practice or scouting practice), as well as the practice bundles that are formed within the system, is important to find potential points for interventions to facilitate a positive development and contribution to a transition towards more circularity in the construction industry.

To identify the practices which constitute the system of circular material hubs, the focus of this study was mostly on practices-es-entities and the practice bundles they are part of. Spurling et al. (2013) argue that focusing on practices-as-entities helps to identify points for intervention and avoid that the focus in social change is placed too much on practices-as-performance and therefore mainly individual behavior. This means that, to identify potential interventions, it is important not to focus too much on the individual performances of a practice, but rather to look at the practices-as-entities that are a result of the various performances. However, it was still considered important to zoom in and out where needed to identify the practices-as-entities, practices-as-performance, and practice bundles that constitute the system (Higginson et al., 2015). For the present research, it was important to understand the overall practice-as-entity to identify where positive interventions can be made, while also not ignoring that certain practices, such as the sales practice, need a more zoomed in view to understand the differences in their performance and the interventions that might depend on the performance itself. Coming back to the example of the sales practice, this study argues that understanding the difference between the performances of an online and offline sales practice is needed to identify multiple layers of intervention which are specific to the respective performance. Nevertheless, while the differences the performances of a sales practice are crucial to identify targeted interventions, the exploration of the system of circular material hubs itself needs benefits from the understanding of a sales practice-as-entity due to its connection to other practices-as-entities within the system.

7. CONCLUSION

The Conclusion chapter takes a final look at the entire research. While the discussion chapter reflects on the results of the research, the conclusion chapter contains a reflection of the entire research process. First, the four sub-research questions are addressed, followed by a reflection of the limitations of this study, recommendations for circular material hubs providers and other practitioners in the construction industry, policy recommendations and finally suggestions for future research.

The construction industry consumes large amounts of resources while also creating a significant amount of construction and demolition waste (C&D waste), carbon emissions and greenhouse gases emissions. This calls for new strategies to minimize the environmental impact of the construction industry. Instead of discarding building components after their first life cycle, it is crucial to reuse them. Circular material hubs are a potential solution. In academic literature, little can be found on the topic of circular material hubs and especially on the system of circular material hubs. Even though places where building components get processed and resold already exist for longer, circular material hubs as we know them today, including their business case and field of activity only emerge in recent years. This exploratory study aimed at investigating the system of circular material hubs in the Netherlands to understand the extent to which it facilitates the transition towards a circular construction industry. Therefore, the main research question was as follows:

What does the system of Circular Material Hubs in the Netherlands currently consist of, and which practices performed within this system facilitate material reuse in the Dutch construction industry?

The research question was investigated through four sub-questions, which were formulated to cover all important areas of the research. The sub-questions for this research are answered in the next section of this chapter.

An exploratory qualitative research approach was chosen to obtain fundamental information about the system and to lay the foundation for future research. The theoretical framework developed around Social Practice Theory (SPT) allowed to look at a more technical topic, namely the reuse of building components, through a socially oriented lens. Semi-structured interviews with thirteen representatives of the construction industry allowed to identify different practices, bundles of practices and performances of practices (practice-as-entity and practice-as-performance) which are crucial to understand and define of the system of circular material hubs.

7.1. Research questions

In the following, each sub-question will be answered separately:

SRQ1: Which practices are performed in circular material hubs to reintroduce secondary building components into the material cycle and make them available for reuse?

Circular material hubs perform a range of practices to reintroduce secondary building components into the material cycle. Not all of them, however, have to be performed directly at the circular material hub. Three different practice bundles, which are important for the reintroduction of building components into the material cycle, can be distinguished. These practice bundles are:

- Practice bundle I: acquisition practice
- Practice bundle II: processing practice
- Practice bundle III: sales practice.

Each of the three bundles is composed of multiple different practices. In the following, each bundle is explained.

Practice bundle I: acquisition practice

The practices which are part of the acquisition practice bundle can, but do not have to be performed in a circular material hub. This can be explained by the fact that the practices are performed partly on the deconstruction site and partly in the circular material hub itself. To elaborate: When secondary building components are harvested from deconstruction projects, a circular advisor, i.e. a circular material hub employee, visits the site and creates an inventory list of all building components that become available. This means that the circular advisor performs an inventory practice, which forms the basis for other practices that are part of the acquisition practice bundle. This inventory list can then be used to calculate the value of the released secondary building components. This means that the value calculation practice is performed to calculate how much money the circular material hub can earn by selling the available building components. The decisive factor here is that the person performing the practice knows which building components are popular amongst clients and how much can be asked for them. Once it becomes clear which secondary building components become available, and for how much they can be sold, the circular material hub employees already start looking for potential customers.

Customers are mainly trading companies or fixed partners. If the building components can already be sold at this stage, this means less work for the circular material hub, as the building components do not have to be transported to the hub. At this stage, the price for the deconstruction of a building is calculated. Customers are mainly trading companies or fixed partners. If the building components can already be sold at this stage, the circular material hub has less work to do, as the building components do not have to be transported to the location of the hub. As circular material hubs are often part of a company that also has a demolition or deconstruction department, the amount that can be generated from the sale of the building components determines how much the company charges for the dismantling of a building. In the end, it has to be decided whether the circular material hub accepts or declines the secondary building components that become available. For this, it is important to know whether there will be a market for the respective building component or not. This means that only those building components that are expected to be sold quickly are accepted, as it should be avoided that the components remain in the circular material hub for too long.

Practice bundle II: processing practice

The accepted building components that have not been sold beforehand are transported to the circular material hub. All practices that are part of the processing practice bundle are performed in the circular material hub. The practices included in the processing practice bundle can but do not have to be performed. Which practice is carried out depends on the building component and how much and what processing it requires before it can be reintroduced into the material cycle. This means that some building components only need to be cleaned, which requires a suitable cleaning construction, while others are processed into a fundamentally different building component. This is the case, for example, when a door is converted into a tabletop.

Practice bundle III: sales practice

When the building component is ready to be reintroduced in the material cycle, a so-called sales practice needs to be performed. The meaning behind this practice is, as the name suggests, to find a buyer and sell the building component. A fundamental distinction can be made between offline and online sales practices. Which communication channel is chosen depends on the building components and the selected target group. Considerations that are important for this decision are for which target group they are relevant, who is willing to buy secondary building components, and an active decision of the circular material hub providers for or against a specific target group. As an example, fixed partners and warehouses are preferably addressed through an offline sales practice by calling them directly, whereas other players, such as building component scouts or architects are more likely to be reached through online marketplaces. This can be explained by the fact that it is easier for this target group to search for suitable building components on a common sales platform than to go directly to a hub. However, if private customers should be addressed, physical stores are also suitable, as a close customer contact can be established more easily in a store.

SRQ2: Which practices performed in circular material hubs facilitate the reuse of building components in circular designs?

Circular material hubs can facilitate the reuse of building components in circular design practices mainly in three ways.

First, those performing a circular design practice and those scouting building components need as much information as possible about the secondary building components that are available. Circular material hubs must provide at least basic data such as dimensions, material, connection, amount, and a photo. Nevertheless, the motto is: the more the better. That is why details such as scratch resistance, translucency, RAW color, number of colored layers and maintenance are also interesting. Providing all this information means more work for the circular material hub employees, but for those searching for secondary building components, it facilitates the process and improves their understanding of the building component.

Second, it is beneficial if circular material hubs offer their secondary building components in online marketplaces which are shared by multiple providers. For those performing a circular design practice or material scouting practice, it is easier to check one online platform where a wider range of secondary building components is offered rather than visiting separate online shops from different providers. In addition, a larger range of offered secondary building components also means that customers are more likely to find what they are looking for, which in turn might increase the amount of building components that are reused.

Third, as architects are visual and prefer to view the building components in real life if possible, they benefit from an online inventory of the offer available at a circular material hub. Checking which building components are available online before visiting the circular material hub means that those performing a circular design practice or scouting practice can free up time for other tasks. This means that maintaining an online database can be useful for clients and allows them to assess whether the offer of a circular material hub matches their needs. This makes it easier to find building components and provides a better overview of what is available.

To conclude, circular material hubs can facilitate the reuse of building components in circular design practices by (1) providing as much information as possible, (2) selling on shared online marketplaces, and (3) providing an online inventory list of what is available at the circular material hub. Mainly for (1) and (2), but potentially also for (3), the Insert marketplace can play a key role as it was shown that many architects (and hubs) already use this online marketplace.

SRQ3: Which different building component scouting practices are there in connection to circular material hubs?

This research found that for the exploration of the system of circular material hubs in the Netherlands the following two performances of a building component scouting practice are especially interesting: first, scouting building components offline, and second, scouting building components online.

Where building components are scouted depends on the project. Offline, building components can be scouted from donor buildings, directly at circular material hubs or at physical shops run by them, and by using the scouting service of the Insert Foundation. Online, building components can be scouted from online marketplaces and online shops.

Building components tend to get scouted from donor buildings when there is some kind of connection between the deconstruction project and the new construction project, e.g. through the contractor or client. In this case, the carrier of the practice visits the donor building, one or multiple times, makes an inventory of the building components that become available and decides which ones are interesting for the new project. To decide for or against building components, tools such as decision tree charts can be used. If the scouting practice is carried out by architects, visiting the donor building multiple times during while performing the practice allows to think their potential future use while seeing them still built in.

Visiting circular material hubs without having the possibility to check their offer online beforehand is less preferred amongst practitioners, as it is not clear, whether the offer matches the demand. Visiting a circular material hub takes time which can potentially be used for other tasks, hence, combining offline and online performance by checking the availability in an online inventory beforehand is preferred.

Physical shops are the third possibility for scouting building components offline. From the perspective of the provider the advantage of physical shops is that a close connection between client and provider can be established. This study, however, does not have further information on this from the carrier of the offline harvesting practice itself.

Online building component scouting practices are often performed using the online marketplace operated by the Insert Foundation. Due to the characteristics of the platform, the combination of building components offered by multiple providers and the variety of information that must be provided about the building components makes it a preferred platform for those carrying out a scouting practice.

The building component scouting practice can be performed by the following carriers: architects, material scouts, contractors, clients, the Insert Foundation. Even though SPT research does not focus on the carrier of a practice, but rather on the practice itself, this study still wants to emphasis the impact the carrier itself has on the performed practice. Due to their big network, contractors can, for example, impact the scouting practice either by offering a donor building or by connecting different (potential) carriers.

SRQ4: What are opportunities, challenges, and potential future developments of circular material hubs in the Netherlands?

The interviews also allowed to identify opportunities and challenges as well as future visions for circular material hubs.

Challenges identified during the research are (1) the irregular assortment of circular material hubs due to their dependency on deconstruction projects, (2) the degree of uncertainty and the resulting need to stay flexible, (3) missing collaborations at the beginning of a project, (4) potential higher costs, (5) the question who provides a guarantee on the reused building components as well as (6) guidelines and regulations which are not strict enough to increase reuse.

Opportunities, on the other hand, are related to (1) the potential all interviewees see in governmental decisions, (2) collaborations between the parties involved early on in a project, (3) the provision of information and knowledge on available building components, including where they can be found as well as detailed information about them, and (4) the further development of the Insert marketplace, which already implements what many interviewees are calling for, namely a single platform where building components from multiple providers can be found.

The possible future developments identified in this research can also lead to new economic opportunities for circular material hubs. There is a general belief that the construction industry will or must transform in such a way that circular material hubs and marketplaces are potentially not needed in the future anymore as we know them today. More efficient ways of providing secondary building components are expected, which potentially make the need for circular material hubs and marketplaces redundant. In line with this, it is assumed that the role of producers in the provision and use of reusable building components will change. This also requires them to take responsibility for the materials they use in their products and their reuse potential. Circular material hubs, however, could potentially act as a connection between deconstruction project and producers by bringing dismantled products back to the producer. Exploring options for further development of business cases was outside the scope of this study.

7.2. Limitations

The findings of the present research do have some limitations which are explained below.

Social practice theory

The theoretical framework of this research is based upon SPT. The SPT lens proved to be helpful in gathering an in-depth view on the practices and the connections between practices performed within the system of circular material hubs. This allowed different parts of the system to be connected to each other and shows how they potentially influence each other. However, it must be noted that this study is only partly related to SPT. This means that even though SPT was chosen as a lens to look at the phenomenon of circular material hubs and the system they are embedded in, the research also partly aimed at investigating questions which cannot be answered with a SPT approach. SPT helps to understand the connections between practices performed within the system of circular material hubs, as it allows to understand the social dynamics within a specific setting. However, it does not allow to assess (1) challenges, (2) opportunities, (3) potential future developments, and (4) the influence of circular material hubs in the transition towards a more circular construction industry. Challenges, opportunities, and potential future developments cannot be assessed utilizing SPT as they are not practices that can be identified by looking at them through a SPT lens. Therefore, these questions were investigated by asking interviewees directly about their opinions and experiences in terms of challenges and opportunities and their view on potential future developments.

Data gathering method

An exploratory qualitative research design was chosen due to the relatively little knowledge that is available on the topic of circular material hubs in current research outputs. Semi-structured interviews were chosen to collect qualitative data relevant for this study. However, by collecting data through interviews certain limitations had to be accepted.

(1) First, the data quality can vary depending on the skills and experiences of the interviewer (Kumar, 2011). An interviewer who is more experienced in SPT and in asking questions to identify practices performed by the interviewee might have gotten different or more in-depth results. Interviews conducted under the lens of SPT additionally require special skills such as “authentic wonderment that gives the obvious and the ordinary the status of unobvious, interesting and important matters” (Smagacz-Poziemska et al., 2021). As this was the interviewer‘s first experience with SPT, this requirement was not always met. As a result, questions could have been targeted better towards getting a more in-depth understanding of each element (meaning, material and competence) of a practice. As this study is only partly related to SPT, and practices performed within the system of circular material hubs, the interviews were not fully centered around the practices performed by the interviewees. The other focus of the interviews was on identifying challenges, opportunities, and potential future developments of circular material hubs and the system they are embedded in. Interview questions targeted to obtain answers to this part of the research were not created under the lens of SPT. Due to the two main areas of focus of this study, on the one hand the practices and on the other hand the challenges, opportunities, and potential future developments, it was necessary to find a balance between both of them when creating the interview questions and conducting the interviews.

(2) Second, interviews have certain inherent limitations, as they are never objective but reflect the subjective opinion of the interviewee. Therefore, interviews with different interviewees potentially identify different practices. Of course, this research aimed at identifying different practices, performances of practices and practice bundles. However, a more in-depth analysis of the practices, performances and finally also practices bundles would be needed to validate their relevance.

(3) Ideally, the practices identified in this research would have been performed by the respective practitioner during the interview to, for example in form of a walk along interview. The present research, however, identified practices based on detailed descriptions provided by interviewees. A circular design practice is performed over a longer period, as architectural designs are not created in one day only. Therefore, it was more helpful for this exploratory research to get a detailed description of the whole practice rather than just a snapshot of a specific point in time of the practice. However, to get a deeper understanding of different performances of a circular design practice, it would have been beneficial to conduct interviews while the practice is performed. Including observations would have allowed the interviewer to identify different materials of a practice which might have not been communicated by the interviewee due to several reasons.

(4) Practices performed by employees of circular material hubs were identified by interviewing employees in management positions. This allowed gathering data on a variety of practices. However, the focus was on practices performed by employees in management positions. Since these employees are typically not working directly with secondary building components, less information about practices that are performed by manual laborers was collected. Therefore, conducting walk along interviews with workers in the circular material hub and observing the practices performed by them would have added another layer of detail to the results.

Sample population

The sample population consists of five circular material hub representatives from four circular material hubs, four architects and three experts.

The circular material hubs were chosen to represent a variety of circular material hubs in the Netherlands. This means that they were selected according to their specifications, e.g. which building components they handle or their target group. Despite certain similarities, there are also major differences between the circular material hubs under investigation. Circular material hubs with different priorities and sizes were deliberately selected to provide a broad overview of the entire system. There is, for example, only one circular material hub which does not sell to private individuals and only one which repurposes building components into new furniture. These differences were intentionally sought to represent a greater variety of circular material hubs and to collect a wider range of information. The collected data complement each other and together allow an exploration of the entire system. Despite the steps undertaken in this study being replicable, the results can be expected to vary depending on the circular material hubs under investigation due to the exploratory and quantitative nature of the study. Studying a greater variety of circular material hubs could have resulted in a broader view on the system of circular material hubs in the Netherlands. An even more diverse sample of circular material hubs, however, exceeded the scope of the present study for time and personnel reasons.

All architects included in the study are aware of the environmental impact of the construction industry and the need to transition to a circular economy. This allowed to discover information about their circular design practice, as they are already designing with secondary building components on a regularly basis. It was intentional to only select those architects who are already part of the system of circular material hubs to explore the current state of the system. Including architects who are not or not regularly performing a circular design practice to investigate their relation to the system of circular material hubs was outside the scope of this study.

A sample population including contractors, material scouts and producers would have allowed to create a bigger picture which takes more perspectives into account. Despite these stakeholders being part of the system, they have only been covered superficially in this research. It has been shown that these stakeholders are important constituents of the system, but their importance was only explored from the perspective of the architects and circular material hub representatives. However, investigating the system of circular material hubs by actively including these stakeholders would have allowed to gain a more comprehensive understanding of the system.

Location differences

The results may also vary depending on the area or country of implementation. The results refer to the present context, namely the geographical restriction to the Netherlands. As the Netherlands is one of the leading countries in transition towards material reuse and circular economy transition, it was relatively easy to find potential participants who fit into the scheme and already work with secondary building components (getting these people to take part in an interview is a different matter). In countries with a more advanced or a less advanced circular economy, the results may be different due to a different system in which circular material hubs are embedded.

7.3. Recommendations

Research into the system at circular material hubs has shown that the system extends beyond the actual circular material hub location. The recommendations are designed to facilitate the transition towards a circular construction industry by supporting material reuse and the integration and expansion of activities of circular material hubs.

Recommendations for circular material hubs

(1) The first recommendation concerns the identification of client needs. It has been shown that circular material hubs do not generate a particularly high profit. Yet they are operated because all representatives agree that the reuse of building components is necessary. To expand their operations, it is recommended to get a better understanding of target groups, clients' needs and adapt their sales practice according to it, i.e. which communication channel targets which target group. Circular material hubs which target clients from the construction industry must be aware of two things: (1) those clients need to have detailed information data about the secondary building component (dimensions, connections, color, etc.), (2) they prefer harvesting building components on one shared platform rather than multiple small ones. Therefore, greater emphasis should be on collaborations between multiple circular material hubs to sell secondary building components on one shared platform. The online marketplace from Insert meets the requirements for such a platform. Using the Insert marketplace has two advantages for circular material hubs: (1) they do not have to maintain a platform themselves, (2) they simply need to upload the construction components they want to sell, and (3) they are more likely to be discovered by chance by other customers of the online marketplace.

(2) The second recommendation concerns the adaption of the circular acquisition process. The construction industry is slow to change. To drive change regarding the use of secondary construction components, it is recommended to adapt the circular acquisition process to the linear one as much as possible. Acquiring secondary building components should not be much more

difficult or time-consuming than primary building components. Therefore, the circular system needs to be adapted in such a way that choosing secondary building components does not take more time or effort. To do so, it is recommended that circular material hubs cooperate with larger warehouses and as mentioned above, offer secondary building components together with other suppliers on one sales platform.

(3) The third recommendation concerns the development of new business cases. Circular material hubs potentially no longer exist in the future as they do now. It can be assumed that there is a change in the entire system. Therefore, circular material hubs need to ask themselves how they can develop and stay relevant. This can, for example, imply the development of new business strategies. They can use their accumulated knowledge and skills to support other, newly emerging companies, e.g. harvesting secondary building components for specialized companies or taking over their logistics.

(4) The fourth recommendation concerns an extended employment of people with a distance to the labor market. Circular material hubs frequently employ people with a distance to the labor market. The decision to hire workers with a distance to the labor market can be of social or financial nature, but in any way, it is an important contribution to our society. Therefore, expanding the employment possibilities of people with a distance to the labor market is recommended. To do this, it is necessary to find out in which other areas they can be involved and subsequently offer the necessary training.

Recommendation for other practitioners

(1) The first recommendation concerns the education of architects. The findings suggest that carriers of a circular design practice need to be flexible and creative. Therefore, it is recommended to incorporate circularity into the education of architects right from the start. It is suggested to transform both bachelor's and master's degrees in architecture, while putting a greater emphasis on bachelor students. This is argued with the fact that bachelor students are still at the beginning of their academic education, which potentially gives them more time to become familiar with a circular design practice. In addition, it is possible that some students have not yet had any contact with circularity, while others are already more familiar with this topic. At the beginning of the bachelor's program, it can therefore be ensured that relevant courses are offered that are designed to provide all students with the same level of knowledge. To educate practitioners who perform a circular design practice instead of a linear design practice, it is necessary to investigate the impact of current efforts at Dutch universities. This forms the basis from which the transformation can eventually take place.

(2) The second recommendation concerns the clarification of scouting options by those conducting a building component scouting practice. It must be clear where secondary building components can be found and how best to approach the scouting process to achieve the best possible outcome. Those conducting a scouting practice should be provided with an overview of online or offline sites where building components can be found. It should be specified which building components are offered. While it is of course not possible to specify exactly what is offered, the basic differences such as building component category can be addressed. For easier communication and practicability, it is recommended that there are specific records of the procedure within the company so that the practice can be carried out equally by all potential carriers.

Policy recommendations

The participants of this research agreed that the government has the power, and must also use this power, to increase material reuse through regulation and legislation. The government must actively create regulations that demand and promote circularity. As in all other industries, profit, and financial benefits also play an important role in the construction industry and especially in decision making. It has been shown that new construction components are used if they are cheaper than secondary ones. Therefore, choosing secondary building components must bring either financial or economic advantages (or other advantages which are strong enough to persuade those actors who do not care about environmental matters).

(1) The first recommendation concerns the dismantlability and detachability of building components. It is advised that only building components that can be dismantled or detached may be produced. Additionally, these building components must consist to a high degree of secondary materials. Building components that must be disposed of after their first life cycle due the material quality issues or the way they were built must be permitted. Instead, building components must be detachable to enable exchanges where needed. This also aims to increase the responsi-

bility and accountability of producers during the entire life cycle of the building components.

(2) The second recommendation revolves around incentives for material reuse. As mentioned before, incentives need to be created to increase building component reuse. However, these incentives do not necessarily have to be of direct financial nature (but can indirectly lead to monetary savings). To provide an example: Construction projects that have a higher proportion of secondary building components are processed faster and receive feedback (approval/denial) more quickly. If the decision is positive, the construction projects can be started much faster. This example is merely intended to show in which direction incentives can possibly go.

(3) The third recommendation addresses the specified regulations in relation to sizes etc. The goal is to create regulations which support building component reuse. However, it has been shown that certain regulations potentially prevent reuse. For example: Current regulations stipulate certain dimensions for certain building components. At the same time, dimensions of building components change over time. As a result, past dimensions may not correspond to current specifications and can therefore not be used, even if their quality would still match current regulations. Therefore, the regulations should be relaxed or there should be regulations specifically designed for secondary construction components.

(4) The fourth recommendation targets the Dutch housing program (Programma Woningbouw). In 2022, the Ministry of the Interior and Kingdom Relations stated that half of the annual housing production shall be achieved through circular and industrial construction by 2030. In this case, circular construction is related to industrial construction, including digitalization, automation, unification, and standardization. To also place a targeted focus on materiality, it is recommended to specifically mention secondary building components to promote their reuse.

7.4. Future research

The highly explorative and qualitative nature of this research has laid the foundation for further studies on circular material hubs and the transition towards a circular construction industry. The findings and limitations of this study also raised further questions that are relevant for future research.

(1) This study represents a great variety of circular material hubs that can be found within the system of circular material hubs in the Netherlands. However, it does not claim to represent the entirety of existing circular material hubs, but rather describes the phenomenon of circular material hubs based on a range of selected circular material hubs. To get an even more in-depth understanding of the Dutch system of circular material hubs, it is recommended to repeat the study with a more diverse sample of circular material hubs. Rather than putting the focus on the number of circular material hubs under investigation, i.e. aiming for a sample including more circular material hubs that are similar to the ones studied in the present research, it is recommended to aim for a greater variety.

(2) This study explored the system of circular material hubs in the Netherlands. On an international level, the Netherlands is one of the top nations when it comes to secondary raw materials use. This means that the circular material hubs investigated in this study are part of a construction industry which has already moved further towards a circular construction industry than in other countries. In addition, a great amount of other academic literature on circular material hubs also refers to the Dutch or northern European context. To better understand the system of circular material hubs and to transfer it to an international European context, further research is needed in countries that are less advanced in terms of circularity. A recommended research question is: "How does the system of circular material hubs in the Netherlands differ from the system in other European countries?" (Add a country if it is possible to find an aspect that makes the Netherlands unique) For such a research, a case study approach is recommended.

(3) Circular material hubs help to make secondary building components more accessible to actors in the construction industry. However, according to a circular material hub representative, there are more efficient ways to handle secondary building components than at circular material hubs. At the same time, the present study found that some interviewees think that circular material hubs will not exist in the future as we know them today. This can, to a certain degree, potentially be connected to an increasing importance of producers. This leads to the following question: "What does a more efficient system of secondary building component distribution look like?". This research question aims to address whether circular material hubs are an efficient solution for the distribution of secondary construction components and whether this can be made more efficient by

involving other actors, such as producers, so that the transition to a circular construction industry goes faster.

(4) Following up on the research explained above, the question arises how circular material hubs can change their business case according to the changes that come with a transition towards a circular construction industry. In case circular material hubs will not exist as they do now, the question arises how their accumulated knowledge and their network can still be used to facilitate a circular construction industry. Therefore, the following question arises: "Will circular material hubs become less important in the future and if so, which other business strategies can they adopt to contribute to a circular construction industry?" For such an explorative research, it is suggested to conduct interviews with circular material hub providers, producers, warehouse operators, building component scouts, contractors and architects.

(5) The study found that stronger collaborations at the beginning of a construction project are important to make sure that circularity is considered throughout all stages. This has raised the question of how stronger connections between circular material hubs can help to increase the reuse of building components and facilitate the transition to a circular construction industry. This leads to the following research question: "To what extent would a stronger collaboration between circular material hubs be beneficial for increased use of secondary building components?" As this study only conducted interviews and did not bring together two or more circular material hub representatives, it is suggested that future research holds a focus group to discuss the potential advantages and disadvantages of stronger connections. A co-creation session can then be held to work out how this collaboration can be implemented.

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APPENDIX A - PERSONAL REFLECTION

In this chapter of my thesis, I want to reflect on my personal journey over the last twelve months. Despite all other chapters being developed around the topic of research, this one is intended to provide some insights into my very personal experiences, learnings, struggles and take aways. Each section is structured roughly the same way: first, I will reflect on a certain topic, provide my view on it, what I could have done differently, what I have learned, and I can use the experience in the future.

My experience with academic writing

Going into this thesis, I did not have a lot of experience in academic writing. My bachelor's degree focused on gaining design skills and learning how to develop and communicate architectural concepts, build models, and study architectural history. Academic writing, however, was hardly touched. Hence, up to February 2023, the month I started working on my thesis, the only experience I had was what I have learnt in the previous one and a half years of my MSc MADE education. Right from the beginning I knew that there is a lot I have to learn while writing my thesis. It took me a long time, until the end of my thesis process, to understand which points should be dealt with in which chapter. Even though there is still a lot to learn, improve, and practice until I feel comfortable writing a research report without questioning what to include in each chapter, I am proud of the progress I made over the last twelve months. Compared to the knowledge I had at the beginning of my thesis process, my skills improved due to the regular support of Mart and Bas, and various online platforms which are specialized in explaining the structure of academic reports. By discussing the structure of each chapter over and over again, Bas and Mart helped me to gradually realize how the chapter organization could be improved. I am intentionally writing could rather than should here, as I have also learnt that there is not one single guideline to follow. As Mart mentioned once, it also depends on the researcher whether certain contents are discussed in one chapter or another. However, it is precisely these opportunities to adapt the structure to your own preferences and research that made writing my Master's thesis a challenging but yet rewarding process.

Learning: Writing each chapter of a thesis is an iterative process. Sometimes it is an effort to delete a paragraph completely when you have already put a lot of work into it. Nevertheless, being able to let go and take on a new perspective to improve your own work is a valuable skill.

Overcoming struggles

Working on a graduation project is not a linear process. Sometimes there are lows, characterized by doubts and struggles, when you are at the limits of giving up. But there are also highs, characterized by the feeling that you achieved something you are proud of or that you managed to do something that before seemed impossible. For the longest time, the lows outweighed the highs and there were many hurdles along the way that I did not expect before I started working on my thesis. But when I realized that I could do it and that I could finish what I had started, things started to improve again.

The biggest hurdle I had to overcome was connected to the theoretical lens I chose. Understanding social practice theory and the definition of a practice well enough to apply to apply it to my research turned out to be harder than I thought. I was able to overcome the former through many conversations with my supervisors and friends from MADE, reading papers and the realization that I do not have to think as complicated as I first assumed. Social practice theory can be very philosophical, which means that working with it can go in many different directions. But it is not necessary to think as complicated as possible. Realizing that I can overcome my problems related to social practice theory by trying to simplify what is already in my mind helped me to improve my understanding of practices.

Next to the above-mentioned hurdle, I also struggled to collect the data I needed for my research. At the beginning of the thesis process, I had multiple data gathering methods in mind that I wanted use. However, I soon realized that getting in contact with practitioners in the construction industry can be hard. Sending many emails but getting hardly any responses made me doubt my study and my abilities. Why was I not able to find people who are willing to participate in the study? Why did they not reply anymore? Is it because of my e-mail and my wording? Am I not showing enough initiative? Or is my study simply not interesting enough? Many thoughts came to my mind, but finally I was able to solve the issue by being persistent and not feeling too invasive about contacting people several times. At first, I did not want to be too intrusive, as I was afraid to leave a bad impression right from the start. But I realized that it is necessary to send weekly reminders if I want to talk to a person working in the construction industry. Especially since a lot of them are quite busy. Looking back, I should have been more persistent. In the end, I had to drop one of my data gathering methods to finish my research. I do still believe that it would have added great insights and additional information to my research, however, I was not able to do it within the time I had left. If I had the opportunity to collect the data again, I would focus more on getting a commitment from each participant as soon as possible, even if the session itself would take place at a later date. Nevertheless, I am proud that I managed to carry out this research on my own. I have never done any research on my own before, so on a personal level it is already a success for me that I managed to get to where I am today.

Communication and work attitude

No matter what I do, whether it is in my everyday life or related to my studies, I always try to give it my best. Even though there are of course setbacks from time to time, I usually do not get to a point where I want to quit. At the same time, I also always have the urge to work on something and be active. While working on the thesis, my personal work attitude got challenged. I had to realize that if I want to give it my best, I sometimes have to take breaks. It can happen that a task feels almost impossible to complete or that you are not happy with the result you are getting. I had times when I wanted to quit, when I thought I couldn‘t finish this thesis because I felt a mental block as soon as I started to work on it. I wanted to give up and accept that I maybe have to change my approach and look for another topic. But usually, I do not quit when something starts to get challenging. What helped me during these times was to open up about my feelings, fears, and concerns, to be honest to myself and to share them with my supervisors. Once I was able to reach out to for help, a conversation with my supervisor Mart was what changed everything for me. We talked about my struggles and together came up with a plan on how I can twist my thesis in a way that I can still finish what I have already started. I truly believe that without this conversation, I would not have had the believe in myself to finish my research. If I could do it again, I would keep my supervisors updated, both on what I was able to achieve and the struggles I am facing. What I take with me is that trying to avoid the work you have to do does not help but just makes it worse. The same applies to pushing a confrontation with a problem you are facing away for as long as possible. What does help is to look at what you already have, see what you can already do (or answer) with this information and identify what you are still missing. What did indeed help me the most was to put up a deadline for myself up to which the situation has to improve. If the situation had still not improved at the end of this period, I would have known, at least for myself, that I tried my best to improve the situation. Additionally, I did realize that it is helpful for myself to take breaks, especially in those times where I need them more than in others, e.g. due to illness or other personal struggles. Taking a step back and regaining the strength that it takes to work on a thesis (or any other job) is necessary. Putting yourself first and taking care of yourself is what it takes to give your best to everything you are doing.

Learning: Asking for help is not a shame but a strength. It is not necessary to overcome every struggle by yourself and it is good to take some rest. Setting yourself a deadline Setting yourself a limit prevents you from finding yourself in a spiral of procrastination and doubt for too long.

Process & Planning

Looking back at my own planning and process, I do recognize that there are many things I could have done better. Even though I did create a rough planning at the beginning, including the time I want to spend on each phase of the process and dates for certain milestones, I did not stick to this planning. Due to unforeseen, personal issues as well as falling sick while participating in a one-month elective course, it became a challenge to follow my planning. Taking responsibility, both for yourself and the work you are doing, also means to recognize when the moment has come where you need to take it slower and take care of yourself. When I realized that I cannot give my best if I do not prioritize my own health, I had to take a step back and get better again. Even though taking a rest felt like losing time, I do think that it was the right decision. And in the end, I do know that there is not something like losing time, especially when it comes to your health.

However, what I do question is whether I would take an elective course again while working on the thesis. The honest answer is, I do not know. On the one hand, I could not work on the thesis full time while being sick and taking a course. On the other hand, I was able to learn new skills and a program which I already wanted to learn for years. In any case, I would already take this into account in my planning and do not make the mistake to think that I can manage both without any compromises. In addition, I would give myself a little more time from the beginning for the individual steps so that they can be completed, also taking into account that I have never written a thesis before and might take longer for each step. Looking back, it would have been important to structure the planning so that I could finalize my data collection before the summer, as it was very difficult to get in touch with people from the construction industry during the summer. Or otherwise plan the meetings months ahead for right after the summer break. It would have been crucial to considering from the outset when the required interview partners might not be available.

Learning: It is important to create a schedule that allows for possible unforeseen changes. Being honest with yourself on what you can or cannot do within a given amount of time, and taking your individual starting point into account allows to create a more realistic planning.

Conclusion

Looking back at the last year, I can say that I struggled more than in any other academic year before. However, I am also proud of myself for overcoming the struggles I was facing. If I could start from the beginning, I would do a lot differently with the knowledge I have today. But that is the big difference. I did not have the knowledge I have today twelve months ago. I learned a lot, not only about circular material hubs, academic writing, and research, but also about myself. In the end, I do believe that being able to take the learnings from this experience to make it better the next time is the most important thing. Nothing is perfect from the start, and the question is whether perfection even exists, but the important thing is that one continues to develop, learn, and improve - and that is what this work stands for.