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CREATING AND CAPTURING VALUE THROUGH BUILDING PRODUCT REUSE

Multiple case study on reutilisation of concrete in construction projects

Master's Thesis
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ABSTRACT

Mari Riuttala: Creating and capturing value through building product reuse – Multiple case study on reutilisation of concrete in construction projects
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The construction industry has a major environmental impact due to its high global figures for resource consumption, waste generation and emissions. Building product reuse has been identified as a means to target these challenges, but more understanding is needed on how reuse could contribute to value creation and value capture for construction industry actors. Existing studies on the topic have been mostly focused on technical feasibility for reuse and design approaches. For this reason, this study aimed to find out how reuse processes for concrete building products are formed, and what participation in such a reuse process entails for value creation and value capture for each identified key actor in the construction value chain. In addition, the factors determining value capture in the reuse processes have been analysed.

The research design of this study is formed around a multiple case study strategy. Circular value chains and circular business models (BM), as well as product recovery and reverse logistics processes especially from a construction industry perspective have been utilised as a theoretical background. For empirical findings, a qualitative analysis of three diverse construction projects involving reuse of concrete in new construction, was conducted. The research data was collected by qualitative methods, including observations, and secondary research material and semi-structured interviews with interlinked key actors in the reuse value chains.

The findings of this study indicate that the reuse of building products can bring value to actors in several ways depending on the reuse process. Reuse can also contribute to business opportunities in building product lifetime extension to both established as well as emerging actors. Value capture from reuse may manifest as, e.g., functional use value, information value, reused product resale, service fees from deconstruction, design and consulting, firm-level brand value, as well as avoided waste handling costs. Value capture from reuse may require the involvement of certain value capture determinants to realise. This study suggests that value capture in reuse processes is determined by 1) the presence of strong demand for reused products, 2) the properties of both the donor and the receiver buildings, 3) the actors having a common goal towards reuse, 4) contractual agreements, 5) legislative involvement and 6) experience, optimisation & economies of scale.

This study expands the existing knowledge base of reuse and product recovery research, circular value creation and circular BM research, and circular construction research. The study also has contributions to practice. It is suggested that policy makers should guide incentives for building product reuse to construction companies to drive demand from the downstream of the value chain. Building owners and demolition companies should explore possible benefits of deconstruction and agree on reuse early on in construction projects. The cascading reuse of building components should also be considered. Further research ideas include conducting more case studies on why certain reuse projects fail while others succeed, as well as studying BM implications of reuse to even more actors.

Keywords: building product reuse, CE, circular business, circular economy, circular value chain, concrete, construction, product recovery, reuse, value capture, value creation

TIIVISTELMÄ

Mari Riuttala: Arvonluonti ja arvon haltuunotto rakennustuotteiden uudelleenkäytössä – Monitapaustutkimus betonin uudelleenhyödyntämisestä rakennusprojekteissa
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Rakennusteollisuudella on suuret ympäristövaikutukset sen maailmanlaajuisesti korkean resurssinkulutuksen, jätteen syntymisen ja päästöjen määrän vuoksi. Rakennustuotteiden uudelleenkäyttö on tunnistettu keinoksi kohdata nämä haasteet, mutta lisää ymmärrystä tarvitaan siitä, kuinka uudelleenkäyttö voisi edistää arvon luomista ja arvon haltuunottoa rakennusalan toimijoille. Aiemmat aiheesta tehdyt tutkimukset ovat keskittyneet enimmäkseen uudelleenkäytön tekniseen toteutettavuuteen ja suunnitteluratkaisuihin. Tämän vuoksi tässä tutkimuksessa selvitettiin, miten betonisten rakennustuotteiden uudelleenkäyttöprosessit ovat muodostuneet ja mitä uudelleenkäyttöprosessiin osallistuminen merkitsee arvoketjun avaintoimijoille arvonluonnin ja arvon haltuunoton kannalta. Lisäksi tutkimuksessa on analysoitu arvon haltuunottoon vaikuttavia tekijöitä uudelleenkäyttöprosesseissa.

Tämä tutkimus noudattaa monitapaustutkimuksellista tutkimusstrategiaa. Työn teoreettisena taustana toimivat kiertotalouden arvoketjut, kiertotalousliiketoimintamallit sekä tutkimukset tuotteiden ennallistamiseen ja käänteisen logistiikkaketjuun liittyen erityisesti rakennusalan näkökulmasta. Empiirisiä havaintoja varten tutkimuksessa tehtiin kvalitatiivinen analyysi kolmesta erilaisesta rakennusprojektista, joihin sisältyi betonin uudelleenkäyttöä uudisrakentamisessa. Tutkimusaineisto kerättiin laadullisin menetelmin hyödyntäen havainnointia, sekundaarista dataa sekä puolistrukturoituja haastatteluja uudelleenkäytön arvoketjujen avaintoimijoiden kanssa.

Tämän tutkimuksen tulokset osoittavat, että rakennustuotteiden uudelleenkäyttö voi tuoda toimijoille arvoa useilla tavoilla uudelleenkäyttöprosessista riippuen. Uudelleenkäyttö voi myös edistää liiketoimintamahdollisuuksia tuotteiden eliniän pidentämiseen liittyen sekä vakiintuneille että uusille arvoketjun toimijoille. Uudelleenkäytössä arvon haltuunotto voi ilmetä esimerkiksi toiminnallisena käyttöarvona, tiedollisena arvona, uudelleenkäytettyjen tuotteiden jälleenmyyntinä, purkamisen, suunnittelutyön ja konsultoinnin palvelumaksuina, yritystason brändiarvona kuin myös jätteenkäsittelykustannusten välttämisenä. Arvon haltuunotto uudelleenkäytöstä saattaa edellyttää tiettyjen arvoa määrittävien tekijöiden toteutumista. Tutkimuksen tulokset osoittavat, että arvon haltuunottoa uudelleenkäyttöprosesseissa määrittävät 1) uudelleenkäytettyjen tuotteiden voimakas kysyntä, 2) rakennusosia luovuttavan ja vastaanottavan rakennuksen ominaisuudet, 3) toimijoiden yhteinen tavoite uudelleenkäyttöön, 4) sopimusasiat, 5) lainsäädännöllinen vaikuttaminen, sekä 6) kokemus, optimointi ja skaalaedut.

Tämä tutkimus täydentää olemassa olevaa tutkimustietoa uudelleenkäytöstä ja tuotteiden ennallistamisesta, kiertotalousliiketoiminnasta ja kiertotalouden liiketoimintamalleista, sekä kiertotaloudellisesta rakentamisesta. Tutkimuksella nähdään olevan myös käytännön tason hyötyjä. Ehdotetaan, että päättäjien tulisi ohjata rakennusalan yrityksille kannustimia rakennustuotteiden uudelleenkäyttöön edistämään kysyntää arvoketjun loppupäästä. Rakennusten omistajien ja purkuyritysten tulisi selvittää ehjänä purkamisen mahdolliset edut ja sopia uudelleenkäytöstä jo rakennusprojektien varhaisessa vaiheessa. Myös rakennusosien kaskadiperiaatteen mukaista uudelleenkäyttöä tulisi harkita. Jatkotutkimuksena voitaisiin tehdä tapaustutkimusta siitä, miksi jotkin uudelleenkäyttöprojektit epäonnistuvat, kun taas toiset onnistuvat. Uudelleenkäytön vaikutuksia liiketoimintamalleihin voitaisiin myös tutkia vielä useamman toimijan näkökulmasta.

Avainsanat: arvon haltuunotto, arvonluonti, betoni, CE, kiertotalouden arvoketju, kiertotalous, kiertotalousliiketoiminta, rakennustuotteiden uudelleenkäyttö, rakentaminen, tuotteiden ennallistaminen, uudelleenkäyttö

PREFACE

This master’s thesis study has been conducted at research group CITER in Tampere University. When I started working on this thesis, circular economy research was still relatively unknown ground for me personally. Yet, during these months my knowledge on circularity has exponentially grown, and hopefully circular economy will be a recurring topic during my career in other assignments as well. I look forward to seeing how circular economy practices advance in construction and other industries in the coming years.

I wish to thank everyone contributing to this master’s thesis. First, want to thank my thesis supervisors for their patience and helpful guidance during my thesis-writing journey. I also want to thank my colleagues in the research group for their peer support − lunch breaks with you sharing your own thesis-writing stories were valuable and needed. A thanks also goes to all my research interviewees who provided me the opportunity to collect valuable information for this thesis. Finally, a special thanks to my friends Lotta & Marianne and my boyfriend Niklas for their support.

With these words, my thesis, and hence, my master’s degree in Industrial Engineering and Management is now finalised. I can proudly say “I made it”, and even learnt something along the way. I look forward to what the future has to offer.

Tampere, 12 May 2022

Mari Riuttala

CONTENTS

LIST OF ABBREVIATIONS

3R	Reduce, reuse, recycle (hierarchical return loops in a circular economy)
BM	Business model
CE	Circular economy
DfD	Design for deconstruction
EoL	End-of-life (refers to a product reaching the end of its lifecycle)
EPV	Extending product value
OEM	Original equipment manufacturer

1. INTRODUCTION

1.1 Background and motivation for the study

The construction industry is a significant source of emissions and waste. In 2018, the manufacturing of building materials was estimated to account for 6 % of global energy use and 11 % of global greenhouse gas emissions (IEA Global Status Report, 2019). The construction of a building consumes carbon-intensive resources, and its demolition creates waste material. For example, in 2019, 13.7 million tonnes of construction and demolition waste was generated in Finland (Statistics Finland, 2021).

The world's most commonly used building material, concrete, is also the second most-consumed resource in the world, with an annual production of about 4,2 billion cubic meters (Betoniteollisuus ry, 2021). Given the significance of concrete as a resource, there exists great potential for reducing harmful environmental impacts in the construction industry by changing how concrete is used in construction. In addition, construction industry actors from builders and product manufacturers to waste management centres have the potential to capture value by participating in sustainable value creation.

Reducing the use of building materials at the beginning and accumulated waste at the end of a building's lifecycle can be achieved by adopting circular principles in construction, seeing waste as a resource and current buildings as valuable material banks (Geldermans, 2016), components of which are waiting to be gathered and reused. Reusing allows for virgin materials to be conserved and thus has the potential to solve environmental challenges in three ways − decreasing carbon emissions and energy use, reducing the generation of waste and delaying resource depletion (Cooper & Gutowski, 2015; Rose & Stegemann, 2018; Pongiglione & Calderini, 2014). Given these reasons, there exists also a societal push to promote reuse across all sectors. The Finnish Government has set a goal to have a circular economy (CE) in Finland by the year 2035, promoting reuse as one of the tactics to reach this goal (Ministry of Employment and the Economy, 2021). Reuse was also one of the main principles described in the European Union Waste Framework Directive, which has provided the basis for the current national Finnish waste law. In the waste hierarchy as provided by the directive, *reuse* ranks as the second most preferred waste minimisation tactic right after waste "prevention" and before "recycling". (Waste Framework Directive, 2008)

Buildings are usually designed to have a long lifecycle, and their structural components are thus made to withstand even hundreds of years (Rasmussen et al., 2019). Yet, many buildings face early demolition because they do not meet the current demand for location, condition or purpose (Thomsen & van der Flier, 2011). Reuse has been presented as an option to retain value embedded in such obsolete buildings. According to a study by Huuhka et al. (2015), the prefabricated concrete elements in the current Finnish apartment building stock from the 1970s could contribute to the construction of nearly 108 000 modern detached houses. Thus, there exists a lot of untapped potential in the reuse of construction products, and for the reuse of concrete in particular.

The act of reusing existing structures and building materials is not new and has been going on for centuries. The practice has been motivated in the past by, for example, the conservation of historical architecture and making efficient use of scarce building materials (Bertino et al., 2021). Yet, in recent years, a generous amount of research on circularity and reuse in the construction sector has emerged, making the topic now more relevant than ever. Recent studies include systematic reviews that combine extant literature (*see* e.g., Rakhshan et al., 2020; Iacovidou & Purnell, 2016; Eberhardt et al., 2020). Still, most reuse related research in the construction sector is focused on the waste management of end-of-life (EoL) buildings or the design implications of new buildings to enable future reuse. Therefore, there is a gap in the understanding of how the current building stock could contribute to value creation and value capture when its elements are recovered for reuse in new buildings. Some authors, e.g., Hopkinson et al. (2019) have begun to approach the topic of structural building product reuse from a value capture perspective, but more research is needed as several practical cases of successful building projects involving reuse start to emerge and value creation gained from them is possible to study.

To meet these needs, theory related to the economic value from reuse in the construction sector is expanded by conducting a multiple case study focusing on three diverse construction projects involving the reuse of concrete and how the potential for value creation and value capture manifests in them.

1.2 Research objective and research questions

The purpose of this study is to <u>increase understanding of the business and value potential related to building component and material reuse</u>. The special interest of this thesis is on the business implications of reusing *concrete.* This research aim is met by undertaking a multiple case study consisting of three current and past building projects, where a reuse process regarding concrete has or will be implemented.

The research purpose has been further divided into three research questions, which will be answered in this report. The first research question aims to identify what phases are included in the reuse of building products. Through answering the first research question, an initial understanding of the diversity of reuse processes is gained. This research question also aids in identifying the roles of actors required in the reuse processes. The first research question is formulated as follows:

RQ1: What are reuse processes like for building products, especially concrete?

The second research question focuses on the value perspective of the reuse process. This research question is divided into two subquestions. This study will look into what value implications regarding value creation and value capture there exist for actors involved in a value chain of building product reuse. The goal is to, on the one hand, know how realised reuse processes have provided value to actors involved, and on the other hand, explore the possibilities of future business opportunities of reuse enabling potential value creation and value capture. Thus, the second research question is formulated as follows:

RQ2: How can the reuse of building products, especially concrete, enable value creation and capture for actors involved in reuse processes?

a) How does value creation and capture realise for actors in building product reuse?

b) What kind of business opportunities can be identified for actors in the reuse of building products?

Finally, this study aims to identify factors enabling value capture in the reuse process for building products. Again, value capture determining factors linked to both past practices that were deemed successful as well as determinants for future value capture are of interest. The third research question is formulated as follows:

RQ3: What determines value capture potential in the reuse of building products, especially concrete?

The term *reuse* here refers to high-value use, either by reuse of whole components, or by ’upcycling’ building materials. However, more emphasis is given to the reuse of building products on the component level. The recycling of concrete in the form of ”backfilling”, while also useful in some cases, is largely considered downcycling and thus left out of the scope of this study.

1.3 Structure of the report

This section shortly reviews the structure of this thesis. The thesis continues from here on with a theoretical overview from multiple research areas. In Chapter 2, the concepts of value creation and business opportunities are examined from a CE perspective. Chapter 3 takes a closer look into the concept of reuse, explaining what types of reuse there are according to literature and presenting a generic process of reuse. In Chapter 4, literature and concepts of reuse are explained within a construction industry setting. The theoretical overview concludes with Chapter 5, where a summarising table of literature from all of the three categories of earlier chapters is presented, and a theoretical framework is constructed.

Next, Chapter 6 presents the research methodology. In this section, the used research methods are explained, including the choice of data collection methods, multiple case study strategy, case selection criteria and data analysis methods. The chapter concludes with an assessment of the internal credibility of this research.

In Chapter 7, the results from the multiple case study are presented. The chapter begins with a short introduction to concrete as a reusable building material, followed by the case studies. In subchapters 7.2-7.4, each of the three cases is described and analysed. The cases are analysed with regard to each of the research question, involving the reuse process configuration, value implications to the actors involved and value capture determinants. In subchapter 7.5 the findings from the three cases are then analysed in a comparative multiple case setting. The chapter concludes with a final discussion on the findings.

The conclusions of this study are presented in Chapter 8, including the key findings, originality of this research, contributions to both theory and practice, the limitations to be considered when applying the findings, as well as suggestions for future research avenues.

2. VALUE IN A CIRCULAR ECONOMY

This chapter begins the literature review section of this study. In this chapter, the concept of value creation is explained, and how it manifests in the context of CE and systems of multiple actors, and what value creation logics and business opportunities have been identified in the literature.

2.1 Value creation

Value is a key concept in business research, and an important component of a company's business model (BM). A BM can be described as "*the rationale of how an organization creates, delivers, and captures value*" (Osterwalder & Pigneur, 2010). Indeed, most BM frameworks seem to revolve around the term "value" occurring in various configurations, usually *value proposition*, *value delivery/creation* and *value capture* (Ranta et al., 2018).

In the BM framework, a value proposition describes what "value" a business promises to offer its customers, thus describing the purpose of the business. Value delivery, on the other hand, focuses on the activities needed for an actor or a system of actors to enact their value proposition to customers. In order for a business to function and create sustainable value also to its internal stakeholders, it also needs to capture a share of the value it has been a part of creating, which is described as the value capture component of the BM. Value capture thus considers the revenue streams and cost structure of the business. (Richardson, 2008; Osterwalder & Pigneur, 2010)

Thus, the BM describes the logic by which business entities create value to their selected customers and to themselves. Value may be created in different kinds of systems, and value creation can, on the other hand, be viewed as a process of activities with a focus on the focal firm as a value creator or a set of actors creating value (Porter, 1991). According to the *value chain* theory (1985; *see* Porter, 1991), the purpose of value chains is to ultimately create customer value through the process of employing several activities requiring both tangible and intangible assets. These activities may be, for example, tasks related to the manufacturing of products, or supporting activities linked to, for example, designing the products. When considering the interlinked value chains of all the actors required for the creation of the final offering, the value chains may be described with the common term "value system" (Porter, 1991).

There are different types of value to be created, and in business and marketing research distinction is sometimes made between two types of value: *exchange value* and *use value* (Bowman & Ambrosini, 2000). While use value is perceived by customers, exchange value refers to the monetary amount paid for the perceived use value. On the other hand, Chesbrough et al. (2018) argue that use value is something that an actor creates for itself, while exchange value relates to value creation through the exchange of resources between actors (Chesbrough et al., 2018).

Value creation can be viewed as a process where a firm combines acquired use value from suppliers with labour to create new use value for customers (Bowman & Ambrosini, 2000). The interpretation of Lepak et al. (2007) on value creation is that the source of value creation develops or performs new contributions, e.g., products, services or processes, that make the targets of value creation (users or customers) receive "*a greater level of novel and appropriate benefits - - than [they] currently possess, and that they are willing to pay for*" (Lepak et al., 2007).

Value can thus be created from the acquisition of suitable resources and performing value-adding labour on these resources which yields some kind of valuable output (Bowman & Ambrosini, 2000; Brandenburger & Stuart, 1996). New value is created from existing resource value but also from the competences of the business working on those resources (Brandenburger & Stuart, 1996; Porter, 1991).

In this thesis, one of the examined themes is how different types of value can be created from resources and activities performed to them by actors in a circular value chain. Implications to value chain actors' BMs are also of interest.

2.2 Value creation in the circular economy

The established business and value creation literature is mostly set in a world of *linear economy*, in which value creation systems are based on a consumption model where virgin resources are extracted from nature, and products reaching the end of their use have no further value and are disposed of. Recently, however, more sustainable ways of value creation have been increasingly studied in the context of *circular economy* (CE). CE can be summarised as "*an economic system that replaces the [EoL] concept with reducing, alternatively reusing, recycling and recovering materials in production/distribution and consumption processes*" (Kirchherr et al., 2017). In a CE, there is no traditional concept of "waste", but rather, outputs and side streams of some processes may become inputs, or resources, to other processes. The resources from which value is created are acquired from an existing stock of materials and products, transforming linear value chains into circular value loops (Reike et al., 2018).

According to Ellen MacArthur Foundation, the three guiding principles of CE are to:

- design out waste and pollution
- keep products and materials in use, and
- regenerate natural systems. (Ellen MacArthur Foundation, 2022)

The CE also includes an important goal of *hierarchal* disposal and reutilisation of end-of-use goods. In a CE, the existing "stock" of manufactured objects should be primarily preserved (Stahel, 2019, p. 17). The reasoning behind this is that when products are *reused,* they retain both the *material value* of the resources in the product but also the *added value* from the labour and energy that was required in the making of the product, implying that products are more valuable than simply the sum of their materials (Stahel, 2019). The idea in a CE can thus be summarised as retaining and exploiting the existing value of goods by increasing the efficiency of using goods instead of producing them (Stahel, 2019, p. 6).

Frameworks describing CE propose reverse flows of consumption for goods made of both biological and technical nutrients (Ellen MacArthur Foundation, 2019). Products made of biological nutrients should be able to be safely returned to the nature's cycle at the end of their final use, where they may become feedstock for new life to grow. The products made from technical nutrients, for example, metals and fossils, should remain in use for as long as possible, according to the principles of the waste hierarchy, which is presented in Figure 1. The waste hierarchy has been adopted in the European Union as a guideline for national legislation (Waste Framework Directive, 2008). Of the waste

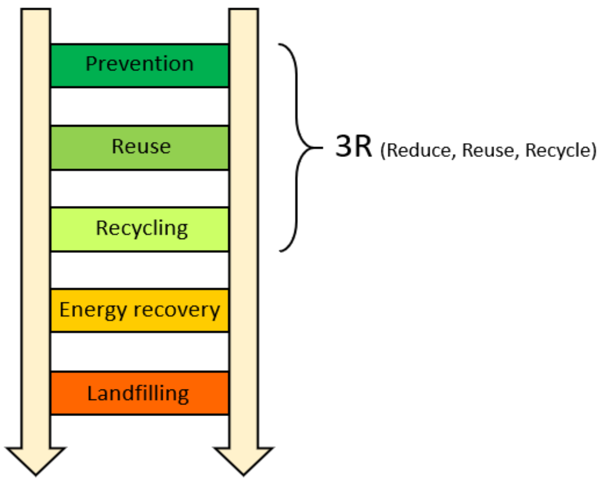

Figure 1: An illustration of the waste hierarchy. The top three steps of the hierarchy present the 3R principle of CE

hierarchy, the preferred alternatives are waste prevention (reducing the use of resources), reuse and recycling, which make up the *3 Rs* of CE (Reike et al., 2018).

The CE is a rather new stream of research. However, CE has been described as an umbrella concept merging several existing research streams, such as the blue economy, biomimicry, industrial symbiosis, reverse logistics, closed-loop supply chains and remanufacturing. (Lahti et al., 2018; Geisendorf & Pietrulla, 2018)

2.3 Circular value chains

In order to attain the goals of CE as previously described, changes are required in the BMs and the roles of business actors within value chains. As CE implies that linear value chains for products are substituted with circular loops, where the products' life does not end after its first point of consumption (Larsson, 2018, p.106), novel ways of organising business activities are needed.

Value chains in a CE can take various forms to meet the goals of *closing*, *narrowing,* and/or *slowing* resource loops (Bocken et al., 2016). When resource loops are closed, this requires the existence of return loops for products, constituting the *closed-loop supply chains*. In closed-loop supply chains, products are collected from their point of consumption to be returned to use (Schenkel et al., 2015). Having to take into account the entire lifecycle of a product means that actors in the design, manufacture, retail as well as customers as both users and suppliers of products in the return loop need to be considered (Yang et al., 2017). Indeed, the CE needs several actors to work towards common goals within value chains or ecosystem-wide value networks (Aarikka-Stenroos et al., 2021). If a company wants to operate as part of a CE, it needs to consider more stakeholders than in linear economy, but it also has the potential to create value to more stakeholders than before (Lahti et al., 2018). Stakeholder theory and multi-actor theoretical frameworks have been utilised within CE and sustainability studies due to the impact of circularity on businesses on the systemic level (e.g., Aarikka-Stenroos et al., 2021; Yang et al., 2017).

The systems of multiple actors within circular value chains can be formed in various ways. For example, Hansen & Revellio (2020) have distinguished in their study between four different CE value creation architectures: *vertically integrated*, *network*, *outsourcing* and *laissez-faire* ("do nothing"). The value creation architecture here refers to the structures of actors needed to add value to a product and bring it (again) to market (Hansen & Revellio, 2020). As Hansen & Revellio's (2020) study in the context of the smartphone industry suggests, *central coordinators*, who may be original equipment manufacturers (OEM) or retailers, can employ various roles in the circular loops of repair, reuse, remanufacture and recycling. They may take control of the return-loop service operations themselves or have contractual relationships with other loop operators to enable reuse. The laissez-faire architecture refers to the existence of independent loop operators, “gap-exploiters”, who capture the closed-loop value while the OEM/retailer focuses on its regular, linear business (Hansen & Revellio, 2020).

Figure 2 presents the “butterfly diagram” of CE, which shows how different actors in a CE are linked by the reverse cycles of long-life product reuse and recycling (Ellen MacArthur Foundation, 2019).

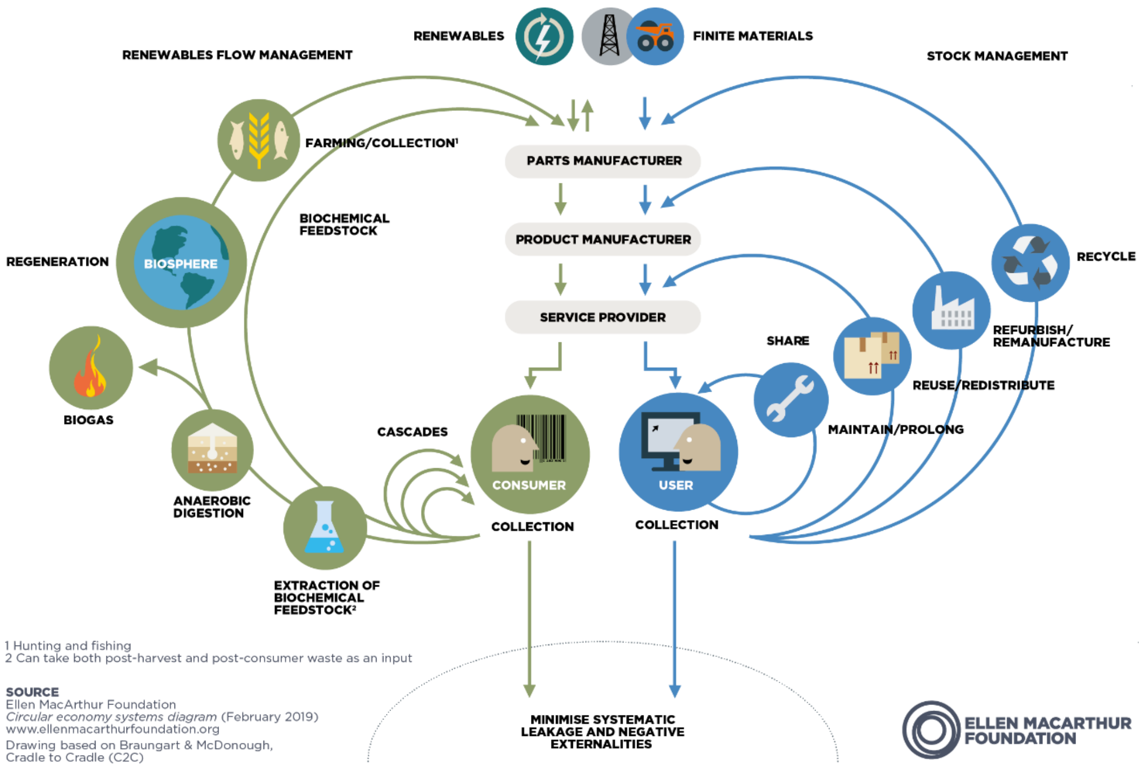

Figure 2: The butterfly diagram of circular economy, depicting the reverse cycles of product and material flows along the value chain (Ellen MacArthur Foundation, 2019)

Circular value chains may involve new types of activities stemming from involving recycled materials in production, new kinds of design methods and reverse loops for product take-back, recovery, and reutilisation complementing the forward loops (Whalen, 2019). Circular value chains thus may involve entirely new business operators or the expansion of existing businesses. One such method for examining value opportunities in the CE is utilising different value mapping tools. Through the identification of “uncaptured value” (value missed, value destroyed, value absence and value surplus) businesses can capture value in a CE by, e.g., increasing the efficiency of production processes to decrease material and energy consumption, utilising waste and existing materials as resources for further value creation (Yang et al., 2017; Nussholz, 2018).

In order for these actors to participate in reuse, they need to be able to capture value for themselves, resulting in the need to innovate BMs across the entire value chain.

2.4 Circular business models and strategies for value creation

Circular BMs provide businesses opportunities for new kinds of value creation, and the topic has been abundantly studied in recent years (e.g., Nussholz, 2017; Ranta et al., 2018; Whalen, 2019; Linder & Williander, 2017). Nussholz (2017) defines a circular BM as "*how a company creates, captures, and delivers value with the value creation logic designed to improve resource efficiency through contributing to extending the useful life of products and parts - - and closing material loops*". Thus, the circular BM brings a circularity aspect to the traditional BM framework (Ranta et al., 2018). Circular BMs also tend to have a more comprehensive view of the targets of value creation, encompassing even value creation to the society (Lahti et al., 2018; Lüdeke-Freund et al., 2019). The circular BM creates opportunities for businesses to redesign their value propositions. For example, the dual role of the customers as both the end users as well as suppliers of used goods means that companies may need to consider value propositions to suppliers as well (Whalen, 2019; Hopkinson et al., 2020).

Businesses operating in the CE environment have various possible strategies and logics for value creation. For example, Ranta et al. (2020) describe four types of value creation logics in circular BMs: *value resurrection*, *value optimisation*, *value sharing* and *value replacement*, arguing that circular principles pose good business opportunities because of their profit potential (Ranta et al., 2020). On the other hand, Bocken et al. (2016) have described various ways that BM strategies can be used to close, slow and narrow loops of consumption of goods. These different strategies are next discussed in closer detail.

Enabling **long product life** (classic long-life model) refers to a BM where products are designed to have a long life and high quality. These products often have a premium price, but the product lasts longer in use, so the customer does not need to replace it so often. In addition, this strategy creates business opportunities around repairing and maintenance to be captured either by the manufacturer itself or some third-party business. Similarly, **encouraging sufficiency** means that instead of selling consumers new products frequently, they are encouraged to make the most of what they already have. (Bocken et al., 2016)

Product as a service strategies also usually include long-life products. According to this logic, manufacturers and service providers do not sell products, but instead the customer only pays for access to the product, for example through a monthly subscription. (Bocken et al., 2016) Product as a service model also may include the **sharing** of a product (Bocken et al., 2016), which means that several users may utilise one product at the same time or each in turn. When one user no longer gains value from the use of the product, instead of becoming waste as in a linear BM, it can be passed on to another user who gains value from it. In the product as a service model, because the service provider has made an investment in the product, it has an incentive to ensure a long product life, so that they can guarantee revenue from the product for as long as possible.

Extending resource value and **industrial symbiosis** strategies aim to close resource loops by assuming resources at the material level as well as waste and side-streams from other industries as inputs to the manufacturing process (Bocken et al., 2016). In Figure 2 this is presented as the role of the parts manufacturer. These strategies enable value capture from the lower cost of resources when compared to acquiring virgin materials.

The special interest of circular BMs when studying value creation and value capture from reuse is *product lifetime extension* BMs (Ertz et al., 2019). According to the **extending product value** (EPV) logic, businesses may create and capture value from providing an offering (services or products) that enables products to last longer in use. The logic may entail that products that are at their end-of-use are collected from their previous owners, recovered back to good quality and then sold to new users (Bocken et al., 2016). A business may utilise this model by exploiting their own products for reselling or remanufacturing, or a third-party “gap-exploiter” can recover some other company’s products for sale (Bocken et al., 2016). The gap-exploiters are non-OEMs who take on a BM contributing to product life extension, and these BMs have been studied in the ICT sector (Whalen et al. 2018), for example. It should be noted that product owners can exploit the residual value of their products also directly by themselves, selling their used products in secondary markets to other consumers/businesses. These consumer-to-consumer segments thus also contribute to product lifetime extension. (Yrjölä et al., 2021)

Studies on EPV BMs are a key source in finding out what business opportunities organisations can capture from reuse. Whalen (2019) has studied EPV BMs from a set of 56 BM cases and identified three types of BMs that extend product value and as such also increase resource efficiency. These three BMs (“facilitator”, “redistributor” and “doer”) have been categorised mainly based on the level of interaction with the product.

The facilitator and redistributor BMs create value to used product suppliers and reused product buyers by providing a service or a platform for their transactions, while value is captured by the focal firm through, e.g., advertising fees or commissions. In the “doer” category, the focal firm alters the products through refurbishing or repair, and then captures value from resale revenues or service fees. (Whalen, 2019) Similarly, Yrjölä et al. (2021) have created a typology EPV BMs focusing on second-hand businesses, identifying that such businesses may fall in the categories of “connectors”, “supporters” or “controllers”. Together with Whalen (2019), these groupings show that businesses can contribute varying amounts to the value creation within a reuse process between the used good suppliers and buyers. Businesses may, e.g., simply provide a platform for the second-hand exchange, thus benefitting from a light cost structure and gaining revenues from advertising space and listing fees. The focal firm may also take some responsibility for the quality of the products, thus decreasing the risk from the buyer or instead have an even greater influence over the reuse transaction, capturing value by employing sales margins within the role of an intermediating retailer. (Yrjölä et al., 2021; Whalen, 2019)

Ertz et al. (2019) have created a taxonomy on product lifetime extension BMs utilising a quantitative literature review method. The authors have found seven different types of product lifetime extension BMs, which are: *relational product-as-a-service, brick&digital product nurturers, quality product designers, second-hand vendors, marketer-managed access systems,* and *peer-to-peer access brokers.* The different BMs utilising product lifetime extension follow one of two strategies: nature or nurture. The *nature* strategy for product lifetime extensions relates to designing products so that they will last longer in use, and the *nurture* strategy describes practices that extend the product’s useful lifetime while it already is in use (Cox et al., 2013).

The link between product value extension and the value chain is also visible in the previous Figure 2: If sufficiency is encouraged, users maintain product ownership and have their products kept in good condition by regular maintenance and repair. Service providers may facilitate reuse by offering a platform and organising redistribution. Product manufacturers can remanufacture their reclaimed products and resell them. (Ellen MacArthur Foundation, 2019; Lüdeke-Freund et al., 2019)

In the following chapter, the concept of *reuse* is further explained, and how the concept links to the EPV BMs. It is also examined what steps are included in a process of reuse.

3. REUSE AS A PROCESS

The previous chapter explained the concept of value in a CE, and how value is retained and created by CE principles. Next, a closer look will be given to what reuse is. This study deals with reuse of tangible goods in product form, and thus the reuse of e.g., software or water has not been discussed.

3.1 Defining reuse

Definitions of reuse are various and are largely dependent on the context. Indeed, several different perceptions as to what constitutes *reuse* can make it challenging to compare reuse practices across different industries (Russell & Nasr, 2019). “Reuse” logically means *using something again*, but based on reviewing the literature for this study it was found that even within CE research there is debate as to what the object of reuse is (product, component, material or waste), what constitutes using it “again” (e.g., is it necessary that the reused good is acquired by different user or ownership is changed), can its purpose change when it is reused, and what recovery operations are allowed on it.

Reuse is commonly included within the R-imperatives in CE (Reike et al., 2018). Reuse is often distinguished from the concept of *recycling*. In recycling, the identity and functionality of the original good is lost as it is processed (Thierry et al., 1995; Hansen & Revellio, 2020), but in reuse, the product retains the “value added” from the making of the product. This “value retention” often discussed in CE refers not to the retention of economic value as such, but instead to the preserving of *intrinsic value* embedded in the good (Reike et al., 2018). A key benefit of reuse compared to recycling has been noted as not having to spend energy in processing the product to material level, only to spend more labour in turning that recycled material back into a new, functional product (Stahel, 2019; den Hollander et al., 2017).

Some forms of recycling, however, can be considered higher value operations than others. In CE, distinction is often made between *upcycling* (primary recycling) and *downcycling* (Bocken et al., 2016) Downcycling refers to goods being processed and utilised in a way that their value is decreased, whereas in upcycling, products and materials are processed so that their value is retained or increased (Bocken et al, 2016).

In the introduction it was first stated that reuse has the potential to affect environmental issues on three levels: reducing resource depletion (using only existing resources), reducing emissions and energy use (not having to alter the product), as well as reducing waste (the product becomes useful after its life). The environmental benefits are clear, but what about economic value? How can actors capture value from reuse, when the concept of reuse is built on reducing consumption and relying on as few new resource inputs as possible? As it turns out, reuse includes potential for value creation and value capture on many levels. These will also depend on the type of reuse and amount of processing required by the focal actor whose value creation and capture are observed. Next, it is examined what the literature says about different types of reuse and what implications they have for value creation.

3.2 Types of reuse

A review of papers regarding reuse revealed that the concept of reuse is more multidimensional than suggested in the rather simple “3R” classification in CE terminology. It was found that, much like the CE itself, also reuse is an umbrella term including several closed loops of consumption. Reuse may or may not involve physical alteration to the original product. When the product is physically altered, it is called product recovery (Thierry, 1995; Fleischmann, 2000) or asset recovery (Ayres et al., 1997) or a value-retention process (Russell & Nasr, 2019). The value-retaining processes contribute to value creation in different ways due to their distinct needs for processing and resource input requirements (Russell & Nasr, 2019). The types of reuse and their value implications are discussed next in closer detail.

Direct reuse and repurposing

Direct reuse is the “purest” form of reuse, because it requires no changes done to the reusable product itself, aside from slight touch-ups (Russell & Nasr, 2019). Examples of direct reuse include consumer-to-consumer exchanges of goods in flea markets, or reuse facilitated by waste management organisations (Ertz et al., 2019; Alexander & Smaje, 2008).

A more “high-end” setting of direct reuse is second-hand exchange. Companies employing second-hand BMs can facilitate the exchange of used goods between suppliers and customers by simply providing a platform for redistributing goods (Yrjölä et al., 2021). Businesses may also participate more in the value creation process of sellers and buyers by e.g., carrying some of the risk related to the product’s condition, or by gaining ownership of the product and serving as a retailer. In that sense, businesses may establish value propositions for both the original user and the buyer of the product. (Yrjölä et al., 2021; Whalen, 2019)

Direct reuse within B2B markets may enable companies to tap into win-win opportunities where both the seller and the buyer benefit. For example, within the biotechnology industry companies may opt to sell or even donate their old lab equipment to other companies, thus gaining value by getting revenue from resale, but also convenience from the freed-up space in their facilities. The buyers, on the other hand, which may consist of smaller businesses or universities, are able to buy high-quality products of limited supply for a fraction of the price (Veleva & Bodkin, 2018).

Repurposing can be considered a special case of direct reuse. Repurposing does not necessarily indicate a change of ownership of the product but instead the term suggest that the product is used in a different context than it was designed or previously used for, either by the same or a different user (den Hollander et al., 2017). A practical example of repurposing would be consumers reusing of empty ice cream boxes as leftover food containers.

While forms of direct reuse don't appear to involve physical alterations to goods, the changes in use context or product ownership/possession are value-adding processes where the product first seen as invaluable or even waste is turned into something someone (else) values. Direct reuse is ranked high in the waste hierarchy because of its high value potential with little to no energy or material losses, but one of its downsides is that the reused product may not meet current standards and its functional lifetime is not extended prior to reuse (Russell & Nasr, 2019; Galbreth et al., 2013).

Repairing

Repairing includes a service or a process where a product's functionality is restored, thus recovering its value (Russell & Nasr, 2019; Hansen & Revellio, 2020). It is more profound a change to the product than preventative measures such as a maintenance service, where the product is kept in possession of its original owner and ensured that it does not lose its functionality in the first place (Lüdeke-Freund et al., 2018). Repairing is sometimes considered a part of refurbishment (den Hollander et al., 2017). Repairing does not indicate that the product would need more added inputs, other than labour of the repair service provider. Repair services provide revenue flows for companies selling durable goods, such as industrial machinery, or enable the functionality of firm-owned goods in product-as-a-service business strategies (Bocken et al., 2016).

Refurbishing

Refurbishing refers to extending the product's use by doing cosmetic or slight functional changes to the product, so that it may continue to serve its purpose for longer (den Hollander et al., 2017). Refurbished products may not meet the original specifications of the product, which is why refurbished goods, like those directly reused, are often resold at discount prices (Russell & Nasr, 2019). Refurbished products are also often sold without the same product warranty as new products (Russell & Nasr, 2019). In practice, refurbishing may, depending on the product and its condition, include the cleaning and grinding of the product's surface or as much as replacing worn-out parts. Refurbishment as a BM was found popular within the mobile phone industry, where "gap-exploiting" companies collect, repair, refurbish and resell used phones (Geyer & Doctori Blass, 2010; Whalen et al., 2018). Because refurbishment does not extend the product's EoL as such, the resale value of the refurbished product is largely dependent on the used product's condition and time of acquisition from users (Geyer & Doctori Blass, 2010).

Remanufacturing

Remanufacturing (component reuse) is a largely studied type of reuse found in literature, although many of the papers written on the topic do not have a CE perspective. Remanufacturing was found to co-occur with reverse logistics and product/asset recovery keywords, and the point of view of the studies was mostly that of the OEM.

Remanufacturing is commonly described as the disassembly of a product to reveal and recover a valuable "core", which may then be reused as part of a new product by augmenting it with new components (Östlin et al., 2008; den Hollander et al., 2017). Remanufacturing is usually part of the manufacturing process of the OEM who has designed the product for disassembly, enabling cost efficiency and fast parts removal. Remanufacturing products enables the OEM to internalise the value of the product's components, so that they may serve as inputs in a new manufacturing process (Hopkinson et al., 2020). The OEM can sell the product "as good as new" for customers, with a warranty similar to a new product, not necessarily even needing to state the "sustainability" element in their value proposition (Russell & Nasr, 2019; Hopkinson et al., 2020).

The efficient dis- and reassembly may require intricate details about the product and its design (Fleischmann et al., 2000), indicating that remanufacturing may not be as easily a "gap-exploitable" recovery process as refurbishing. For example, while investigating LED-lamp value recovery options for a recycling company, Rahman et al. (2019) discovered that the net cost of processing lamps for reuse (considering estimated resale value) was too high due to a lack of initial design for disassembly by the OEM.

A summary of the types of reuse is presented in Table 1.

Table 1: Types of reuse described by various authors, and how they are linked to value creation.

Type of reuse	**Definition** (*cursive* refers to direct quotation)	**Link to value creation**
(Direct) reuse	"*Reuse and redistribution means using a product again for the purpose for which it was originally designed and produced, with little enhancement or change.*" (Lüdeke-Freund et al., 2019) Arranging direct reuse can be done to "*- - those products that are in sufficient working condition, not requiring any component replacement or repair, and to which quick and easy aesthetic touch-ups can be performed - - no disassembly, removal of parts, or addition of parts occurs*" (Russell & Nasr, 2019) [Preparing for reuse means] "*checking, cleaning or repairing recovery operations, by which products or components of products that have become waste are prepared so that they can be re-used without any other pre-processing*." (Waste Framework Directive, EU, 2008)	Preserves product value. Requires no reprocessing labour or additional material inputs, implying less costs. Product may be sold for cheaper price or donated. Supplier may avoid waste handling costs.
Recontextualising/ repurposing	"*- - use of an obsolete product - - - without any remedial action, in a different context than it was - - originally designed for*" (den Hollander et al., 2017)	Preserves or improves product value. Requires no reprocessing labour or additional material inputs, implying less costs.
Repair	Repairing is "*- - simply the correction of specified faults in a product.*" (King et al., 2006) "*- - repair activities bring the entire product back to its original functioning capacity - -*" (Russell & Nasr, 2019)	Restores functional product value. Requires some labour and additional material inputs. Implies service business opportunities for OEMs and independent repair shops.
Refurbishing/ reconditioning	"*Reconditioning involves less work content than remanufacturing, but more than repairing.*" (King et al., 2006) "*the process of returning an obsolete product to a satisfactory working and/or cosmetic condition, that may be inferior to the original specification, by repairing, replacing or refinishing all major components that are markedly damaged, have failed, or that are on the point of failure - -* " (den Hollander et al., 2017)	Restores functional and perceived product value. Requires labour and some additional material inputs. Implies business opportunities for gap-exploiting refurbishers or OEM subcontractors.
Remanufacturing	"*a series of industrial processes in a factory environment, whereby* [the remanufacturer], *disassembles obsolete products into components, - - recombines those components - - with as few as possible new*	Restores or improves product value, preserves core value.

	parts, to manufacture new products of a similar type and specification - - [that have a] *warranty that is identical to that of an equivalent product manufactured out of all new parts"* (den Hollander et al., 2017) *"- - more profound than refurbishing and leads to products as good as new, or even better than new."* (Lüdeke-Freund et al., 2019) "*- - an industrial process where worn out/broken/used products referred to as cores are restored to useful life. - - the core passes through a number of remanufacturing operations, e.g. inspection, disassembly, component reprocessing, reassembly, and testing - -"* (Östlin et al., 2008)	Value may be internalised by the OEM. Requires lots of labour and additional material inputs, which may be offset by the material and product value of the recovered core. Product may be sold for at least the same price as new products. Requires investments from the OEM in design-for-disassembly and reverse logistics.

The types of reuse discussed above describe mainly the operations done to the goods that end up in reuse. Such operations can be viewed as part of a product recovery process, which more accurately describes the three elements that make up "reuse": the disposer market, product recovery operations, and the reuse market (Fleischmann et al., 2000).

3.3 The reuse process

The product recovery process, or "reuse process", is a typology depicting the process of reusing a good ("object of reuse"). (Reike et al., 2018). When reuse is considered, one should look at the both the supply and demand for the object of reuse (Thierry et al., 1995; Reike et al., 2018). For 'reuse' to realise there thus needs to be a source for an EoL product, but also demand for the reused product. Fleischmann et al. (2000) refers to the former as *disposer market* and the latter as *reuse* market.

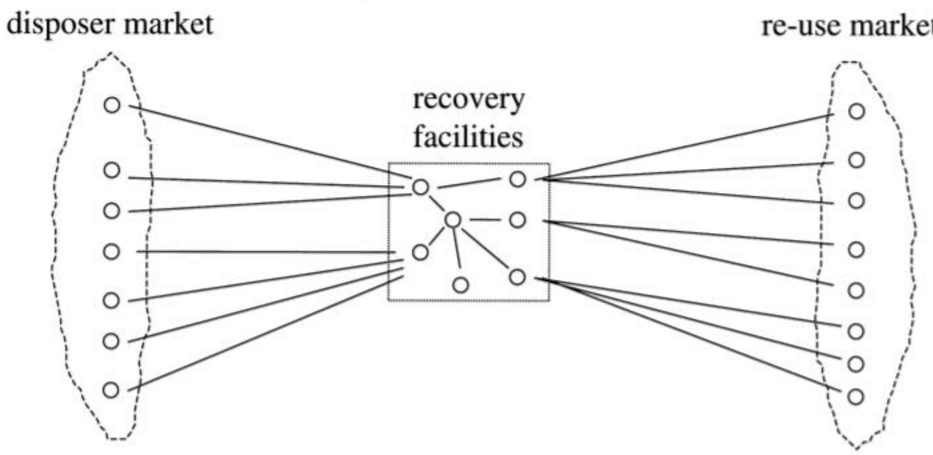

Figure 3: Product recovery network typology by Fleischmann et al. (2000)

Figure 3 presents the product recovery network typology by Fleischmann et al. (2000). The figure demonstrates the aggregate categorisation of the reuse process phases. The disposer market describes the *supply* of objects of reuse. After all, for a good to become reused, it first should be used. Thus, the disposer market contains information on the previous owners and users of the object of reuse (Fleischmann et al., 2005). The objects of reuse may be acquired from their prior possessors in various ways, and there are several strategies in product take-back to enable a sufficient supply of product inputs for the focal firms (Östlin et al., 2008). For example, in remanufacturing, the original manufacturer of the object of reuse may organise reverse logistics to regain ownership of products sold to their own customers (Thierry et al., 1995). On the other hand, a gap-exploiter may acquire objects of reuse from the customers of OEMs (Rahman et al., 2019). The suppliers of these products have an important role in ensuring further reuse potential. It has been found that the initial condition of the supplied object of reuse partly determines the costs incurred in later stages of the reuse process (Whalen et al., 2018; Geyer & Doctori Blass, 2010).

The *product recovery* is understood here as an umbrella term consisting of the various operations that are done to the objects of reuse before they are delivered to the reuse market (Fleischmann et al., 2005). These potential pathways were described in the previous chapter. Aside from actual reprocessing of the objects of reuse, the goods may need to be disassembled (when component reuse is in question), collected, inspected, stored and tested, among other steps (Gallo et al., 2012). However, if direct reuse is in question, no special recovery may be needed. Figure 4 presents a generic reuse process where objects of reuse end up from use to reuse.

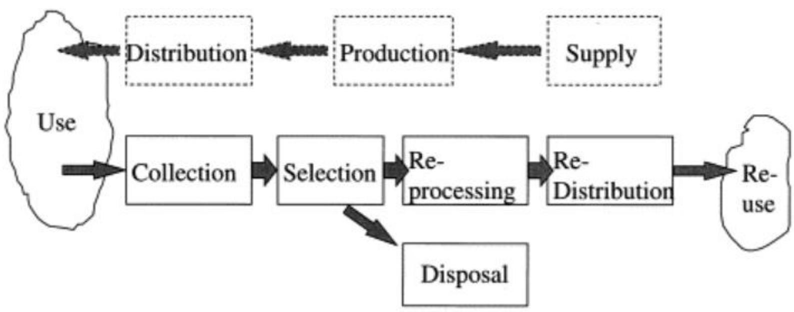

Figure 4: Product recovery chain by Fleischmann et al. (2000)

As opposed to linear production processes, the reuse process is often not stable and needs to adapt to the possible variations in input materials and output products (Brissaud & Zwolinski, 2017). These variations and uncertainties may be linked to differences both in collectable product quality as well as quantity. Objects of reuse may be collected for recovery at different stages of their lifecycle in varying conditions, and they may also contain different levels of upgrades (Goodall et al., 2014). Input symmetry (Rahman et al., 2019) poses challenges for reuse on the component level especially, which may hinder adoption of economies of scale. Because the previous user determines when the product can be collected (Goodall et al., 2014) to serve as an input to the reuse process, it may be difficult to estimate when products become available for reuse. The amount of available product inputs can thus limit the efficiency of product recovery operations (Ayres et al., 1997).

Finally, the *demand-side* (reuse market) of the reuse process depicts the need for the reused product. Reuse does not realise before the products actually end up in reuse, and therefore distinction should be made between processes that only prepare products for reuse versus those that contain the entire closed loop of the reuse process (Russel & Nasr, 2019). The reused product can be reused as part of another product as a component of a whole (e.g., remanufacturing), or the reused product can be redistributed as is (e.g., direct reuse/refurbishing). The target market for reused products may be divided based on whether the reused product comprises a “primary” good or a “secondary” good. Secondary goods are perceived as lower in quality by the customers, whereas primary goods may be sold as new and are perceived as high-quality (Gallo et al., 2012; Fleischmann et al., 2005).

4. REUSE IN THE CONSTRUCTION SECTOR

The construction industry is an interesting setting to study reuse. First, the industry is project-based, with value chains managed by temporary project organisations (Winch, 2014). Second, buildings are strongly location-dependent with long lifecycles limiting building stock renewal (Boardman, 2004). Third, the construction industry is highly regulated, further complicating the acceptance of novel technological and design approaches (Rameezdeen et al., 2016). Finally, the industry is characterised by fragmented supply chains with various actors and chains of contracts (Adams et al., 2017). For these reasons, reuse literature should be reviewed within this context as well.

Reuse in construction has been studied from various points of view and involving various forms of reuse. For example, Gorgolewski (2008) divides reuse of building materials and components into three categories: 1) reuse of an existing structure on site ("adaptive reuse"), 2) deconstruction of components and relocation and rebuild to another location, and 3) reuse of individual components ("component reuse"). Hence, reuse within a construction industry setting can occur both on the building level and component level. Reuse types 1 and 3 are discussed more in detail below.

Adaptive reuse takes place in the building level, it thus regards the reusable "product" as the entire building, or its structure, as opposed to particular elements in the building (Foster, 2020; Iacovidou & Purnell, 2019; Gorgolewski, 2008). Adaptive reuse may be understood as all the forms of changing the use for existing buildings by e.g., renovations, while maintaining the structure mostly intact. Thus, the motivation for adaptive reuse comes from utilising existing components in the building and improving its use value to better suit modern needs while maintaining emotional, historical or architectural value related to the building's exterior (Foster, 2020). Adaptive reuse has also been called "creative reuse", as it often involves a creative insight from the designer to rethink the building as different than it was before. Examples of adaptive reuse are abundant around the world. For example, a unique seed-shaped multipurpose building located in Milan has originally been used for a meeting and event venue but has since been adapted to an IBM Italy innovation hub (Ahrend, 2022).

Because buildings are location dependent, even if a building is not considered valuable in its current location, its components may prove valuable in a different setting (Cheshire, 2016, p. 9). *Building component reuse* refers to utilising prefabricated parts salvaged from an old building in the construction of new buildings (Rakhshan et al., 2020). Old buildings (donor buildings) may become obsolete through various factors, after which they can become inputs to reuse processes, so they do not lose their value on the component level (Thomsen & van der Flier, 2011).

The reuse of secondary building products requires that the components are first salvaged from an existing building. A term which thus quickly emerged in the research on reuse in construction is "deconstruction". *Deconstruction* is a process where a building is systematically dismantled in order to salvage high-value secondary materials for reuse, recycling and even remanufacturing (Pun & Liu, 2006; Dantata et al., 2005; Akinade et al., 2020). The process is sometimes described as ”construction in reverse”, where the building is dismantled starting from the parts that were last installed (Pun & Liu, 2006). In addition to the actual process of disassembling the building and removing its elements, some authors also consider the act of subsequently reusing the components as also being a part of deconstruction (e.g., Thomsen et al., 2011). Deconstruction can be further classified as either non-structural or structural deconstruction. Whereas non-structural deconstruction − for example removing and reusing windows and doors from a building − is rather simple and the products have a solid market, structural deconstruction is trickier and still remains an uncommon practice (Bertin et al., 2020).

Due to its overall rarity, and potential for savings in cost and environmental emissions, structural building component reuse has been largely studied in recent years. Studies have been conducted mostly from a technical perspective and focusing on steel and timber as reusable materials. The reuse of steel has been studied in e.g., Dunant et al. (2018) and Pongiglione & Calderini (2014). The several studies suggest that steel elements, although already having great recycling potential, are also highly reusable building components. Also, the reuse of timber, both from the point of view of deconstruction methods (Diyamandoglu & Fortuna, 2015) as well as the *cascading* of timber (Niu et al., 2021) has been investigated. In cascading, timber can have several uses in its lifetime, first for example as a beam, then cut into boards, then cut into chips to make particle board and finally sawdust. Only after the material value of wood has been entirely exhausted, it is finally burnt for energy. Concrete as a reusable material is discussed more in detail in Chapter 7.1, as the material makes up the context of this study.

Also upcycling of non-building components having applications to construction has been investigated, for example in the cases of using shipping containers (Bertolini & Guardigli, 2020) and wind turbine blades (Joustra et al., 2021) as building components. Conversely, building material from demolitions can be upcycled to products outside the construction sector, such as toys, chairs and drawers (Zaman et al., 2018). Such examples aptly demonstrate that both the “supply side” (the disposer market) and the “demand side” (the reuse market) in construction material reuse can include other industries as well.

Figure 5 presents a type of “ideal process” of reusing valuable components from old buildings. The figure depicts the process by which innovations are required for disassembling buildings in the current building stock that has not necessarily been designed for deconstruction. Initially, building owners need to find creative ways to deconstruct such buildings, which may be a slow, ineffective process at first and still resulting in some waste. Only after this first “cycle of use”, future buildings should be designed for easier disassembly from the start, so that when those buildings are eventually deconstructed, it saves time and resources. (Cai & Waldmann, 2019)

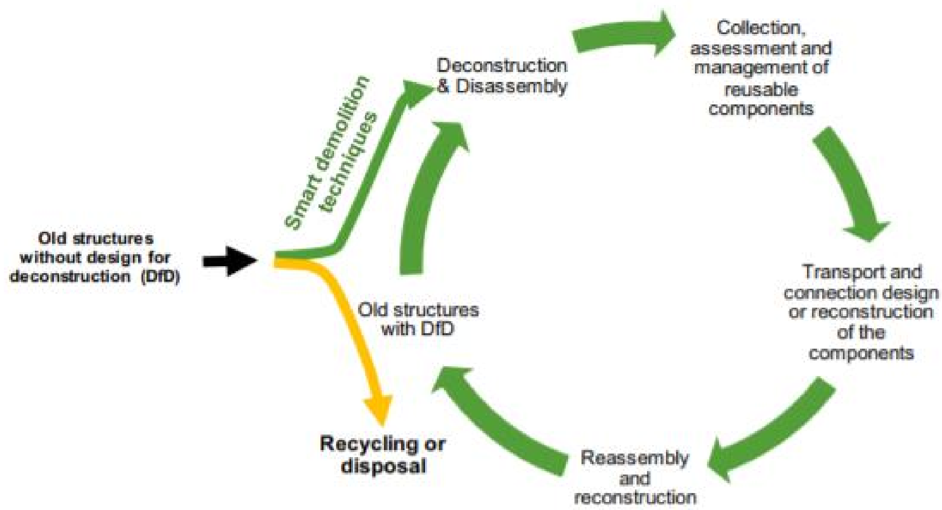

Figure 5: The ideal reuse of value components in eco-construction by Cai & Waldmann (2019)

The process of reusing building components has been studied from the point of view of reverse logistics and closed-loop supply chains research, which emphasise building product reuse as an opportunity to extend product lifecycles (Hosseini et al., 2015). Reverse logistics has been studied mainly in the Australian construction industry (e.g., Hosseini et al., 2015; Chileshe et al., 2016; Rameezdeen et al, 2016; Pushpamali et al., 2020). Reverse logistics in construction may be defined by as “*the movement of products and materials from salvaged buildings to a new construction site*” (Hosseini et al., 2015). This definition is different from traditional reverse logistics within a manufacturing context, because the goal is not to move the product back to the original location, but to a new site (Hosseini et al., 2015). Adding to this, the concept of closed-loop construction suggests that new buildings should be made from reused resources, and the materials “*infinitely recycled through natural or industrial processes”* (Sassi, 2008).

The entire reuse process of construction products may be comprehensively presented as a process combining both reverse logistics and closed loop construction principles. Together, these practices have been described as post EoL building operations (Jayasinghe et al. 2019), which are defined as “*operations and processors initiated for regeneration of materials and products at the [EoL] building [which] result into value-added products which will be available in the secondary markets for construction industry”* (Jayasinghe et al., 2019). In essence, the complete reuse process of building elements can thus be modelled as the route of the elements from EoL donor buildings to product recovery operations and further to redistribution and reassembly as part of a new buildings in a secondary market. This framework is presented in Figure 6.

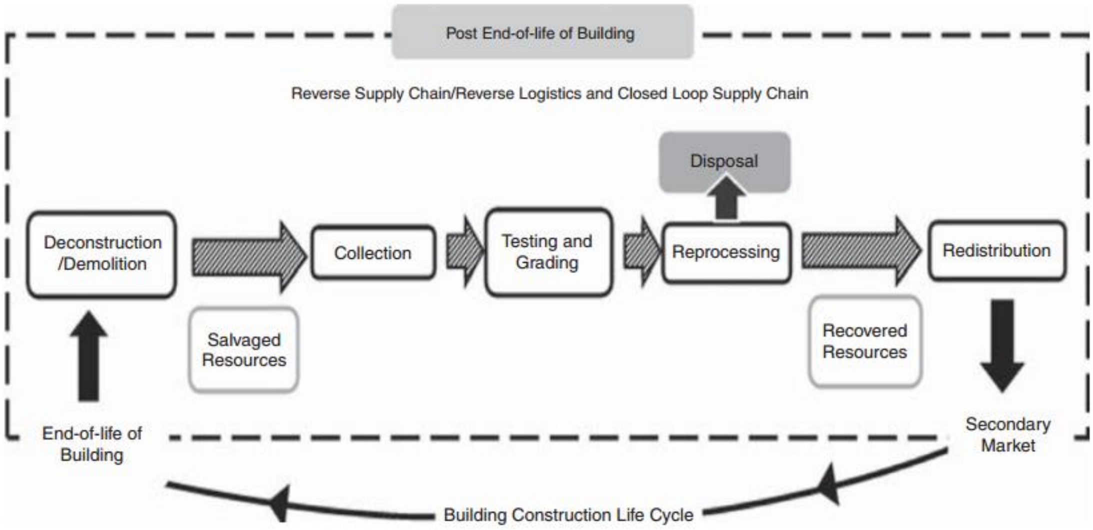

Figure 6: Reverse logistics and closed-loop supply chain operations within the construction sector, from Jayasinghe et al. (2019)

The approach of Jayasinghe et al. (2019) seems fitting for this study as it encompasses various forms of reuse and is essentially a “product reuse process” framework tailored for the construction sector. The model can thus be utilised as a preliminary framework for studying the formation of reuse value chains within the construction industry.

The design of buildings for reuse has been studied largely as it may contribute to “closing the loop” in construction materials by two ways: On the one hand, designing buildings to include secondary materials may reduce the consumption of virgin materials and the accumulation of waste from EoL buildings (Iacovidou & Purnell, 2019). On the other hand, designing new buildings to be easily adaptable, deconstructable and including standardised components when possible may improve the utilisation of their structure and components in the future (Eberhardt et al., 2020). For example, a literature review by Iacovidou & Purnell (2016) reveals that interventions for promoting reuse in the construction sector by design principles fall into five categories: 1) adaptive reuse, 2) deconstruction, 3) design for deconstruction (DfD), 4) design for reuse, and 5) design for manufacture and assembly. Of these approaches, adaptive reuse and deconstruction represent practices that can be aimed at the current building stock, whereas DfD, design for reuse, and design for manufacture and assembly are efforts to enable future reuse. Similarly, Eberhardt et al. (2020) have identified several building design and construction strategies which enable the reuse of building products on the building, component and material level. Such practices include, for example, modular design of building components, the utilisation of prefabricated elements in construction, and designing buildings to have independent layers which can be deconstructed with ease (Eberhardt et al., 2020).

However, there is found to be lack of incentives to design products and buildings for deconstruction (Adams et al., 2017), and the environmental benefits of DfD may realise only after several decades, in case of concrete possibly after 100 years (Rasmussen et al., 2019). Life cycle analysis calculations also favour global warming reducing practices of the present instead of those realising in the future (Rasmussen et al, 2019). The careful design and fabrication of reusable building components has been found to increase initial costs, energy consumption and emissions, but on the long term, if the components do end up in reuse, they have the potential to decrease waste (when demolition is not required) and contribute to material/component savings in new construction or resale potential to external actors (Akbarnezhad et al., 2014).

As a conclusion, when compared to the potential value of reusing components from the existing building stock, economic and environmental value gains from DfD are less certain and may occur only after a long time. Thus, this notion strengthens the decision of the author to focus on exploring the reuse of existing buildings and components, as its benefits are expected to realise sooner. Because the (structural) components of a building are made to withstand time − decades, even a hundred years − they have the potential to create value for a long time. After all, product durability contributes to the slowing of resource loops and enables the product's reuse (Bocken et al., 2016).

Reuse of building materials has been identified as an important way to minimise waste. The motivation for reuse may derive from building owners and demolition and construction companies wanting to cut down on the costs related to disposing of waste. (Rakhshan et al., 2020) For example, Boardman (2004), presents three timeframes to minimising construction and demolition waste: On the short term, waste can be reduced by reusing or recycling the waste generated at demolition (or deconstruction). On the medium term, buildings should be built to include reused components (which will reduce the demand for virgin materials), and on the long term, buildings should be designed for deconstruction. Focusing on deconstruction as a mere waste management practice may be a challenge as old buildings at the end of their lifecycles are sometimes seen as just a liability and mainly something that should be easily get rid of (Rose & Stegemann, 2018). Chileshe et al. (2016) in their study have found that among construction and demolition companies, deconstruction is seen as more of a waste minimisation tactic targeting the minimisation of waste disposal fees, while utilising reused building materials and components in new construction was not seen as an attractive option. In that sense, more research is needed on capturing the value potential that closed-loop construction with reused building products has to offer.

One of the interests of this study is what determines value capture potential in the reuse of building materials. Since reuse is still not yet an established phenomenon in the western construction industry (Adams et al., 2017), the research on reuse in construction has been mainly focused on findings from pilot deconstruction projects (e.g., Zaman et al., 2018) and identifying *barriers* and *enablers* or *drivers* for making reuse and other sustainable practices more common in the industry (see e.g. Chileshe et al., 2016; Dunant et al., 2018). These findings are important to examine as they may have contributions to the value capture potential for businesses.

For example, Rakhshan et al. (2020) in their comprehensive systematic literature review have focused on identifying and categorising drivers and barriers to building component reuse. They discovered and categorised several economic, legislative and social/organisatory factors from literature. It was found that drivers and barriers relating to building product reuse may be present in various phases of the reuse process. Based on the literature review, the economic drivers for building component reuse stem from, e.g., a potential for savings in material costs and avoided waste handling fees (Rakhshan et al., 2020).

Barriers for building product reuse have been largely associated with the difficulty of obtaining building components from donor buildings, as deconstruction may be more time-consuming, costly and challenging compared to traditional demolition (Dantata et al., 2005). It may also be difficult to find skilled workers to implement deconstruction activities or finding enough storage space in the worksite for salvaged materials (Zaman et al., 2018). However, revenue from selling the used components may decrease the costs and involve potential for resale revenues (Dantata et al., 2005; Huuhka, 2010).

In addition to reverse logistics challenges linked to deconstruction, the insufficient supply of secondary building materials may also hinder closed-loop construction (Rakhshan et al., 2020). In addition, because the building industry is highly regulated, the quality of the reusable components is especially important. That is why the potentially low quality of salvaged building components may hinder their reuse, implying that the reuse process needs to be carefully implemented for maximum value retention (Chileshe et al., 2016; Akinade et al., 2020).

The value and benefits of reuse in construction industry are often viewed from a demolition contractor perspective. Van den Berg et al. (2020) have conducted an ethnographic study on how demolition contractors choose which building components end up in reuse and which do not. They have found that a building product may end in reuse in demolition projects if 1) economical demand is identified for its reuse, 2) the demolition contractors distinguished appropriate routines for disassembly, and 3) the contractors may ensure their future reusability (regarding, e.g., storage time). A need for clear financial case for reuse as well as commercial viability have also been identified as drivers for reuse in construction (Adams et al., 2017). On the other hand, Rose & Stegemann (2018) have identified that building demolition contractors find it hard to evaluate whether there is demand for a particular building component or not, which is why building components often end up in waste skips. In addition, remanufacturing and upcycling are not promoted as relevant options for waste reduction in the waste hierarchy, which means that products not assessed for direct reuse may become directly recycled (Rose & Stegemann, 2018). However, with contractual clauses, demolition contractors can be enforced to minimise waste and segregate it accordingly in demolition projects, which may then enable future reuse of the products within closed-loop construction (Ajayi et al., 2017).

The literature also suggests some benefits and implications of reuse to various actors in the construction value chain. Reuse has proven to yield benefits for the reusers of materials, in the form of social value by reducing the costs for the buyer (da Rocha & Sattler, 2009) or serving a special clientele valuing the historical perspective and uniqueness related to used building components (Chileshe et al., 2016, da Rocha & Sattler, 2009). For instance, da Rocha & Sattler (2009) have studied the reuse practices within Brazilian construction industry. They found that reuse processes from beginning of the value chain to the end are made up of varying configurations of actors, and while the different types of actors (such as demolition companies, antiquarians, and builders) are present in many reuse processes, their relationships and roles in the value chains are sometimes different. Research has identified the importance of collaboration between actors and a common desire for reuse in the construction value chain as keys for success of reuse (Hart et al., 2019; Adams et al., 2017; Rakhshan et al., 2020).

5. SYNTHESIS OF THE THEORY AND CONSTRUCTING THE THEORETICAL FRAMEWORK

This chapter draws together the concepts of value creation and value capture, reuse concepts and the construction industry perspective with a comprehensive literature table and its interpretation. Finally, concluding the theoretical overview section of this report is the construction of the theoretical framework used later on in the analysis of the results.

5.1 How reuse creates value − examples from literature

Table 2 presents a selection of research done in various industries from the topic of reuse. A selection of 14 papers have been reviewed from the point of view of three dimensions: *value creation*, *value capture*, and *determinants for value capture*. Only few of these papers address these topics directly, however, and hence the author has used her own judgment in making comparable value related findings based on, e.g., reported economic benefits.

To gain a comprehensive picture of the value creation and capture logics from reuse, papers from several industries were chosen, including research on reuse of various type of electronics (Whalen et al., 2018; Rahman et al., 2019; Veleva & Bodkin, 2018; Geyer & Doctori Blass, 2010), furniture reuse (Alexander & Smaje, 2008) and reuse of solid waste (Zacho et al., 2018). In addition, a three-industry spanning case study (including automotive, healthcare and office product industries) by Hopkinson et al. (2020) was also included. Because this thesis focuses on the construction sector, it was important to include also some papers on reuse in this field (by Tatiya et al., 2018; Zaman et al., 2018; da Rocha & Sattler, 2009 and Dantata et al., 2005). These industry-specific papers are not by any means an exhaustive list of existing research on reuse in these industries or gathered in a systematic means (it was found that there are plenty of papers done on, e.g., remanufacturing of cell phones alone). Instead, the motivation for selecting them is that they provide a practical representation of how reuse practices create value and how it may be captured. Finally, in addition to these “sample studies” it was also important to gain some generalisable findings about reuse from a value perspective. Hence, three papers focusing on *typologies* of reuse and relating BMs were researched. These papers have derived their findings from multiple cases with the number of cases ranging from 21 to 56. The findings related to value logics from reuse are discussed next in closer detail.

Table 2: Value creation and value capture insights from reuse literature in various industries

Authors, year	***Research type, context***	***Reuse focus***	***Insights related to how reuse creates value***	***Insights related to how value is captured***	***Insights related to value capture determining factors***
Findings across several industries					
Whalen et al., 2018	Multiple case study examining two gap-exploiter BMs within ICT sector in Sweden	Repair, refurbishing and resale.	Repair/refurbishment can be offered as a **value-creating service** on its own or take place as **an internal process** of a company whose value is created in **take-back and resale of the recovered products**, where **suppliers are financially compensated**, and **buyers gain products at competitive prices**.	Non-OEMs capture value by offering **recovery services** (repair/refurbishment) and **reselling recovered products** for revenue. Costs incurred are related to **labour** and **reverse logistics** (product collection) and supplier **compensation**.	Favourable **location** of refurbishment activities as well as **good quality of product inputs** decrease the cost of refurbishing. Reverse-logistics costs can be minimised by **economies of scale** in product collection.
Rahman et al., 2019	Scenario analysis of different value-retaining pre-processing options of LED lamps at a French recycling company	Disassembly and reuse potential at product, component and material level.	The different value-retention options performed by the recycling company **retain functional value** of products and components − several products sent for material recycling were still in functioning condition.	The recovered products can be technically **resold** for revenue, but the economic value is difficult to realise without market demand.	There are several **system parameters** affecting the profitability of value-retention options. **Development pathways** for realising value from reuse include establishing a **secondary market**, enhanced **design options** and interfirm **collaboration** in the reuse value chain.
Geyer & Doctori Blass, 2010	Economic analysis of cell phone reuse in the UK and US in years 2003 and 2006.	Reverse logistics and reuse/refurbishing.	The collection of used cell phones creates value as an outsourced service to other companies, as well by compensating and/or offering convenience for individuals in product disposal. Reused cell phones provide functional value to buyers.	The refurbishers gain revenue from the **resale of reused phones**, or the **sale of recovered metals** from phones that can't be reused. The reuse rate should be higher than recycling rate for collection to be profitable.	Choices on "***extent and type of reprocessing***" *as well as for handset* ***collection strategies*** *are based on which options* ***maximise the difference*** *between* [product] *resale values and* [related] *costs*". The faster a product is collected from customers after end of use, **the better its resale value**.

Veleva & Bodkin, 2018	Study of EoL management of surplus lab equipment, analysis of public and interview data of 10 biotechnology companies in the US.	Direct reuse & remanufacturing.	*Suppliers* of used equipment gain value by **financial benefits**, **space and convenience**, and sustainable **reputation.** Value is gained also by **cost avoidance**, **ease of disposal** and potential **tax benefits**. *Customers* benefit from the overall **increased supply** of high-demand products that are sold at a **lower cost** or even **donated**.	The study identified several, emerging players offering EoL management services: **online auction companies**, **remanufacturers**, **non-profit organisations** who facilitate donations, and **OEMs**.	The paper does not address this topic in a clear way.
Alexander & Smaje, 2008	Case study on two furniture reuse organisations' reuse schemes in UK in years 2005-2007	Direct reuse	The furniture reuse organisations gain products through donations and sell them to clients at a lower price, creating social and economic value. Alternative costs related to disposal and collection are avoided. Labour is free for the reuse organisations, and creates social value in employment and skill-building.	The paper does not address this topic in a clear way.	The paper does not address this topic in a clear way.
Zacho et al., 2018	Case study of municipal solid waste management in Denmark	Preparation of waste items for reuse.	**Citizens create value to waste management** by first sorting waste in households. The preparation process by the company adds value to the products. **Social value** is created through employment and selling inexpensive products to customers. **Supplying customers** and **the waste management company avoid costs** from incineration.	Value is captured locally at the end of a product's life by the waste management company by **reselling items for reuse in reuse shops**. The company faces costs in **logistics and labour** from preparation for reuse.	The value capture potential depends on the **resale value** for the products but also the extent of **preparation** needed for reuse. Cheap, subsidised labour is required.
Hopkinson et al., 2020	Case study of value creation and capture of three circular businesses in automotive, healthcare and office product industries	Remanufacturing, refurbishing (+ material reuse)	In this paper, value creation is viewed from circular design perspective (how design principles create value)	Businesses may capture value from reuse by "***resale, performance-based delivery** and **internalisation***".	**Design**, new **BMs, reverse networks** and favourable **system conditions** are key building blocks that enable realisation of value creation and capture from CE.

Findings from the construction industry					
Tatiya et al., 2018	Creation of a cost prediction model and testing it for building deconstruction in Michigan, USA	Deconstruction (disassembly + resale)	The net benefit from deconstruction for demolition contractors may be lower than demolition, considering higher product salvage value and tax incentives.	The paper does not address this topic in a clear way.	Lack of accurate information on deconstruction costs makes contractors choose demolition instead due to financial risks.
Zaman et al., 2018	Whole house reuse pilot project in New Zealand, construction industry	Deconstruction + upcycling	The reuse pilot was shown to create **environmental value**. Value was created in new, **upcycled products** and retaining **emotional value** related to the donor buildings.	Social value is captured by the volunteers involved in the deconstruction and product designing process. The project was, however, not economically viable.	Environmental costs should be internalised, and deconstruction supported to gain economic feasibility.
da Rocha & Sattler, 2009	Study of the reuse process of construction components in Brazil	Deconstruction + refurbishment/repair + resale	Demolition firms gain value from **cost minimisation by resale of salvaged products** (either directly to final customers through retail actors or through refurbishers), end customers gain either high-value products with **historical value**, or lower quality products with **cheaper price**.	Demolition or retail firms gain revenue from component sales to individuals and refurbishers/retailers who then capture value from refurbishing/upcycling and resale.	Given cheap manual labour and demand for salvaged products, the deconstruction is inexpensive. High retail price for products also enables value capture for the refurbishers.
Dantata et al., 2005	Analysis of costs and duration of a deconstruction project in Massachusetts, USA	Deconstruction	Deconstruction brings environmental value from reduced waste and requires less space than demolition due to less equipment.	Deconstruction was found to be more expensive and time-consuming than demolition, making it economically unattractive even considering the reduced costs from resale and avoided disposal costs.	With higher disposal costs and higher contractor productivity through "*training, planning and experience*", deconstruction could become a profitable option to demolition.
Findings from circular BM typologies and taxonomies					
Lüdeke-Freund et al., 2019	Typology of generic patterns in circular BMs, based on 26	Direct reuse, repair, refurbishment & remanufacturing	Reuse BMs retain the product value. Reuse-based BMs can be categorised as "**repair & maintenance**", "**reuse &**	Reuse enables **additional revenue sources** for businesses. **Labour**, **product recovery** processes and **logistics** (and possible	The paper does not address this topic in a clear way.

	cases from various industries.		**redistribution**" and "**refurbishment & remanufacturing**" types.	**resource inputs** in remanufacturing) make up the cost structure of reuse BMs.	
Whalen, 2019	Typology of EPV BMs based on 56 case businesses in various industries.	Product-level reuse (not specified).	The paper suggests three archetypes in EPV BMs: **Facilitator**, **Redistributor** and **Doer**, based on the firm's level of interaction with the product. EPV business models create value to both the **suppliers** and the **customers**.	EPV BMs gain revenue from e.g., sale of "remediated" products, direct resale, transaction fees, take-back service fees from suppliers. Firms may capture environmental, social and economic value.	Costs are minimised when product interaction is small. Costs from product recovery can be offset by **internalising** components into the firm's own production.
Yrjölä et al., 2021	A typology of second-hand BMs based on 21 case businesses from various industries.	Product-level reuse (mainly direct reuse)	Second-hand BMs have different roles (Connector, Supporter or Controller) based on how much they are **involved** in the customer **value creation** of the second-hand exchange.	Revenue streams of studied second-hand BMs were either based on **volume and scale**, **commission payments** or **multiple sources of revenue**.	The paper does not address this topic in a clear way.

As can be seen in Table 2, reuse enables value creation and value capture in various ways. The main focus here is on *economic value* (both direct and indirect), however, other forms of sustainable value (environmental and social value) have also been included as a reference of value opportunities yielded by reuse practices (Yang et al., 2017). Indeed, *environmental value*, which is often a “given” and assumed benefit from reuse and often the main motivation for partaking in reuse activities, has been validated in e.g., Zaman et al. (2018) and Dantata et al. (2005). On many accounts, reuse is also noted to yield *social value* from providing employment to disadvantaged people (da Rocha & Sattler, 2009; Alexander & Smaje, 2008; Zacho et al., 2018). A form of both social and economic value to the receivers of reused products is the fact that reused products are often sold for a lower price than virgin products or may even be donated (Zacho et al., 2018; da Rocha & Sattler, 2009; Whalen et al., 2018; Veleva & Bodkin, 2018; Alexander & Smaje).

Overall, the literature on reuse seems to describe value implications to actors from three categories: the supplier of the object of reuse, (previous owner/user), the business(es) enabling its reuse (focal firms), and the final customer who buys the object of reuse. These emerging findings are presented in Table 3. The value implications of reuse thus seem to have a clear link to the phases of the reuse process as elaborated in Chapter 3.3.

Table 3: Summary of value implications of reuse to actors in reuse processes, according to literature

Value creation to supplier of object of reuse (upstream)	Value capture by the focal firm (mid-stream)	Value creation to receiver of object of reuse (downstream)
+ Financial compensation/resale value (Veleva & Bodkin, 2018) + Convenience (Geyer & Doctori Blass, 2010; Veleva & Bodkin, 2018) + Alternative cost avoidance related to disposal (Veleva & Bodkin, 2018; Alexander & Smaje, 2008; Zacho et al., 2018) - Uncertainty regarding finding demand for the object of reuse (Rahman et al., 2019; Rose & Stegemann, 2018) - (Perceived) costs related to preparation for reuse (Tatiya et al., 2018; Dantata et al., 2005)	+ Internalised value by reuse of components to minimise production costs (Hopkinson et al., 2020) + Revenue from resale or service fees (Lüdeke-Freund et al., 2019; Whalen et al., 2018; Whalen, 2019) - Labour costs related to product recovery (Dantata et al., 2005; Rahman et al., 2019; Zacho et al., 2018; Geyer & Doctori Blass, 2010) - Uncertain, low quality or inadequate supply of input products (Ayres et al., 1997; Goodall et al., 2014)	+ Cheaper/free product (da Rocha & Sattler, 2009; Zacho et al., 2018) + Historical/emotional value relating to the object of reuse (Zacho et al., 2018; Zaman et al., 2018) + Access to high-quality, unique or limited-supply product (da Rocha & Sattler, 2009; Veleva & Bodkin, 2018; Zaman et al., 2018) - Uncertainty regarding the condition of the object of reuse (Yrjölä et al., 2021; Whalen, 2019)

Furthermore, the literature review also suggests that reuse value implications for actors are indeed different in different reuse processes. For example, the amount of product recovery needed to realise reuse seems to have an effect on the type of value gained from reuse. The literature supports the notion that remanufacturing and other labour-intensive types of reuse create value by e.g., advancing employment and resulting in higher quality products (Russell & Nasr, 2019; Nussholz et al., 2020) but have the downside of potentially high processing costs (Rahman et al., 2019, Whalen, 2019). For lower-labour reuse options (e.g., direct reuse) the reuse process is generally less costly, enabling reselling products to buyers for a lower cost while saving materials, but product quality is "second-hand" (Russell & Nasr, 2019). In addition, product recovery functions through repair, refurbishing or remanufacturing may take place as an *internal process* within a (re)manufacturing firm facilitating the reuse, where the product recovery service is not reflected to the value propositions to the customers but instead serves the firm itself. In this sense, businesses can capture the value from reuse in the form of cheaper resource inputs (Whalen et al., 2018; Hopkinson et al., 2020).

Some research gaps were identified based on the literature review. By examining value creation and value capture from circular BM approach (with a focus on product lifetime extension) it can be concluded that there is a lack of research within the CE BM stream focusing on a construction industry point of view. Because the construction industry can be considered a "special" area of research, it needs its own focus. The second angle to identifying the research gap follows from the familiarisation to construction industry research on reuse. Here, it was identified that reuse has been studied from a technical and environmental perspective, with a large section of literature dedicated to the nature strategies of design for disassembly/DfD and other design approaches. Although several notions as to what drives/enables, or conversely, hinders reuse were identified from literature, a comprehensive value-perspective to reuse of construction components was still found to be lacking.

5.2 Framework for case analysis

In earlier chapters, *theoretical literature review* was done to first find out what was known about the key concepts regarding the research problem. Theoretical reviews can be used to identify what theories exist and the relationships between them (Saunders et al., 2019) In this chapter, the theories used as a basis for the case analysis are summarised.

The theoretical basis of this study is formed by many perspectives. First, the reuse process is approached from a technical viewpoint as a combination of several activities involved in the construction project cases. Here, the framework which stems from the general reuse process (Fleischmann et al., 2000; presented in Ch. 3.3) together with the construction industry specific reuse process derived from Jayasinghe et al. (2019) are combined in the discussion and formation of reuse processes of each of the cases from donor buildings through various product recovery activities, to receiver buildings. This theoretical groundwork contributes mainly to RQ1 (the formation of reuse processes in building product reuse) but is also important in understanding the formation of costs, revenues, the actors involved in reuse as well as business opportunities implied by the reuse processes.

Second, taking a value-chain perspective (Porter, 1985; *see* Porter, 1991) a reuse process can also be considered a chain of value-adding activities undertaken by various actors in the reuse process. Each actor needs to consider value implications of reuse with regard to cost and revenues (*value capture*) for its own BM (Richardson, 2008), but also how they create value to other actors in the value chain. The understanding of *circular* BMs and value chains contributes to the identification of *business opportunities* for different types of actors. From the literature, the roles of suppliers, focal firms and (end) customers as both creators and capturers of value were identified – these insights are reflected with the empirical findings. The theories contributing to the case study analysis are summarised in Figure 7.

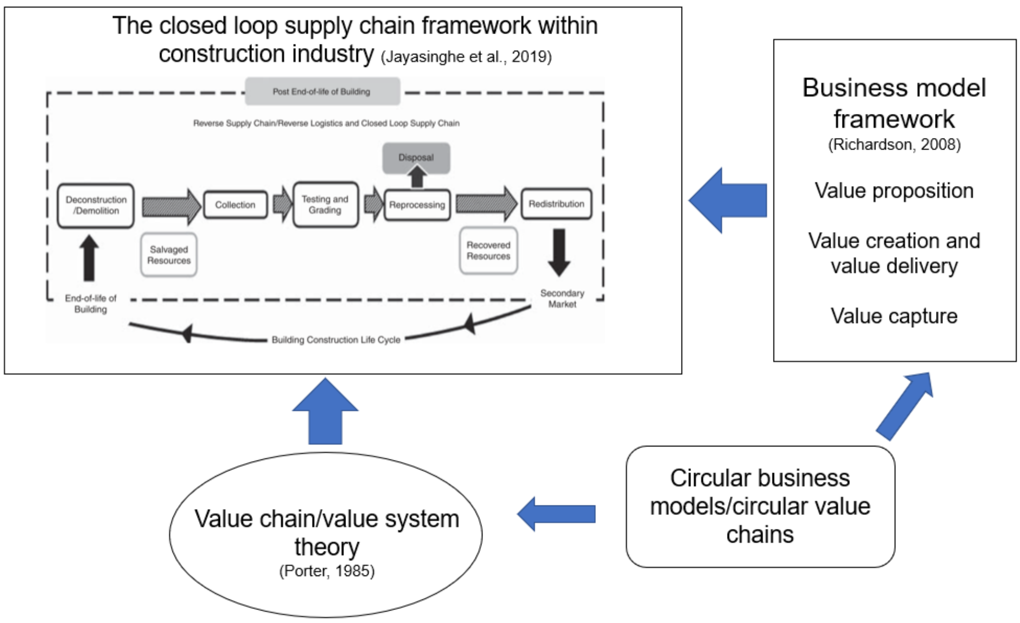

Figure 7: Theoretical framework of analysis

The theoretical framework is a creative combination of various elements and interpretations of value creation in a reuse value system. The theoretical framework should thus be understood as a toolkit of various theories applied to suit this particular study. A creative and flexible approach is required, as the cases and their available data are diverse, and it is not desired to limit the presentation of data too much. Some "freedom" regarding the structure for single-case analysis is needed, as the total contributions of this study are expected to be yielded by the cross-case analysis, where more extensive contributions from one case in a given dimension may supplement the weaker contributions of another case, and vice versa.

6. RESEARCH METHODS

This chapter introduces the methodological choices for the research, with a focus on presenting the empirical research methods. Decisions on research methods have been made to appropriately meet the research objective and answer the research questions as given in chapter 1.2, but as will be shown, practical reasons have also been considered when designing the methods. The research design has been summarised in the “research onion” format in Figure 8.

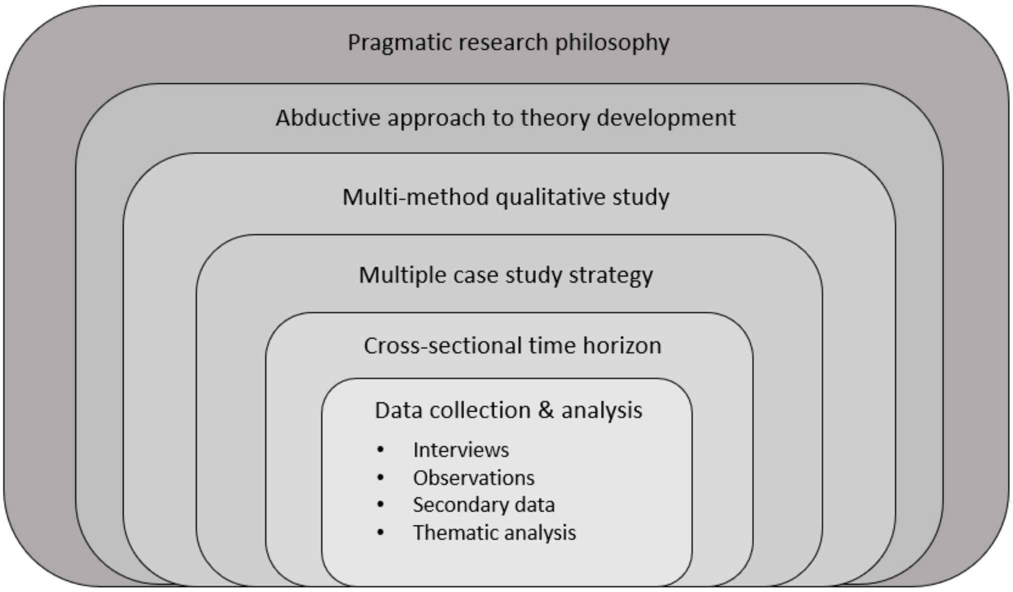

Figure 8: The methodological profile of this study, following the "research onion" format by Saunders et al. (2019)

In this chapter, the research methods summarised in Figure 8 are explained in more detail in the following four subchapters.

6.1 Research design with multiple case study strategy

This is a *qualitative* study, meaning that the empirical data collected for this study is of qualitative nature, focusing on words and text instead of numerical data (Saunders et al., 2019, p. 179). A qualitative research type is chosen, because it is in line with the research aim which is to explore the business and value opportunities related to building product reuse. It is expected that the topic includes intricate details which might not become evident when examined quantitatively (using, e.g., questionnaire forms).

Furthermore, this study utilises a case study strategy, as it is considered fitting for the exploratory research aims of this study (Eisenhardt, 1989). Reuse practices in construction are still a new phenomenon, which is why a careful examination of the selected cases is a good way to learn more about the subject. In addition, this research aims to increase understanding of the subject by a real-world example, and case studies are good for understanding practical, real problems and in understanding studied phenomena in their natural context (Yin, 2018). The strength of the case study thus lies on the rich description of a particular situation and practical manifestations, which may be used to test theory or to derive new insights that may help generate new theory.

In this study, instead of just one case, a total of three cases are studied. Multiple cases have been included to not only gain insights of the reuse phenomenon in one setting but several. There was also a practical reason for choosing multiple cases. Having three cases to study makes up for the limited available depth achieved through investigating single cases. In a multiple case study, what may be lacking in the depth of the individual cases, is thus gained in the versatility of the findings. Including multiple cases allows for the comparison of cases with each other, which may reveal reasons as to why one case may have yielded a different outcome than another (Yin, 2018). Although case studies should not be used for generalisations as such, a case study, especially multiple case study, can be used to identify patterns that can be useful for future research. Thus, utilising multiple cases was seen as important to gain a larger perspective on reuse of building products. The case selection process is explained in more detail in subchapter 6.2.

Case study reports can be structured in various ways (Yin, 2018), but in this study, a combination of single case and multiple case frameworks can be perceived to capture the benefits of both approaches: each case is first individually inspected, and finally the findings are summarised and compared in a cross-case comparative analysis. For practical reasons, an *emergent* case study approach is utilised, which means that, instead of a linear progress in the research process, the case study is shaped by alternating stages of data collection, analysis, and reporting (Saunders et al., 2019, p. 198).

Regarding theory development, this study utilises an *abductive approach*. In an abductive research approach, the existing theory is used where it is appropriate, but the empirical findings also contribute to the creation of new theory. Thus, the abductive approach locates somewhere in between deductive and inductive theory development. (Saunders et al., 2019, p. 153; Dubois & Gadde, 2002) For example, deductive reasoning can be seen in this study in the application of theoretical insights on value creation and value capture from reuse principles as a basis of an analytical framework for interviewing and case analysis. However, induction is used in the end of this report in piecing together the empirical findings with literature, especially regarding the identified value capture determinants.

The author has assumed a *pragmatic* research philosophy. A research philosophy describes "*the beliefs and assumptions about the development of knowledge*" (Saunders et al., 2019, p. 130), and a pragmatic philosophy is understood in the context of this study simply as an aim to create practical knowledge with the resources available for conducting the study. The pragmatic view operates in the background of the decision making in the research process.

This research report describes the studied subject in a *cross-sectional time horizon* (Saunders et al., 2019) because of practical reasons and the limited scope for a master's thesis project. Having said this, one of the studied cases (Case A, *see* chapters 6.2-6.3) involved elements of a longitudinal data collection because the case was still ongoing. In addition, despite the cross-sectional time horizon, the selected cases have occurred in various points in time (*see* Ch. 6.3, Table 4), making their comparative analysis have also longitudinal features despite cross-sectional data collection.

6.2 Case selection

Three cases were chosen for this multiple case study to achieve enough coverage of the phenomenon of reuse in construction, while keeping in mind the practicalities of the available time frame and scope for the study. The cases are represented as construction projects consisting of reuse processes for building products. Selection of the cases was done by *purposeful* (or theoretical) *sampling*. Purposeful sampling means that the cases are selected so that they complement each other, and each add something new to the research (Gummesson, 2017). In that sense, the cases are purposefully different so that a variety in case findings can be achieved (Saunders et al., 2019, p. 198) In addition, purposeful sampling was also the logical choice, because the studied phenomenon is still uncommon, so practical reasons related to accessibility and time constraints had to be taken into account.

As a result, the following criteria was set for the selectable cases:

1. The cases should represent building projects including the reuse of existing concrete in the construction industry (e.g. no DfD projects)
2. The cases should include high value-retaining reuse of concrete (e.g. not just backfilling).

3. The cases should be recent and/or well documented to ensure good data access and topicality.

Case A was chosen first. The choice of Case A was the result of good access to the data as well as its novelty and uniqueness. The selection of Case A, in a way, determined the case selection criteria for the remaining two cases, because further familiarisation with Case A encouraged the decision to focus primarily on *concrete* as a reusable building material. (Prior to this decision, the author was open to the possibility that reuse cases of various building materials would be included.) However, even from the beginning it was important to find cases that had enough in common to ensure relevant *case boundaries* (Yin, 2018). Bounding the case means distinguishing which parts of the data belong to the immediate topic of the case study ”phenomenon” and which are part of the context. Establishing case boundaries helps determine the scope of the data collection.

After Case A was selected, additional cases were searched from a list of references as provided on the website of Finnish Green Building Council (FIGBC, 2021). In addition, participating in events and listening to presentations facilitated by FIGBC was also key to understanding the scope of the studied phenomenon and the number of available cases (*see* Ch. 6.3, Table 5).

Finally, three diverse cases fitting the selection criteria were found, which are presented in Table 4. Case B was selected for variability in point of time (Case B took place about a decade ago while Case A is an ongoing case), while Case C acts as a supplementary case and provides variability to the representation of the studied phenomenon, as it takes place in another country and contains upcycling of concrete in crushed form, as well as the reuse of other building materials.

Table 4: Initial comparison of the cases, presenting their diversity

	Case A	**Case B**	**Supplementary case: Case C**
Country	Finland	Finland	Denmark
Focus of analysis	Prospective/ongoing	Retrospective (> 10 yrs)	Retrospective (< 5 yrs)
Object of reuse	Precast concrete elements	Precast concrete elements	• In-situ cast concrete • Windows • Wood offcuts from production
Type of reuse	Direct, high value-retaining concrete	Lots of quite high value-retaining	Reused & enhanced windows, utilisation of

	reuse (including light recovery processes)	concrete reuse -> from residential buildings to outdoor use, more than 100 concrete elements	surplus wood, upcycling crushed concrete

The cases can be considered *diverse* because they have different (independent) variables (Seawright & Gerring, 2008), at least in time horizon, location, and type of reuse. However, as Yin (2018) mentions, a variable-based approach to comparing multiple cases should be avoided as to not lose the holistic view of the case (p. 196). So, categorising the cases as ”diverse” should not be understood explicitly here, but the term adequately describes the attempt to gain as holistic a view as practically possible by selecting cases that are different in some sense. The cases complement each other, each bringing something new to the research while still describing the same phenomenon.

6.3 Data collection

This study employs the collection of qualitative data utilising multiple methods, making this a multi-method study. The chosen data collection methods were semi-structured interviews, observations (from attended events & selected meetings) and secondary material from public & academic literature, plus other sources. Utilizing such multi-method data gathering allows for *data triangulation* (Saunders et al., 2019, p. 452).

All of the aforementioned data collection methods were used for two purposes within this study. First, the methods were used in forming the overall view of the studied phenomenon, and thus contributed to the understanding of the case context. The (primary) contextual data sources used in this study are listed in Table 5.

Table 5: Contextual data sources in chronological order. The contextual data was gathered in a period of 4 months.

Point of time	**Occasion, topic**	**Role of the researcher**
Late March, 2021	*Theme discussion* One-on-one discussion about CE in construction with a *circular construction researcher.*	Peer discussant
Late April, 2021	*Webinar* Presentations and discussions on the changing construction legislation in Finland and utilising demolition waste of buildings.	Attendee, observer

Late April, 2021	*Webinar* Real estate and construction industry theme meeting including presentations and discussions on the use of recycled products and materials in housebuilding.	Attendee, observer
Early May, 2021	*Interview* Expert interview on reuse of construction products. (Interviewee is a *manager level employee in a construction firm.*)	Host, co-interviewer
Early May, 2021	*Interview* Expert interview on soil reuse. (Interviewee is a *former manager level employee in a construction firm.*)	Attendee, co-interviewer
Mid-May, 2021	*Online workshop* Workshop based discussion on the market potential and policy instruments for utilising building material from demolitions.	Attendee, participating observer
Early June, 2021	*Webinar* Presentations and discussion on CE in the real estate and construction industry in Finland Proper.	Attendee, observer
Mid-July, 2021	*Interview* Expert interview on construction product reuse and CE in demolition. (Interviewee is a *CE specialist in a consulting firm.*)	Host, sole interviewer
Mid-August, 2021	*Interview* Expert interview on concrete-product reuse and related challenges. (Interviewee is a *concrete industry representative.*)	Host, sole interviewer

The other, and primary purpose of data gathering was to collect case-specific data. The data sources utilised for this purpose are listed in Table 6.

Table 6: Data sources for collecting case-specific data

Data type	**Case A**	**Case B**	**Case C**
Semi-structured individual interviews	**I1**: Manager* in Construction company (5/2021) **I2**: Chief in Concrete element manufacturing company (7/2021) **I3**: Manager in Structural design & consulting company (8/2021) **I4**: Site Manager in Demolition company (9/2021)	(Positions of interviewees as they were during the case project in 2008-2010) **I9**: Architect (1) in Architectural design office (9/2021) **I10**: Architect (2) in Architectural design office (9/2021) **I11**: Building consultant in Building consultancy company (10/2021)	-

	I5: Architect in Architectural design office (9/2021) **I6**: University researcher (10/2021)	**I12**: CEO of Housing company (10/2021)	
Semi-structured group interviews	**I7**: Manager & Specialist in City organisation (10/2021) **I8**: Two Managers* in Construction company (10/2021)	-	-
Observations, notes, presentation material	3 meeting attendances, 6 sets of meeting memos	3 presentation materials, 1 presentation video (9 min)	-
Company published data	-	1 company website	2 company websites, 2 analysis reports, 1 white paper publication, 1 book
Media sources	1 news article, 1 project website	1 presentation video (9 min)	8 news articles, 1 trade magazine article
Research reports & publications	-	1 thesis, 1 academic journal article, 1 trade journal article, 1 project report, 1 seminar publication	2 academic journal articles
Other	1 research project funding application	5 chronological photo books of the case project	-

* the same person was interviewed twice: individually and as part of a group interview

As can be seen from Tables 5 and 6, the collection of data includes observations, interviews, as well as secondary data. Next, the different data collection methods used in this study are explained in more detail.

6.3.1 Observations

Contextual data regarding CE practices and potential for the construction sector was gathered as observations from 4 attended online events that were held remotely via Teams. Here, the author had a mainly observatory role, taking notes and listening to the presentations and following discussions in the Teams chat (i.e., the author was not in charge of hosting the events). In the workshop event the author also took a more participatory role because the nature of the event insisted it, but the goal was to learn from the more seasoned experts present at the event. The key observations were written down during the events, but they were afterwards supplemented by the written presentation materials (PowerPoint-slides).

Observations were also used as a method for collecting case-specific data. In Case A, the author attended 3 remote meetings as an observing attendee, taking notes of key details regarding the case project while following the discussion between the project participants. Here, the author was able to get an inside view of the discussions with the key actors about the ongoing state of the reuse case in real time.

6.3.2 Interviews

Interview-data was an important part of data collection in this study. A total of 14 interviews were held by the author together with other participating researchers (in addition to these, the author participated in one contextual interview in a “listening”-role). Out of these interviews, 12 interviews were related to the studied cases, while additional 2 interviews were held to understand the case context. The first interview (**I1**) actually had both an introductory as well as a case-specific role as a data source because it took place so early in the research process, but the other interviews listed in Table 6 were already focusing on data gathering for the case studies. Most of the held interviews had only one interviewee at a time, but group interviewing was also utilised on two occasions for Case A to gather more comprehensive insights from the actors. The interview method was applicable for data collection for Cases A and B.

The case-specific interviewees were *purposively* sampled from employees and management representing the key actor organisations in the cases. The interviewees had diverse backgrounds and expertise. The interviewees were contacted via email and/or by phone. Their contact information was acquired from internal channels within the research personnel. In Case B, some interviewees were sampled by a *snowballing* method, where some interviewees had recommended contacting other potential interviewees that they knew had participated in the case project. For the contextual interviews, the interviewees were gathered based on suggestions and participant lists from the contextual webinars (Table 5).

The interviews followed a *semi-structured* format. In semi-structured interviews, the thread of the conversation is given by the set of predefined research themes (Saunders et al., 2019, p. 437). This type of interviewing was chosen, because there was no need to conduct each interview as similar. On the contrary − since this study is exploratory in nature, it was only natural that the interview questions changed and got more specific as understanding on each case grew after initial interviews. Some of the questions were also altered to suit best for the interviewee’s own background. The interview themes were not, however, very strictly formulated and some questions were omitted in some interviews while included in others. Often during the interviews there emerged a need to ask supplementary questions from the interviewees. Thus, in practice, the discussions included features of *open interviewing* as well. The topics discussed in most interviews and the reasoning for why they were asked are listed in Table 7.

Table 7: Topics of the semi-structured case-interviews for cases A and B, and how these topics benefit the analysis.

Interview topic	Goal of the given topic for analysis
Interviewee's introduction and description of their role in the organisation.	Getting to know the interviewees background for determining their personal knowledge of the project.
The interviewed organisation's role in the case project.	Getting to know the actor's position in the reuse process & determining the focus of the subsequent questions to be asked.
What steps are/were included in the reuse process for this case? • What is/was the source for the building products? • What steps were/are included in the reuse process of the building products? • What was/is the destination for the building products?	Gaining general knowledge about the reuse process, determining which actors are involved and gaining a general idea of the cost intensity of the reuse process, especially regarding the product recovery phase.
Which functions in the reuse process are/were most laborious, risky, difficult or costly, and why?	To determine the costs (value capture) and how the costs are determined (value capture determinants).
How does/did your organisation's current know-how and resources translate to this kind of reuse process?	To determine the costs and business potential.
How could building product reuse be made easier/cheaper/profitable?	To determine value capture determinants.
(Only for Case A) How do you view building product reuse as part of your organisation's business in the future?	To determine business potential and value creation.
(Case A) What expectations does your organisation have for this project? / (Case B) How were the goals for reuse met during the case project?	To determine the expected and realised value creation in the project.

All the interviews were hosted remotely via Teams meetings. The interviews lasted from 45 to 100 minutes, with most interviews lasting about one hour, which was the allocated time reserved for the meetings. The online setting allowed for the interviews to be recorded in video format. During the interviews, notes were also taken to keep up with topics in the conversation. After the interviews, the conversation was usually transcribed in written form for easier analysis. About half of the interviews were transcribed by an external transcription service provider. For practical reasons, the automatic transcription feature in Teams was utilised in interviews that took place from September onwards. For these interviews, the transcription needed to be improved and edited afterwards by the author in sections of text that were considered most important regarding the analysis phase. For the two solely contextual interviews, transcription was not seen as necessary, and thus only written notes and video material was gathered.

6.3.3 Secondary data

Secondary material also constituted a large fraction of the available and utilised material. Secondary data refers to existing data that was initially collected for another purpose (Saunders et al., 2019, p. 338). In especially Case C, the secondary material was the only source of data. In addition, for Case B, secondary sources were considered a reliable source of data due to time passing since the project took place over a decade ago. Access to some potential interviewees who worked on the project was also challenging since they may have changed jobs during this time, and the memory of available interviewees regarding details of the case may have been faded.

Another reason why secondary material was an important data source for both cases B and C is that the cases have already previously been subject to research, so it was beneficial to review the existing literature regarding the cases to find out what is already known about them and what aspects should, if possible, be expanded through further interviews. Secondary material also provided valuable data for researching and reporting the backgrounds of the cases prior to further analysis of the case. For Case A, less secondary material was used because of the project's novelty (meaning that there was still a lack of secondary material) and good access to sufficient amount of data from interviews.

In Case C, secondary material was mainly chosen for practical reasons. It was difficult to gain access to those involved in the case, so the sole source of material was secondary: public internet sources and prior research. Since Case C is a Danish project, not all material was available in English, thus some documents had to be (automatically) translated. However, English material was also easy to come by due to the project's global recognition.

One of the difficulties related to the gathering of secondary data had to do with the case bounding. Because the focus was on the reuse processes in the setting of particular construction projects, and not, for example, so much on individual firms, relevant secondary material was less available. Hence, the seemingly "small" number of secondary documents in Cases B and C as can be seen in Table 6 actually represent a relatively large sample size.

6.4 Data analysis methods

Much like the data collection, data analysis was also done a qualitative fashion. The written data was analysed *thematically* to identify relevant meanings and recurring themes and real events. The case study research strategy and the nature of chosen the research questions were seen to favour qualitative analysis − there was no need to focus on the number of times a certain keyword has appeared in an interview, for example. In this study, it was important to understand the larger meaning behind the data.

A framework for initial analysis as was presented in Chapter 6.2 was utilised to categorise the data in a presentable form when analysing the cases. The framework was a useful tool to determine what should be looked for in the data, and on the other hand, to see how the empirical findings relate to the theory, as per the abductive approach (Dubois & Gadde, 2002). However, the exploratory nature of the study meant that the author did not want to limit the analysis too much so as not to leave out any meaningful pieces of information that would not fit a strict initial framework. The theoretical framework was thus utilised as more of a guide for analysis.

The initial idea was to conduct thematic analysis and coding utilising "Atlas.ti" − a computer-assisted qualitative data analysis software tool, however, the software was found slightly awkward to use, and thus eventually only served the purpose of gathering the interviews in one place of easy access and reading. After further consideration, a combination of Excel and Word was used in categorising findings from data and conducting the qualitative analysis. After conducting the first few interviews, even a standard "pen & paper" method was initially used to familiarise with the data, thus already beginning the data analysis during the interview round. Such parallel analysis and data gathering is considered beneficial for continuous theory-building, especially within case study research (Eisenhardt, 1989).

In practice, the transcriptions of the interviews (in ".docx" format) were familiarised with by first carefully reading through the documents several times. The important sections of text were highlighted in Word so that they would be easily discernible for when the document was read through again. The transcriptions were from 20 to 70 pages long depending on whether the text was fully transcribed by a person or whether it had some automatically transcribed sections left in which made the text format longer. The highlighted sections of text constituted an "in vivo" type of coding where it was identified that something mentioned in the interview was important but not fully understood as to why. "In vivo" coding is natural to use in data-driven analysis such as the inductive phase of this study (Saunders et al., 2019, p. 655). When re-reading the transcriptions, comments were also added directly to the documents as notes. This procedure of highlighting and commenting was repeated for each interview transcription, and yielded findings that could be gathered in a separate document for each of the cases. This method proved to be quite slow to use, as the lengthy documents needed to be browsed several times, but the benefit was that the data became familiar enough that the content of the qualitative data sources was soon easily memorised, and the information could be continuously processed mentally.

Once the findings regarding both case descriptions and value implications were all gathered, the text was edited in a free-flowing narrative form within the single-case settings. The reuse processes themselves were identified thematically from the data from both primary and secondary sources. Regarding value creation and value capture, key actors in each case (for which value implications could be discerned from the data) were used as a guiding format in which to categorise and narrate the value implications of the reuse process. Only one interview transcription was the focus of analysis at a time, which was enabled by the choice to structure the value-related findings for each actor separately (since 1 interviewee often represented 1 actor). However, some findings regarding certain actors were found in other interviews as well, and thus the collection of findings in a single document *per case* was needed. The value capture determinants, on the other hand, were thematically categorised from the data, and here, Excel tabling was utilised to structure the findings. Regarding secondary data in Case C, a slightly altered approach was needed, as the data was in pdf form. Atlas.ti was also used as it allowed for coding directly in the documents, but mostly *in vivo* type of coding was utilised here. Most of the secondary data was already in structured format, and the reporting included the review of how the topic had been previously researched.

The results from the thematic analysis − done for both the individual cases as for the cross-case analysis − constitutes the *analytic generalisation* from the cases, which can be based on ”*corroborating, modifying, rejecting or otherwise advancing theoretical concepts that [were] referenced in designing [the] case study or* - - *new concepts that arose upon the completion of [the] case study*” (Yin, 2018, p. 38). Because this study largely uses abductive reasoning, preliminary findings from prior theory is used to conduct analysis (deduction) and emerging themes from the data are also compared with theory (induction).

6.5 Validity and reliability

Validity and reliability are key criteria for determining the quality of research. Reliability indicates, *inter alia*, how well the study can be replicated by other researchers using the same methods. Validity, on the other hand, concerns whether the conclusions made by the researcher accurately describe the nature of the studied phenomenon. (Eriksson & Kovalainen, 2016)

In this study, reliability is taken into consideration by transparently describing the data collection and analysis methods as presented throughout Chapter 5. The choices made throughout the research process are justified so that readers may evaluate which parts of research should be kept the same and which can be altered to achieve a desired outcome for future studies in the same field. The used sources are also appropriately referenced which aids readers in finding the appropriate data and drawing their own conclusions based on it.

Two of the cases (Case A and Case B) utilised primary interview data. Due to their semi-structured nature only aggregate interview themes are presented in this report; eventually the flow of conversation determined the actual outputs of the interviews. Reliability in this context thus may be weakened, if reliability can be even considered a good metric in qualitative interview studies at all (Eriksson & Kovalainen, 2016). In Case C, the utilised data was all secondary and available online, which can be an asset regarding reliability, whereas validity may be threatened when dealing with only structured data gathered originally for other intentions. Triangulation, which is a good procedure for strengthening validity (Eriksson & Kovalainen, 2016), has been utilised whenever suitable. For example, interview data is gathered from multiple sources and backed with secondary data. Some validity issues may also be linked to the author's lack of expertise in the case context, despite gathering evidence from empirical observations and literature background.

As a conclusion, one may argue that certain choices done in this study with regard to methodology may improve the validity of certain aspects of the research design at the expense of lowered reliability, and vice versa. The reader should also familiarise with the research limitations as presented in Chapter 8.3. The limitations explain under which conditions the findings from this study can be generalised to ensure external validity (Yin, 2018).

7. RESULTS

This chapter presents the empirical findings gained from the three different cases for building product reuse that were chosen for the case study: 1) deconstruction of an office building for maximum high-value reuse of its components, 2) partial deconstruction of an apartment building and subsequent local reuse of its elements, and 3) upcycling crushed concrete for a new building. Each case is first presented in a single-case study framework consisting of a case description and a two-phase analysis section of value implications for actors and the value determinants identified in the single case setting.

This chapter concludes with a summary of the single-case findings and a cross-case analysis where the three main research questions are answered in the multiple-case framework.

7.1 Concrete building materials as objects of reuse

Before moving on to the case results, the role of concrete in building product reuse is shortly discussed − as it is the special focus of this study and present in all of the studied cases.

Concrete is a highly common building material used in construction as both in-situ cast directly in the worksite to the right form, or as prefabricated components delivered to the worksite. Concrete is composed of cement, fine aggregates (sand), coarse aggregates (gravel or crushed stone), water and some chemical admixtures that improve workability (Arm et al., 2014). In addition, concrete may be reinforced with steel to improve the strength and ductility of the structure.

As concrete structures reach the end of their use, the common way to get rid of them without contributing to the generation of waste is to crush the concrete to be used for backfilling (replacing soil that is removed during groundworks) or roadfilling (as sub-base for road construction). Climbing higher in the waste hierarchy, the reuse of concrete has been implemented and researched in both material and product levels − crushed concrete may substitute coarse aggregates in new concrete production and precast concrete may be reused on the product or component level. The latter is more in line with CE and has the potential to retain most of the value of concrete products. Reuse of concrete aggregate in the manufacture of new concrete has been criticised, because while it requires the use of energy in processing, it does not address the real concern of the environmental impact of concrete, which is the cement (Huuhka et al., 2015).

Conversely, environmental benefits related to the reuse of concrete in element form have been identified in studies, even when considering the possibly long transportation distances to the reuse site (Lahdensivu et al., 2015).

Huuhka et al. (2015) and Lahdensivu et al. (2015) have studied the technical feasibility of concrete reuse in Finland. Some regulations prohibit the reuse of concrete elements in Finland. For example, floor height and acoustics requirements mean that old elements may not meet these current standards for high-rise buildings. This does not, however, prohibit the use of these elements in detached houses. (Huuhka et al., 2015) Findings from studying concrete elements of Finnish building stock indicate that although there has not been formal standardisation of buildings in Finland, the dimensions of concrete elements are quite uniform, enabling their reuse (Huuhka et al., 2015).

7.2 Case A: Deconstruction for maximum high-value reuse

7.2.1 Description of Case A

Case A is part of an ongoing Finnish deconstruction and reuse project which aims to pilot the reuse of precast concrete elements from a pre-determined donor building to a new building. The project involves the contributions of several construction industry companies: an architectural design office, a structural engineering company, a concrete element manufacturer, a demolition company, and a property developer. They have a common mission to gain a successful experience from reusing concrete elements, and at the same time gain information on how the reuse process could be improved in

Figure 9: Donor building in Case A.

subsequent projects, and how reuse might influence the actors' own BMs. During the project, the actors meet up in regular monthly meetings to discuss the practicalities of the project as well as ideas on its implementation, led by a coordinating researcher.

The donor building in Case A is an office building located in the city centre (Figure 9). The building has a concrete structure − it contains concrete columns, beams, floors, hollow core slabs and wall elements. As the building is deconstructed, it is intended that suitable precast concrete components from the donor building will be reused as elements in other building projects, to the extent that is possible within the project scope and budget. The donor building is currently in possession of the property developer, which overviews the deconstruction of the building.

7.2.2 The reuse process in Case A

The reuse process for Case A is presented in Figure 10. The condition of the donor building and its structure is first checked by various tests and observations, and thus a *pre-deconstruction audit* is first implemented on the building. This includes doing a digital inventory of the building's structural (concrete) elements based on existing building documents, as well as doing a study on harmful substances in the building. In addition, a structural condition investigation is conducted on the donor building to find out the condition of the elements. The deconstruction planning phase contains all other steps that are needed for the actual deconstruction work, including establishing an order of disassembly for the reusable elements. "Deconstruction" here refers to the actual disassembly of the donor building, and the salvaging of the reusable concrete elements.

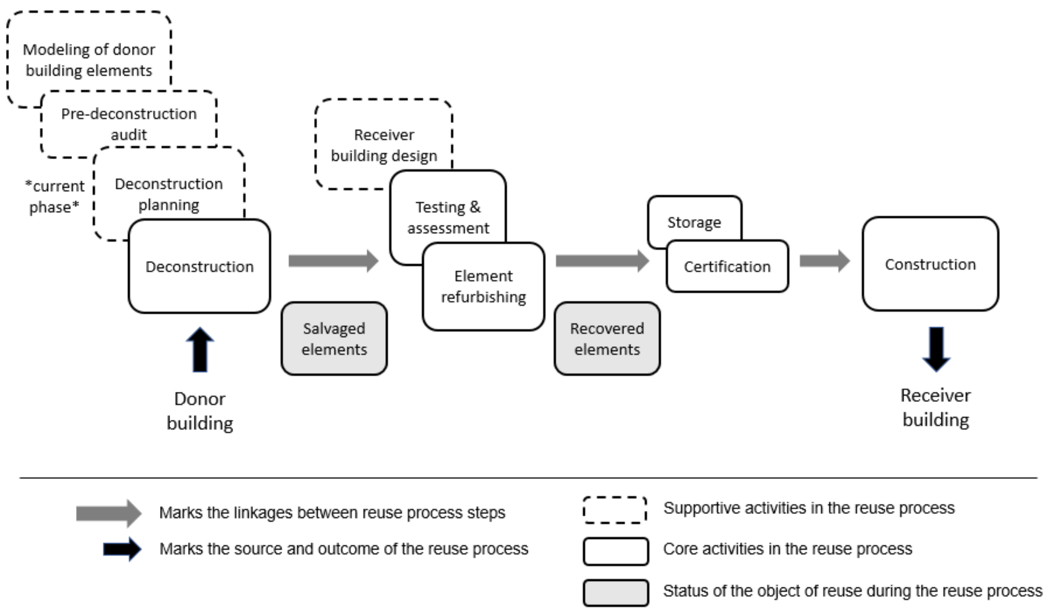

Figure 10: Author's interpretation of Case A reuse process. Currently, the project is in the deconstruction planning phase.

Once the elements have been salvaged, they will be subject to possible further quality testing, after which the elements may need to be refurbished to meet the standards of their use in the receiver building. The elements' condition and target use in the receiver building will determine whether a more comprehensive refurbishment indoors is needed − otherwise the elements are assumably lightly refurbished either on the donor building site before transportation, or on the receiver building site right before assembly (this aspect was still uncertain at the time of data collection). Nevertheless, the interviewees shared the idea that transportation to a storage facility to await reuse was likely needed. The elements will also need to be certified so that they may be comparable to new elements in the building phase. The reuse process realises when a receiver building is assembled to include the used and recovered elements.

It should be noted that the author is not a construction industry expert, and hence (also due to the a priori nature of the data) the reuse process activities and their order in Figure 10 should be understood as illustrative − all of the technical details are not considered essential regarding the objective of this study. At the time of the data gathering for this study, the project is at its early stage, and the physical deconstruction of the donor building is planned to take place in Spring 2022.

7.2.3 Value implications to actors involved in Case A

Going back to Figure 10, it can now be discussed how these different phases of the reuse process for concrete in Case A represent various opportunities for value capture to different actors. The results are discussed from a *potential* value creation and capture point of view, because the data collection has taken place prior to completion of the pilot project, and thus, no realised value could be determined yet.

Structural designer

The structural design and consulting company provides design and engineering consulting services in both building refurbishing as well as structural design. The target of the company's value creation in the system is the property developer. The goal is to enable an adequate supply of intact, reusable elements at a reasonable cost. In addition, the work of the structural designer provides information to the demolition company, who will disassemble the elements. The structural designer is also involved in the structural design of the receiver building, ensuring that the receiver building may partially include reused elements and will meet its structural requirements.

The structural designer's role in the value system is in performing a condition assessment and pre-deconstruction audit of the building, as well as in planning the deconstruction. It is also involved in the structural design of the elements for the receiver building.

> "*Our interest in this project is in developing the design and research perspective: what kind of things need to be figured out [in this project] regarding how the structures are built and what kind of plans are needed for deconstruction… For example, what kind of mountings do we need for deconstructing a building?*" (**I3**)

The work of the structural designer combines the company's know-how on many levels. The company may utilise its existing competence in condition assessments related to concrete structure renovation projects as well as pre-demolition audit experience related to demolition projects. The company also has knowledge from structural design using virgin construction elements. On the other hand, the reuse process includes characteristics that calls for creating totally new processes.

> "*The current methodology [in condition assessments for buildings] does not include practices for investigating the dry, interior concrete structures in any way, because previously there has not been need for that. Now we need to determine the information that is needed from the structures at minimum so that [the elements] can be reused somewhere else*." (**I3**)

The company wants to be involved in the project to develop their role in deconstruction planning. It wants to enhance its know-how and build expertise in deconstruction, thus gaining *information value* from the project for future reuse projects. The company may build on its existing experience in condition assessments from demanding demolition projects.

Taking part in the reuse process enacts the structural designer's circularity and *sustainability values*. More importantly, the company wishes to take a proactive approach in the industry, enhancing their competence in deconstruction in the expectation that it will create *future customer value*. The company recognises that there will be a need for such deconstruction planning services in the future. A manager level employee elaborated:

> "*We know that the demand will be there. - - "We see that [deconstruction & circular construction] might not be business today, next year or even the year after that, but we want to invest in it because we recognise that in the future it will be*." (**I3**)

The company also notes that its customers may face stricter carbon neutrality expectations from legislation, thus making it imperative that they have existing solutions when customers will start to need them.

The interviewee did not believe that the work they're doing in the current reuse process would be conducted as a new, separate service in the future, but rather, that the nature of the work becomes "more value creating" from a resource efficiency and environmental viewpoint. The interviewee also pondered that the design work might become more laborious and demanding for the designers, raising the total fee of the service.

> "*I don't think that this would become a whole new, separate business or that we would need new, separate employees to do this for us, but rather that [providing reuse related services] advances the work of our existing employees in a way that adds more value to our customers and maybe even the society.*" (**I3**)

The employees of the structural designer would gain more competence in providing a pre-deconstruction service, which would be more comprehensive than a traditional pre-demolition audit. On the other hand, the company's designers would have the knowledge of how to design structures in receiver buildings that include also reused elements.

The research material suggests that the structural designer views serving the customer as important and customer value creation to be the imperative for the company's own success. The company representative reflected that the greatest risks in the reuse process are if the deconstruction planning process becomes financially too inviable for the property developer, or the elements cannot be removed intact, so that the property developer is unable to reuse them. For future projects, the structural designer views it important to conduct the assessment services in a resource efficient way. The interviewee highlighted that one element should not be individually studied too carefully, because the costs would get too high for builders to reuse such elements, decreasing demand.

> "*We need to think about how much a new building element and its transportation to a worksite costs and consider that [element reuse] should be able to compete with it. The more we have separate processes designed for individual elements, the more expensive it becomes to reuse that element anywhere*." (**I3**)

In conclusion, the structural designer does not see that it would provide new services as such, but rather that the existing services the company provides would become more value creating for customers enacting sustainability values. By developing its expertise in the areas of pre-deconstruction assessments and planning for donor buildings, and services for structural design of receiver buildings, the company could gain a competitive advantage and participate in a wider array of projects. The design services related to reuse may still be more laborious than the current services the company provides, but these labour costs would be charged from the customer. From this current reuse process, the structural designer expects to capture information value about how to enable reuse efficiently. The company's future value capture potential from reuse relies on establishing cost efficient and unique processes and thus, differentiation from competitors.

Property developer

The property developer is the actor overseeing the entire reuse process. It is the owner of the donor building to be deconstructed, but it also is the construction company in charge of reusing the elements − either on the same lot or in another receiver building. Thus, in this case project, the property developer is involved in both the disposer and the reuse market side of the reuse process. For this reason, in the context of this current project, the company's total value capture potential should be evaluated throughout benefits and costs of the entire process.

The property developer is estimated to face costs at the beginning of the reuse process in its role as the donor building owner. The building will need to be deconstructed instead of demolished, and this is seen to increase costs and thus affect the captured value for the property developer. According to the interviewed manager, the most significant costs are related to labour from disassembling the donor elements (by the demolition company) and the refurbishment operations of attaching new hoisting gear to the elements (by the element manufacturer) as well as the logistics costs of transporting the elements from the old worksite for refurbishment, if needed, and to the new worksite for assembly (**I1**). The logistics costs and energy use related to deconstruction operations, transportation and refurbishment was also mentioned as creating environmental costs. The environmental costs of reuse should not exceed the costs of virgin elements, or the reuse process would not make sense for the property developer (**I1**).

The property developer will need to employ both the structural designer and the demolition company to guide and execute the disassembly of elements, which translates to labour and possible equipment costs. Because the process is new, the property developer also sees risks involved. For example, the company needs to be made sure that the building disassembly is done safely, and the remaining elements are supported, which may translate to more costs.

The motivation for undertaking deconstruction over demolition, however, lies in the value capture potential for the property developer in the construction and marketing/sale phases. The property developer may capture value from reuse by offering to the market new types of *sustainable buildings* that are made from reused concrete elements. According to the interviewed manager, the buildings would not need to be made entirely of reused elements but substituting even a portion of the virgin elements used in a building with reused ones would provide the company an opportunity to brand the receiver building as sustainable. Substituting only few elements in buildings would, according to the interviewed manager, be rather easy to implement and would not disturb the building production process too much (**I1**). The new types of buildings and apartments are hoped to be marketed to *new customer segments*, that would appreciate a building partly constituting of reused elements.

> *"- - we could get a "Globe Hope" type of advantage, that customers would appreciate this [a building/apartment with reused elements], and we might get some tax benefits from it and a good brand image - -*" (**I1**)

It would need to be made sure that the apartment with reused elements is marketed positively, so that the prospective buyers would see reuse as a valuable rather than a risk or as something of low value. The elements' "as new" properties should thus be communicated to the customers as well, so that the perceived value of an apartment is not decreased from the inclusion of "something old" but rather increased from its sustainable considerations. The customers could thus contribute to environmental friendliness by buying such a building or apartment. (**I8**) For the property developer, this all translates to *potential for higher revenues* and *new customer segments*. Discussion also arose around the topic that the company may in the future have a new brand for marketing such sustainable apartments, and that in the future, some customers might not even want apartments that do not include reused elements. Thus, the property developer may also gain *a risk management advantage* by investing in the construction of apartments with reused elements (**I8**).

The property developer is involved in building construction projects taking place in city centres, where the construction of a new building means that another needs to be demolished. According to the property developer representatives, reuse projects such as this pilot project create opportunities for the company in reusing elements on the same lot. (**I8**) Participation in the reuse process also enables the company to implement its goals in carbon neutrality.

The property developer representative sees that the construction firms that reuse the elements (such as themselves) could be major beneficiaries in a reuse process where *tax incentives* could be guided towards the end of the construction supply chain. A similar notion was made in other interviews, where it was highlighted that increased demand towards reused elements would be a strong signal for service and manufacturing actors upstream in the value system (**I2**, **I3**, **I6**). Thus, some kind of legislative instrument would be needed, possibly for the element manufacturer, so that the price per square meter for the reused elements would not get higher than for virgin elements for the property developer. The property developer sees it as a requirement for their value capture that the cost of reusing old concrete elements in new buildings would be at least as cheap as building with new elements.

> ”*If this [element reuse] becomes a norm so that we’d have a material library, for example, - - where elements are sold and available for architects to choose from, they will only [choose the elements] because we calculate that if we would buy emissions permits on virgin elements and buy 30 % of the elements as reused, our total costs would be lower. The whole industry would benefit from this, but the guidance of public authority is needed, the change won’t happen on its own*.” (**I1**)

In addition to the arising direct costs from building product reuse and labour, the building contractor would normally need to take into account a risk premium in its prices to clients when undertaking such a risky project with no prior experience. For example, the property developer representative pointed out that normally their risk buffer for such a “deconstruct & reuse” type building project would be “*so large that no one would buy such as building*”, because currently there does not exist a well-tried technique for those cases. Within the current reuse project, however, they gain safety from a research funding and support from the consortium group, allowing the property developer to test the business opportunities from the reuse process in a rather safe way.

One of the risks for the property developer is related to the time management of the building design phase for the receiver building. An interviewed manager explained that delays may occur during a construction project if the building is specifically designed to include certain reused elements from the donor building, but those elements cannot be salvaged intact after all, in which case the elements would need to be replaced in the design with something else, creating possible delays. Another approach suggested was that the building would be normally designed and only after element salvage it would be determined which salvaged elements could replace for some elements in the receiver building. The latter approach was mentioned to be much more flexible regarding project time, and “*in construction, time is a lot of money*” (**I8**).

In Case A, the property developer assumes the roles of both the donor building owner and the receiver building client. However, in the interviews it was also pointed out that in the future, the roles may be assumed by different organisations. In such settings the donor building owner or the deconstructing demolition company could resell or donate the components to an element manufacturer or a resale organisation.

For the property developer, the greatest cost is currently evaluated to come from the deconstruction phase, mainly the labour costs from using services in deconstruction planning and the actual dismantlement. Hence, value capture for the property developer is largely dependent on the costs occurring in these stages. Interviews with the property developer representatives revealed that the donor building, while not initially “designed for deconstruction”, actually contains properties that make the removal of elements easier − and thus cheaper. For example, the floor height of the donor building makes the elements technically suitable for new building regulations as well, and the connections between the elements are bolted joints which are easily detachable, reducing labour required (**I1**).

The company’s value capture is also determined by the revenues the company might receive from new building sales. There should either be a client willing to pay more to have a sustainable building, or the company should be able to tap into new markets of buyers.

The legislation that enables the company to build using old elements at a cheaper price is also a value capture determinant. It is not reality at the time of the case project but would be needed in the future so that the property developer does not face adverse costs from reuse over traditional construction.

The company may face some internal resistance towards doing things differently. It became quite evident that the property developer may need quantifiable benefits from reuse due to their strict yield requirements. The company needs to think about project-level benefits − it will not execute risky projects because it may lose its profits.

The interviewed manager explained the need for “carrots and sticks” both for deconstruction and the reuse of elements. As a donor building owner, the company wants to clear the lot for as cheap as possible:

> “*If we need to choose between [destructive demolition] and deconstruction, we will choose demolition, it is the cheaper alternative. This is the first point where [legislative intervention] is needed. If we get to choose demolition, we choose demolition*.” (**I1**)

In its role as a builder, the property developer needs to compare the costs of reused elements compared to virgin ones:

> "*If we would have a choice between new or [reused] elements, we would think about which alternative has a cheaper total cost per square meter, also considering the worksite costs. Maybe this phase would need some financial steering as well*." (**I1**)

The interviews suggest that the property developer and builders at the end of the reuse value chain do not face many changes in their business, because the expectation (at least for the future, if reuse projects become an established practice) is that the product would be functionally, aesthetically and legally comparable to virgin concrete elements.

> *"If we would get a modified, reused element, it wouldn't change that much - old or new element, if it has lifting devices in the same place that we want - - then it doesn't necessarily change basic construction work [regarding lifting a wall element in place]."* (**I1**)

Although, two notions were made in the interviews regarding the characteristics of reused elements compared to virgin elements that may have value implications to the builders. First, it was noted that reused building elements have already dried, they have no free cement particles, so if they get wet in the worksite, it will take a very long time for them to dry. Hence, the property developer may need to invest in moisture control equipment for the construction phase, which would add costs. However, the property developer representative also pondered that the dryness of the elements could be seen as an asset as well, because it might manifest in shorter construction times.

In another interview (**I6**), it was also discussed that because the reused concrete is dry, it is also harder than normally, which could be an advantage for its use in construction. However, it was still left unclear, who would reap the benefits of the "extra-hard" concrete.

The property developer representative explained that the testing costs for the elements are higher when there is little information available from the elements, and that the more modern the donor elements are, the better the available data and thus less need for testing them (**I1**), thus stating similar findings as the structural designer.

Demolition company

The demolition company is the actor performing the physical dismantling of the building, operating in the beginning of the reuse process. The company provides value to the property developer by ensuring that the desired elements are safely and carefully removed from the donor building. In Case A, the demolition company has also been involved in the discussion of *what* elements should be removed, but the salvageable elements have mostly been determined at prior stages of the reuse process. The demolition company's role is also to establish a functional order of disassembly for the elements, together with the structural designer.

Deconstruction is largely different from traditional demolition work, where waste is sorted in skips. An interviewed site manager from the demolition company did not see many resemblances between the two approaches:

> "*Normally when demolishing a building frame, if possible, it will be mechanically taken down - - the element will be crushed right in its place. Whereas here we are salvaging them intact… I wouldn't say that disassembling [elements] intact and demolition as waste have much in common*." (**I4**)

The perceived labour intensiveness and slower disassembly time were seen as major hindrances of deconstruction over demolition by the property developer. However, as deconstruction is required so that elements may be reused, the activity is a crucial value creating activity in the reuse process. The demolition company performing deconstruction thus gains a business opportunity in providing a unique *service of deconstruction* for building owners looking to reuse elements themselves or providing them for reuse to another actor. It was also suggested that the demolition company might gain a competitive advantage from their specialised know-how in the deconstruction work, enabling the company to *win more bids* and thus gain more revenue and capture value from reuse (**I8**).

The demolition company in Case A has performed some building deconstruction projects before, but the projects have reportedly mostly dealt with steel frame buildings, which have high material value (**I4**). A manager from the demolition company, while not commenting on the case project directly, explained that in other deconstruction projects the company has identified *use value* for steel structures of buildings, hence opting for salvaging them even in cases where the building owner had not specifically asked to do so (**I4**). The demolition company, while also providing an important deconstruction service to building owners, could in the future even act as an element supplier, selling salvaged elements for reuse to concrete element manufacturers (**I6**).

A representative of the company was slightly sceptical of the reuse potential of concrete elements but concluded that the company is willing and capable of doing anything the client wishes.

> "*Every [element] can be salvaged intact, if the [client's] will is to have them salvaged intact.*" (**I4**)

For the demolition company, the disassembly is not really a risky business − they will be compensated for all the work done if the goals for deconstruction are made clear from the beginning by the client. The expenses in the disassembly phase are expected to come from the manual labour from the preparative work for detaching the elements, the use of crane machinery for lifting the elements, and finally, after disassembly, transportation costs for when the elements need to be transported off the worksite by trucks, possibly in several shipments. (**I4**) If the costs could be decreased by enhanced work processes, this might arguably make the demolition company's offers on such deconstruction projects more desirable to clients, thus bringing in more projects for the demolition company.

The major value capture determinant for the demolition company is thus identified to be the client's (property developer) specific desire for deconstruction, as laid out in the offer request for the demolition project.

Element manufacturer

The element manufacturer aims to create value in the reuse process by providing good quality, recovered pre-cast concrete elements for the property developer to have assembled at the determined receiver buildings. In the case project in question, the element manufacturer is set to perform a service of refurbishing the salvaged elements. The goal is to make the reused elements comparable to new elements − both in a technical and functional sense but also in a legal perspective, so that the elements are not considered as "waste" and meet the standards required from new buildings.

While the role of the element manufacturer in this current pilot project is still changing, the interview with the element manufacturer representative revealed interesting ideas of the company's potential and future role in the reuse process and how it might capture value by seizing new business opportunities from concrete reuse. Some of the data has also been gathered from the company website and relating interviews with other actors in the project.

The company already has some sustainability initiatives in its business, and it aims for being a frontrunner in sustainability in its field. The element manufacturer has a sustainability strategy, which is complemented by novel solutions in enhancing the environmental friendliness of concrete. The element manufacturer's offering today includes also concrete elements where a low-carbon technology has been utilised. The company also already utilises internal circulation of crushed concrete in its own production.

> *"this [project] fits our sustainability strategy just right"* (**I2**)

By reusing elements or externally sourced crushed concrete in production, the company might be able to improve its environmental impact figures and reduce its total CO2 consumption in a quantifiable way, which could enhance the entire company's *competitive advantage*.

Just as for the structural designer, participation in the current reuse process − regardless of the element manufacturer's exact role in it − enables the company to think of ways to make concrete reuse a part of its business in a profitable way. Hence, information value is also important for the element manufacturer. In addition, the small-scale pilot project that is now ongoing was discussed as having intrinsic benefits to the company as well regarding customer satisfaction and brand value. The pilot project includes customer collaboration, which according to the element manufacturer interviewee is an important value for the company on its own. In addition, it was discussed that even on the small scale, reusing elements in a new building can be an important way for the element manufacturer to gain good *brand image*.

Future value capture potential for the element manufacturer was discovered to relate to the *product recovery and resale of concrete elements* salvaged from EoL buildings. The element manufacturer would be able to capture value from reuse by treating the salvaged concrete elements as *inputs in their production process*, which would yield new kinds of products as outputs to be sold to construction companies. The element manufacturer does not see that reusing already existing concrete elements would be a threat and cannibalise their sales, but instead wants to focus on the business opportunities related to new production processes and products.

> "- - *we have our basic materials, but in addition we might have these kinds of semi-finished products, that go through processing instead of having to be cast first*" (**I2**)

It did not appear that a specific, new type of clientele would need to be established for selling the reused products, but that the current customer base would be offered the new product type.

> "*I would see that our customers [for reused elements] would be the same as they are now"* (**I2**)

The company's suppliers for used elements would depend on the reuse process: whether the actor who owns and deconstructs the donor building would be the same who builds using the reused elements, or whether there exists some kind of intermediator to whom the deconstructor first sells the elements and who then resells them to the element manufacturer. This has implications to the division of captured value as well.

> ”- - *we still need to think about what the business model would be: whether we would buy the semi-finished products and sell finished products or would [the*

used concrete] be just material for us which either costs or doesn't cost - depending on where the interests are regarding its use - -." (**I2**)

The element manufacturer's potential for capturing value from reuse is supported by its existing manufacturing competence and resources.

"*we have a pretty good idea of what elements have been made and how they can be repaired and then reprocessed for reuse*" (**I2**)

Such analogies of reuse compared to the element manufacturer's "business as usual" were interesting to inquire as they were seen to affect the company's ability to create value and minimise costs. For example, the interviewee explained that they can utilise existing processes related to quality management for the reuse:

"- - we have good know-how also for when things don't always go right, if some part is accidentally left out in production - - I would see that [reprocessing used elements] is a same kind of procedure that we use today in such error situations, so those best practices can be transformed into techniques we can use for re-processing." (**I2**)

In addition, the company may employ its existing production facilities and crane equipment for moving, reprocessing and storing the elements when an outdoors, on-site repair of elements is not sufficient. Analogies were found also relating to the (re)manufacturing process itself. If the reused element requires, for example, some surface treatments, the process would be quite similar as in virgin concrete element production, because such procedures would take place after casting anyways.

The interviewee highlighted some challenges related to capturing value from reuse. One of the challenges relates to the fact that concrete is a cheap material to manufacture as new, which may make its reuse not desirable at least from a cost savings point of view. In addition, refurbishing existing precast concrete elements limits some of the benefits that are associated with the moulding process: during moulding the concrete can be cast to the desired form from the beginning, and the element can already be equipped with the required parts. On the other hand, skipping the casting phase means that some of the follow-up activities related to moulding may not be required. For these reasons, it was suggested that an entirely new production line might be needed:

"- - *we probably wouldn't [reprocess elements] on all our production lines, and it might be an entirely separate one - - because it's clearly different and we do not need to do follow-up on the product to the same extent as in concrete casting, so it might need its own process - - If we apply [reprocessing] within an existing,* *efficient production line, then it might [harm that line as well] and get unreasonably expensive* - -" (**I2**)

Efficient processing and economies of scale seemed to be an important factor influencing the element manufacturer's value capture potential. It was considered beneficial that reprocessing the elements could turn into a process instead of just individual cases of repairing specific elements.

"[The element reprocessing] is not necessarily expensive as such, but our standard production is pretty efficient and inexpensive - - so all that reprocessing and labour becomes expensive in relation to that." (**I2**)

The interviewee also pondered the option that the company might have a legal obligation in the future for receiving or utilising used concrete elements in their production but concluded that it would probably not work. Instead, the process should also include the role of the newly constructed buildings that would include the reused elements as well.

Some factors also arose considering what would make the reuse process cheaper and more profitable for the element manufacturer. It was found that standardisation of elements to be used in new construction would be useful and could enable refurbishing elements more efficiently. It was also considered important that one shouldn't "try too hard" to refurbish everything, but instead refurbish those (standard) elements that are easily refurbished and then recycle the rest. This, in addition to legislative guidance could enable the element manufacturer to capture value from element reuse.

- - *"[the reuse of elements] is practically possible to fit in our processes, if we can only get the design and standardization to work and some form of [financial] support or sanction to make it economically viable business.*" (**I2**)

Architect

The architect's role in the reuse process is in the design of buildings with the reused elements. Thus, the actor is focused on the downstream of the reuse value chain, within the disposer market. The architect's role within the pilot project in Case A has thus far been focused on general advising and business potential mapping, and also working on the inventory model of the donor building so that the element data can be utilised by the demolition contractor in the planning of the disassembly order for the donor building, and on the other hand, by the property developer in the consideration of how the elements might be reused in new receiver buildings. The representative of the architecture design office views the company's involvement in the project as important in enabling future reuse (**I5**).

> "*I view it important that our company can contribute [within this project] - - to perceiving the old building stock in new ways - -*" (**I5**)

The architect will also gain *information value* from participating in the project, enabling them to rethink what the industry might require in the future from architects.

> "*Due to the kind of investigative nature [of this project] - - we will help in everything that we can, and we will also learn from it ourselves. Because there are no clear roles [for actors] unlike in new construction [with virgin resources].*" (**I5**)

Indeed, the architecture company representative pondered that the designer's role in the value chain of reuse might be more prevalent than in traditional construction. This might mean that the architects might gain more revenues and capture more value as their significant efforts are recognised. The architect's creativity is seen as an important value creating activity in the reuse process.

> *"There exists great potential that the construction process will become largely designer and architect-oriented in determining what use the elements could be best suited for*". (**I5**)

Logistics company

The logistics company was not among the interviewed actors in Case A, but other interviewees mentioned on several accounts the key role of a logistics service provider that would likely undertake some of the roles that in the pilot project are operated by the structural designer, demolition company and the element manufacturer.

The logistics company would first, and foremost, be needed to safely and carefully transport the salvaged elements from the donor building worksite to other locations (**I1**). The logistics service is different from the transportation of demolition waste and thus careful considerations are required of the potential logistics provider to enable value creation in other links of the reuse value chain.

It was also suggested that possibly the same actor who transports the elements (the logistics company) would be in charge of checking the measurements of the elements, installing possible tracking devices, storing the elements and/or redistributing them along the value chain. Thus, the logistics provider might operate somewhere in between the donor building owner, demolition company and element manufacturer. In that sense, the data suggests that entirely new kind of businesses might be formed in addition to the expansion of existing companies' offering.

7.2.4 Value capture determinants in Case A

The preliminary results from Case A suggest various determinants that could enable construction industry actors to capture value from the reuse process. These determinants thus contribute to either minimising costs or gaining revenue as a result of reuse.

The labour required in the deconstruction phase was seen as an important cost determinant in the reuse process for Case A. While actual deconstruction had not yet realised, the property developer in particular had already suspected that certain costs and risks would be linked to deconstruction. Assembling the elements in the receiver building was not, however, predicted as very costly. Hence, factors that would contribute to easier/faster/safer/cheaper deconstruction can be seen as value capture determinants. The property developer noted that laborious workphases related to element salvage could take more time which might indicate *increases to the project duration*, which could result to additional costs.

> "*I would guess that the biggest costs would come from deconstruction, then the [reprocessing] on the element. I don't see that [re]assembly would be [that much more expensive], aside from the possible [moisture] protection - -*" (**I1**)

The donor building in itself was found to be *a good fit for deconstruction*. The property developer representative elaborated the reasons for why the donor building was chosen for the reuse project, highlighting its *technical characteristics*:

> "*It is an office building, and despite being made in the old days, it fortunately has a floor height of 3 meters - the columns and beams are theoretically reusable even in the current room height. That's the first reason. The second is that it is a beam-post system, and I checked the structural drawings and they [elements] were attached with bolt joints - - the deconstructability is easy. It just happens to be a good building*." (**I1**)

Easy deconstruction was seen to not only minimise costs for the building owner, but it was also important in enabling value creation and value capture in further phases of the reuse process*: if the elements could be sparingly salvaged, they could also be recovered and resold* with minimum repairs needed by the element manufacturer or other actors. *The building type of the donor building* was generally seen as important in determining how its elements may be reused and in what types of locations.

> "*It is not yet very clear what type of buildings these elements would best fit in, and it is largely dependent on how old the donor buildings are - there are different*

element typologies and characteristics in different eras which will influence the possibilities for further reuse." (**I5**)

The *chosen types of donor elements* were seen to affect some costs that may arise during the reuse process. It was mentioned, for example, that indoor elements are not designed to endure extensive moisture or frost so if they would be planned for reuse, there would probably be extra costs related to protecting the elements during deconstruction and having to store them indoors (**I1**, **I3**). On the other hand, the outer wall elements in the donor building were estimated to be unfit for reuse due to changed building requirements and the elements' exposure to weather in their lifetime. (**I8**) Regarding the deconstruction planning, the structural designer stated that an "ideal" donor building would be made of components that are similar to each other, and preferably precast elements so that the assessment and planning functions would take less work and thus create more value for the customers (**I3**). Also, when the manager level interviewee of the property developer's was inquired as to how the costs related to deconstruction might be lowered, DfD in newly designed buildings was mentioned.

"*We should make standardised, simple joints, that are not covered by casting - - the building frame should be similar to a steel frame with bolted joints - those are easy to deconstruct - - simply open the bolts, remove the elements and they are good to go if the measurements match - - somehow if we could make the [concrete] elements similar to those then it would work. Then deconstruction would not really be costly anymore.*" (**I1**)

Sufficient information of the donor building was also noted as important for value creation and value capture. For example, when the structural designer representative was asked about what would make the reuse process easier for the company, the interviewee mentioned the importance of existing, correct element drawings of the donor building. Knowing the exact location of the elements was not considered that important, but in order for the structural designer to deliver value in the reuse process, it needs to know what type of elements, in what quantities and with which measurements are included in the donor building.

"- - that's one of the biggest criteria, if we wouldn't have any drawings of the building, no information about where those elements are, then we would have to manually find out which elements are precast, which ones are cast on site… - - where the joints of the elements are… If such things need to be investigated separately [for each element], then I think that the price tag per element will become so large that it is not financially profitable anymore." (**I3**)

Overall, the actors had a shared view that reuse should be done in a “reasonable way” so that the possible benefits from reuse would not be outweighed by the costs related to deconstruction, examining the elements, and reprocessing them for reuse. It was suggested that *one should not “try too hard” to reuse certain elements* in primary locations if it would get too challenging, but instead find alternative ways to utilise the elements in secondary use. For example, the element manufacturer representative suggested that such elements that would be too expensive to be reprocessed for further reuse could be crushed and utilised in the production of new elements instead (**I2**).

> ”*We shouldn’t try too hard [to reuse elements], but keep it within reasonable limits, and demolish the rest - - it would probably even be sensible to demolish [structures] quite extensively and utilise only certain types of elements for which there are existing [reutilisation] processes available.”* (**I2**)

Because Case A is still a pilot project, several actors highlighted future value potential instead of value realising in the now. Some determinants identified were those that enable value creation and value capture in the future.

One of such determinants was enhanced processes enabling *scale production and operations*. On the one hand, “economies of scale” was highlighted on the systemic level across the entire reuse process as actors learn how their future role in the process might look like and how they should accommodate their BMs for reuse. The actors were hopeful that the pilot project would yield information on how element reuse could be done in the most cost-efficient way possible. On the other hand, scale production and scaled processes were deemed important value capture determinants for individual actors. For example, as pointed out in the previous chapter, the element manufacturer would benefit from *scaling the production of reprocessed elements* to make them competitive with virgin elements. In addition, *more efficient deconstruction planning and dismantling processes* in the deconstruction phase would be beneficial for actors providing such services because non-value creating activities could be omitted from the process.

Regarding both the revenue and cost-side of value capture, almost all of the key actors in the reuse process highlighted the importance of some form *of legislative or regulatory involvement that would make reuse more profitable* for the actors. This was deemed important because of the piloting nature of the reuse process in Case A: the reuse process still involves a lot of development and lack of aforementioned economies of scale creating costs. For example, the property developer suggested that incentives should be guided towards the deconstruction and reutilisation of used elements in new construction in the form of *tax deductions*, which would compensate for the risks and added labour required by the reuse process, or alternatively, *tax increases* for virgin concrete products that would make reusing elements a competitive alternative (**I1**). The reused elements could also be *recognised in environmental product declarations as "low-emission" products*, which might bring a competitive advantage for the element manufacturer (**I2**).

The interviewees pointed out the importance of legislation as a value capture determinant. In order to realise business benefits on a larger scale, the legislation should accommodate to the changing demands that reuse poses to the industry:

> "*We kind of assume [in the current construction sector] that we might bring these old elements into the old way of doing things in construction, by simply replacing new elements with old ones - -and otherwise retaining all the existing processes, attitudes, and legislation. - - It can't succeed, except maybe on a small scale but it will never become a bigger business*" (**I5**)

Despite the importance of legislation and guidance in the initial transition in the industry towards reuse, the actors saw that on the longer term, reused elements and the business ecosystem around them would and should be competitive with linear processes even on its own, without significant interference from public entities.

For value capture from reuse, another approach identified was to *find a suitable client or buyer* for the actors' business offering. For example, the interviewed university researcher visualised a future scenario in which investors or other buyers would be interested in having sustainable buildings in their portfolio and even be *willing to pay more for buildings made of reused elements*. This would drive demand for reused elements at the end of the value chain which would transfer to business opportunities for actors in the upstream of the reuse value chain supplying the elements (**I6**). The client may also be a public organisation, like the city, that enacts its sustainability strategy by establishing CE criteria for their building projects, thus enabling reuse-focused actors to gain a competitive advantage (**I7**). For example, in the previous chapter, the expected demand for pre-deconstruction services was identified as the driver for value capture for the structural designer (**I3**), and the demolition company representative noted that they are willing to commit to deconstruction if a client willing to pay for the extra labour is present (**I4**).

The importance of *a committed client* was found to be high in such pilot projects where reuse still constitutes a "special case" in construction and not an established practice. Thus, the lack of scaled business could be in some cases compensated by a client willing to assume the risks and extra costs related to reuse.

"*I would see that if [the reused elements] could be utilised only in specific [receiver buildings], the market would be left quite small. Such special buildings [including reused elements] would be made only if some customer would especially want them*." (**I1**)

7.3 Case B: Partial deconstruction and local reuse of concrete elements

7.3.1 Description of Case B

Case B is a building deconstruction and renovation project of that took place in the city of Raahe during years 2008-2014, in the housing area of Kummatti. The case deals with a selective, partial deconstruction of 7 apartment buildings built in the 1970s. Approximately 120 apartments were removed from the buildings and the salvaged concrete was reused in both element and material form locally on the worksite but also in other locations. The remaining apartments were renovated to be more attractive for residents and more energy efficient (Hagan & Kontukoski, 2009).

The case was first studied in a master's thesis study back in 2010 (Huuhka, 2010), when the project was still ongoing. Back in the day, "case Kummatti" appeared in local media outlets and local people in Raahe were interested to follow the completion of the deconstruction project. The project was even followed by a photographer, resulting in 5 photo books of the project. The case is still relevant today due to its pioneering nature. It is largely considered a "success case" of element reuse in Finland, and it was most recently studied in 2019 in Huuhka et al. (2019) as a Finnish case of "downsizing" − the term referring to a building that is altered to meet the decreased demand for housing in one area.

At the start of the project, there were 13 apartment buildings and a total of 364 apartments belonging to the neighbourhood. The Kummatti neighbourhood was suffering from a bad reputation at the time and the buildings had high vacancy rates − especially the larger, family sized apartments were low in demand (**I12**). In addition, the buildings themselves were in poor condition and some had even been subject to vandalism (**I9**). The housing company that owned the buildings ("client") wanted to improve the occupancy rates in the buildings in the neighbourhood. Thus, the housing company decided to enrol in a development program for declining neighbourhoods (*fin*. "Käyttöasteprojekti") organised by The Housing Finance and Development Centre of Finland (ARA), where the client received funding for a building project to improve the neighbourhood (**I9**).

As part of the project, the housing company organised an architectural design competition in 2006, where a criterion was set that none of the apartment buildings could be totally demolished. Demolishing entire buildings and potentially constructing new ones in their place was seen as not only an expensive solution but one that would not have improved the condition of the buildings or the desirability of the neighbourhood (Huuhka et al., 2019; **I9**, **I12**). The design competition was thus won by architects with a building design that combined partial deconstruction, or "downsizing" the apartment buildings so that some of the larger apartments would be removed altogether. The remaining apartments would be renovated, and the buildings' energy efficiency would be improved (Hagan & Kontukoski, 2009). The original design included the downsizing of all of the 13 apartment buildings, but due to subsequent changes in housing company management the downsizing was eventually implemented only on 7 buildings. As a result of deconstruction, the three buildings of three floors and no elevators were downsized to a height of 1-2 floors, and five buildings of six floors were downsized as well (Huuhka, 2010).

The main design of the building was provided by the architects, but otherwise the implementation and construction design were provided by the main contractor, a local construction company. The construction project was a "design-and-build" type, in which a main contractor ("construction company") oversaw both the structural design of the buildings and also the deconstruction and renovation/construction work. (Huuhka, 2010; **I9**, **I10**).

7.3.2 The reuse process in Case B

The donor buildings in the reuse process of Case B consisted of 7 apartment buildings: 3 slab block buildings with originally three floors, and 4 point block buildings with originally six floors (Huuhka, 2010). The construction project was divided into two "phases", where the lower buildings were deconstructed and finished first and the higher buildings were deconstructed and renovated after that (**I9**, Huuhka, 2010).

The reuse process began with the deconstruction of the unneeded apartments. The deconstruction process was begun from the three lower buildings. The primary goal was to ensure that the remaining structure in the buildings would remain intact; the salvage of the elements for reuse was only the secondary goal (**I9**). Indeed, when the disassembly began, initially the elements were dropped to the ground and crushed into a rubble. By using a magnet, the steel sections were removed from the rubble so that the crushed concrete could be salvaged to be utilised in backfilling. However, the rubble was found to quickly clog the worksite, and create additional hindrance in the form of noise and dust. Hence, later on, the building elements were decided to be removed by cutting them utilising a remote-controlled robot (**I11**). A tower crane was then used to pick up the removed elements (the elements had the hoisting gear still attached to them, which enabled their easy lifting) and stack them in a designated area by the buildings.

During deconstruction, workers did not need to be operating inside or on top of the buildings. Reportedly, only one supervising person needed to be present to oversee the removal of the elements and to inform the tower crane operator on what to do. (**I11**)

Figure 11: Donor building in Case B, showing how the building looked like at the beginning of the deconstruction and reuse project. (Photo provided by an interviewee)

In the downsizing of the first three buildings, the salvaged elements were the property of the construction company. The construction company decided to donate the salvaged elements to people living around the area, who had heard that such a deconstruction project was taking place in Kummatti. People came to pick up the elements by themselves, and the elements were thus removed from the worksite shortly after they had been salvaged from the buildings. The whole elements were reportedly reused as in farm buildings, but exact information could not be deduced on where the elements ended up or whether the construction company received money for the elements or not. (**I12**)

The deconstruction of the four remaining buildings, 7 floors high this time, had bigger goals for reuse. Having witnessed how easily the elements actually could be salvaged and how well they were preserved in the process, the remaining buildings were deconstructed with the elements' reuse as an aim from the start (**I9**). The receiver buildings had been decided: the elements would be reused in carports, maintenance buildings and community spaces (gazebos, barbeque shelters etc.) in the yard areas of the neighbourhood. Figure 12 shows the construction of a maintenance building utilising the reused elements.

Figure 12: Construction of the maintenance building from reused components in Kummatti, Raahe. In the distance, a partially deconstructed finished building can be seen. (Photo provided by an interviewee)

The receiver buildings/structures were thus mostly open spaces that located outdoors. The maintenance building was a closed space but nevertheless not intended for people to stay a long time in. For these reasons, the elements could be safely reused in these structures without much recovery operations needed. The elements had simply been pressure-washed with water during disassembly. The elements had some graffiti markings on them (due to prior vandalism in the donor buildings), but there was no need to remove them, as the elements were covered with colourful painted metal plates after being assembled in their new use. The elements were cast in place within the new structures, and some of the elements were sawed to get them into a decent shape for the receiver buildings, but the procedure was mostly that the elements were taken “as they are” and instead, the receiver structures’ designs were altered to meet the demands of the donor elements. As a result, over 100 solid elements from mostly the balcony segments of the buildings were reused as whole elements within the neighbourhood. (**I9**)

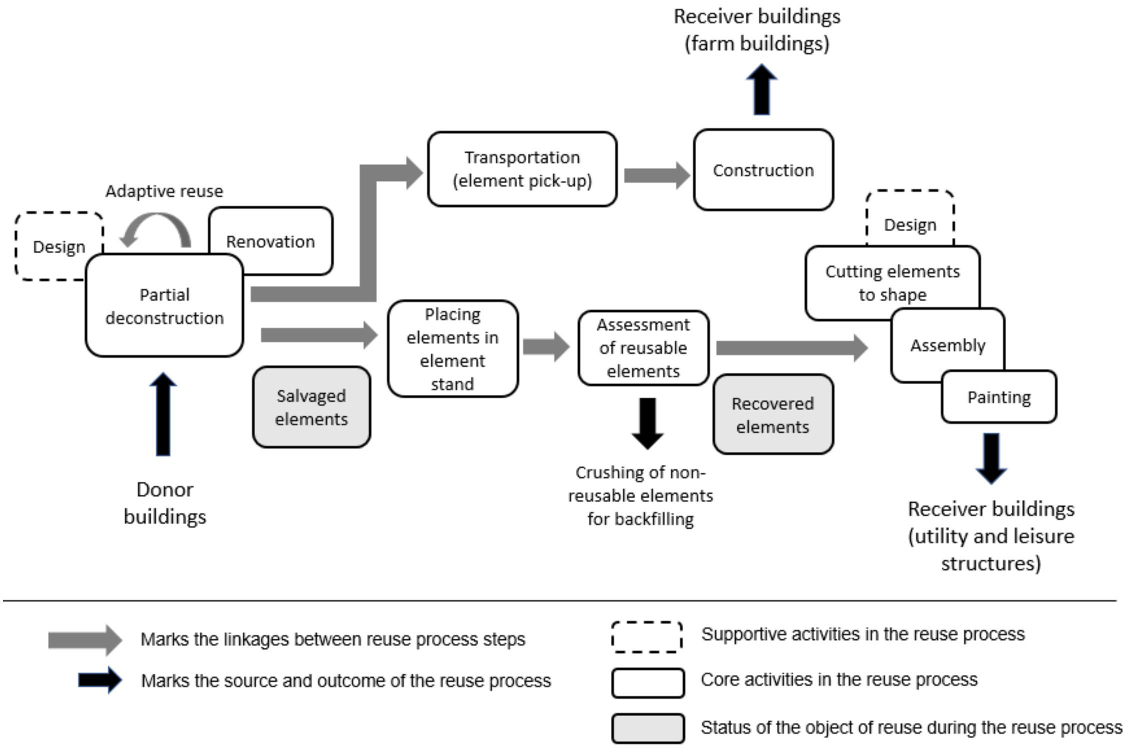

Figure 13: Case B illustrative reuse process

Finally, Figure 13 presents the reuse process within Case B. As can be seen from the figure, several pathways for reuse were present: the donor building was reused adaptively by renovation, while the salvaged elements continued to be reused along two different paths − on the same site and in other sites.

7.3.3 Value implications to actors involved in Case B

This section describes the realised value for key actors involved in Case B: the client (housing company), the construction company, and the architects. The client was assisted by a building consulting company that was also one of the interviewees but not an analysed "actor" on its own.

Client

The client in Case B is the housing company who owns the donor buildings. For sake of convenience, the residents of the buildings in the neighbourhood are also considered part of this actor category.

The client company (including the residents of the area) was considered the actor who benefitted the most from reuse. By participating in the reuse process in Case B, the client gained several types of realised value from concrete reuse, mainly increased revenue from increased occupancy rates, cost savings from avoiding alternative costs, as well as internalised functional value. First, from adaptive reuse, the client achieved its goals in decreasing the vacancy of the buildings, thus contributing to both increased revenues and cost minimisation. The occupancy rates of the buildings were increased from less than 80 % to 100 %, which the client mentions to be the most important benefit they received from the project (**I12**).

Getting rid of the large, low-in-demand family-sized apartments through partial deconstruction enabled the client to have better occupancy rates, in which sense reuse indirectly contributed to higher revenues. However, adaptive reuse of the buildings also enabled that the buildings were left with *larger common areas* per resident, because while the number of apartments decreased, the common areas were kept the same. It was argued that, if the buildings would have been instead demolished and built anew, the new common areas would have been made smaller (**I10**). Thus, functional value was indirectly gained for the housing company.

By reusing the concrete structure of the building, the housing association was also able to avoid costs related to the construction of a totally new apartment building, while still receiving a make-over for the building which made it more attractive than before. (**I12**, Huuhka et al., 2019)

The housing company's role in the construction project of Case B did not include the design or planning of the work as such − that was left for the construction company and, initially the architects. However, the client had strictly set targets for the project regarding on its outcome, costs and duration. The realisation of these targets was actively monitored by the client (**I12**), and thus the client created value for itself by its actions and ensured that the value capture expectations would be realised.

The costs were monitored by the client closely throughout the project's implementation. The housing company representative memorised that the costs of the downsizing and reuse project were only 60 % of the costs of demolition and construction of entirely new buildings (utility buildings included) from virgin materials. Due to continuous cost management throughout the project, the costs of the partial deconstruction and reuse project for the client ended up being even more than 100 000 euros below the planned budget. (**I12**)

Second, the housing company got functional value from the reuse of concrete in the utility buildings outdoors. The buildings were needed anyway, so the client saved virgin material costs in the assembly of the outdoor structures. Additionally, the availability of "free" elements was speculated to have led to the construction of more covered car parks than would have otherwise been made (**I10**). Thus, the client gained use value and was able to internalise the material value of the elements.

> "*All of [the new structures] were most likely needed, we didn't set out to create anything unnecessary. Except I don't know if there would've been so many covered [carparks] if these kinds of elements hadn't been available*." (**I9**)

It was also speculated that the utility buildings, containing durable concrete, would more likely be preserved in use for a longer time than if other materials would have been used (**I10**). The architect interviewee explained that normally, such structures would be made of wood or other "lighter" materials, but because the concrete elements were freely available, they were utilised.

For the construction company, the cheapest option was to reuse elements that did not need any work done to them. This meant that the elements were reused in their current size, meaning that the residents got some communal spaces that were larger than otherwise would have been. Thus, the reuse of elements allowed for creating the utility and leisure spaces as potentially *larger* than normally, indicating another aspect of functional value yielded by element reuse.

> "*There was a kind of barbeque shelter and some other shelters in the yard - - surely they would have been more on the small-scale if the [existing] elements would not have been utilised in them*." (**I9)**

The housing association also deemed it important that waste should be minimised in the project. Functional value was related to reusing the remaining concrete finally in crushed form in the worksite.

> "*The goal was that no waste would go to landfills - - the material that did end up in landfills was mostly the plastic packaging from new furniture and fixtures*." (**I12**)

Construction company

The construction company, operating on a design-and-build contract in the project, created value in the reuse process for the client by means of both partial deconstruction and renovation of the donor buildings as well as by providing solutions for assembling the reused elements in the outdoor structures on the yard areas. A representative of the construction company could not be reached, but the other actors involved in the case shared their experiences on the value implications of the construction company.

For the construction company, the value captured in the project was related to *information value*, and improving the construction processes, as estimated by the other interviewed actors. The construction company was able to learn new deconstruction and assembly methods both with an enhanced learning curve throughout the project, as well as in future projects (**I12**). Due to the strict cost requirements the construction company was forced to create solutions that fit within the tight budget frame.

When asked about the cost implications and laboriousness of deconstruction for the construction company, the client representative answered that they do not believe that the deconstruction was that laborious at all, because the construction company had developed a good and cost-efficient solution for deconstruction, which also enabled them to win the bid (**I12**).

According to the client interviewee, the construction company was new to such deconstruction and assembly projects. The construction company was, however, considered to have created innovative approaches in deconstruction and reuse which made the client choose their offer over other, more expensive offers.

> *"[The construction company] had not done such a project before. They saw it as a challenge and they needed to develop their work a lot, - - but they learnt and used the same techniques later on in their other projects, so that was a great benefit to the construction company*." (**I12**)

For example, the construction company developed a way to assemble parts of the buildings in the ground-level, from where the building segments were lifted using cranes to the floors above.

The construction company was able to donate the elements (that the client did not need) to individuals external to the project. The people that received the elements picked up the elements from the site by themselves, so the construction company was able to avoid costs related to the elements' disposal.

> "*Every time someone came to pick up elements, the construction company saved lots of money. - - They did not have to [transport] the elements anywhere or crush them for backfilling*." (**I12**)

> "*The biggest benefit [of element reuse, for the construction company] was the fact that [the elements] did not need to be transported anywhere and then bring something new as a replacement. We would've gotten a double fee for taking the usable elements in a landfill and then bring new, more expensive elements as a replacement*." (**I12**)

Reportedly, the construction company also may have received some money for the donated elements, and thus some *resale value* might also have been present (Huuhka, 2010).

Another avoided cost for the construction company had to do with the selected method of element removal in the deconstruction phase. The elements were first tried to be removed by controllably crushing them in place in each of the floors. However, this was found to create lots of noise and dust as well as clog the worksite, so the elements were from then on removed by cutting them into manageable pieces and hoisting them out of the building by using a crane.

It was, however, unclear to the interviewees, whether the project had been profitable as such for the construction company. The interviewees pondered on a general level that they do not believe that the project brought "losses" to the construction company. It may be argued that the construction company provided important value creating activities in the reuse process of Case B, most likely benefitting from the developed practices later on in their business activities. On a sidenote, the construction company that, at the time of the project, was still a small and local group of workers and designers, is today a major player in the construction industry.

Architect

Two of the architects involved in the case project were also interviewed. While the questions were mainly directed towards the general benefits received from the case project altogether, it was also important to hear the architects' perceptions of their role and value implications in the reuse process.

The architects were not involved in the structural design of the buildings or planned the implementation of reuse as such (this was the work of the construction company), but much like the construction company, they were a key link in the value chain, and their design created value for the client who praised the design and mindset of the two architects. The architects' design had not been the cheapest option of the design competition, but their design was chosen by the client for its innovativeness and reasonability. (**I12**)

It was, however, deduced that the architects did not "capture" much direct value from the reuse process, for them the design was "just as any design work" reward-wise, as an architect interviewee explained (**I9**). Also, when inquired about future business implications the reuse project may have since yielded to the architectural design office, no direct causal relationship could be deduced relating to Case B. Although, discussion arose regarding the general "popularity" of the reuse case on the national level, and how this might have brought more visibility for the actors involved, the architects including (**I9**).

7.3.4 Value capture determinants in Case B

Because Case B represents a retrospective case, it is beneficial to look back to what were some of the factors that enabled the actors capture value from reuse.

Even from the beginning, the project's goal was set to adaptive reuse for the remaining buildings and reuse of elements on site in the construction of the maintenance and recreational buildings. This *common goal was communicated* to the contractors (architects & construction company), enabling them to find value-creating solutions fitting these criteria. That is, reuse within the project was expected by the client on the outset and was not a decision left for the contractors alone. The housing company highlighted as the key success factor in the project also *the excellent design* provided by the architects, and the fact that the *bidding process was not based only on "cheapest price"*. This enabled the client to choose the best and most fitting architect group to design the buildings and meet the objectives of the project. (**I12**)

In the bidding competition for selecting the construction company, it was required that the deconstruction methods used would not compromise the remaining building. Also, the bidding competition was based on criteria of both price *and* quality, and thus the client gave recycling a 60 % weight factor in the selection of the contractor (Huuhka, 2010). The client especially mentioned that the design and bidding competitions were successful in finding contractors that "knew what they were doing" and didn't choose too difficult methods of working (**I12**).

The *calculations the client made beforehand on the financial profitability of the deconstruction and reuse project* were also arguably important for the value capture from reuse. The client knew that the project would be "viable" and this, together with the design-and-build contract form, minimised financial risks related to reuse. The initial costs were complemented with *constant monitoring of the project's results*, ensuring that the work of contractors remained within the budget and adhered to the specific requirements for the end result. (**I12**)

> "*All decision-making was based on the significantly cheaper price of the [donor] buildings' renovation [when compared to demolition & new construction].*" (**I12)**

It was also highlighted that the key actors involved in the reuse process (client, architects, construction company) comprised *a good team* and *their communication and attitude towards reuse was remarked as excellent*. This was partly contributed to the good selection criteria the housing company used for choosing the contractors, but also the contractual division of responsibilities − *the design-and-build contract form* was also highlighted as a key value determinant and success factor in the interviews, because it allowed the construction company to take control over both the design and implementation of deconstruction and construction and find solutions that they knew they could implement. The design-and-build contract also ensured that the construction company was invested in their work.

> *“[Design-and-build contract] was absolutely important, there would have otherwise been so many [uncertainties] and conflicts*.” (**I11**)

A few value determinants were identified regarding especially the reuse of elements. First, the elements’ salvage from the donor buildings was not really an “extra” cost in the sense that *the buildings needed to be deconstructed anyway* due to downsizing goals. Also, the choice of a “delicate” deconstruction method was motivated by mostly the goals of keeping the remaining structure in the donor buildings as intact as possible. As a result, the actors were left with a supply of elements whose subsequent utilisation was only seen as seizing a good opportunity. Thus, *adaptive reuse of the donor building* actually became a value determinant for element reuse in new receiver buildings.

Second, it can also be argued that because the project was well “marketed” in the media and *well-known in the local area that it was so easy to find demand for the salvaged elements* that were not needed by the housing company (**I11**, **I12**). The popularity of the project in Case B can thus be considered to have contributed to value capture for the construction company by enabling the resale and donation of the elements to external actors.

Just like in Case A, also in Case B value determinants were found relating to *the donor building’s properties*. The donor building was partly so easy to deconstruct because it was *designed and constructed in a “simple” way* according to the interviewees. For example, the elements were easy to lift with the cranes during deconstruction because the elements still had their lifting gear attached − they had not been cut off during their original assembly (**I9**). Also, the client representative mentioned that the donor (apartment) buildings were designed so that similar apartments were stacked on top of each other and thus the unwanted, large apartments could be removed rather simply by removing a segment of the building altogether, which was also a cheap solution (**I12**).

> ”*The construction methods back in the day [when the donor buildings were made] may have been in favour of [deconstruction]*.” (**I9**)

In addition, the choice of the proper receiver buildings was important. The buildings in which the salvaged elements were reused were *secondary* buildings in the sense that they were not intended for similar use than they had been in in the donor buildings. *Because the receiver buildings were not intended for housing or similar high-value and* *high-standard uses, this enabled that cost-intensive steps related to element recovery, repairs and possible certification could be omitted.* There was also less ambition regarding the aesthetic details of the receiver buildings, such as the car sheds (**I9**, **I12**).

> *"[The elements] were used in the structures of outdoor buildings which were then re-upholstered - - There were no kind of visual or health-related factors that really needed to be considered*." (**I9**)

The client also highlighted as one of the reasons for the project's success the *motivation for preserving the donor building with emotional value*. It was seen that if the buildings would have been sold to property developers, the old buildings might have been seen as "waste" rather than a building with existing historical value that should instead be renovated. But because the donor buildings had a history in the possession of the housing company, the client was keen on preserving them and finding alternative solutions for the vacancy problem (**I12**).

7.4 Case C: Concrete upcycling in a new building

7.4.1 Description of Case C

Case C serves as a supplementary case within this study, as it contains reuse of also other building materials in addition to concrete, it takes place in Denmark and the available data consists of solely secondary sources.

This reuse project deals with concrete upcycling in the construction of Upcycle Studios, a residential building in Denmark that was built during 2015-2018. The building is located in the Orestad region in Copenhagen. Upcycle Studios is a housing complex consisting of 20 three-storey terraced houses, with a total size of 3340 square meters. Upcycle Studios is designed by architectural designing company Lendager Group, which consists of three business units (building design, upcycled materials production, and consulting). (Lendager Group, 2021) Other actors involved in the project are a real estate company (NREP), a construction company and a consulting engineering company AG Gruppen, as well as a waste treatment company Norrecco (Sustainability, 2020).

Upcycle Studios is designed to be sustainable on many levels: material and energy consumption as well as social aspects have been taken into account in the building's design (Sustainability, 2020). The building includes also aspects of the Sharing Economy and flexibility principles: the houses are for rental use and suitable to be used for both working and free time and for people in different stages of life. In addition, the building includes roof gardens and solar panels. (Lendager Group, 2021)

Figure 14: Receiver building (Upcycle Studios) in Case C. (NREP, 2021)

However, the most ambitious goal in Upcycle Studios is related to its use of materials. Three types of building materials that, instead of ending up to waste have been utilised to a large extent in the construction of the building. Surplus wood has been utilised in the flooring, walls and facades of the building, and 75 % of the windows originate from abandoned buildings and have been upgraded to suit modern standards and reused in Upcycle Studios. Most of the concrete cast for Upcycle Studios is “upcycled”, containing concrete aggregate from the construction of Copenhagen Metro. (Lendager Group, 2021) Lendager UP, Lendager Group’s subsidiary specialising in upcycled products, describes their view of upcycling as a “*process whereby the value of waste materials is increased through the recycling process, ideally also creating a product with a longer lifespan than the original*”. (Lendager Group, 2021) Upcycle Studios is also mentioned to be “designed for dismantling” so that its building parts may have a second life when they are no longer used in the building (Lendager & Pedersen, 2020), however, this accuracy of this statement was not further elaborated in the available data.

Upcycle Studios is globally renowned, and the building has been awarded for its innovativeness, making it a “success case” regarding design. Upcycle Studios has made it to the finalists for Fast Company’s “World Changing Ideas Awards” in 2019, in the “spaces, places and cities” category (Clendaniel, 2019). Upcycle Studios has also won a Danish Design Award in 2019, in the “Save Resources” category (Danish Design Award, 2019). The jury of the contest commented:

"- - *Upcycle Studios demonstrates good design, materials innovation and process documentation that is highly praiseworthy and sets a great example for others to follow and join*." (Danish Design Award webpage, 2019)

According to the designing company, Upcycle Studios had the goal of acting as a benchmark for how sustainable construction can be achieved in a cost-efficient manner, at no expense of aesthetics (Lendager Group, 2021). The key actors in the project, mainly Lendager Group and NREP, have provided extensive calculations related to the energy use and costs among the building's lifecycle (*see* Sustainability, 2020). These documents have been utilised also as secondary data for this case.

7.4.2 The reuse process in Case C

Case C involves the reuse of three types of material: concrete, wood, and windows. The reuse pathways for all of these materials are different. Whereas in the reuse process of Case B, the same donor buildings resulted in various types of receiver buildings, in Case C, the donor structures are different but end up in the same receiver building.

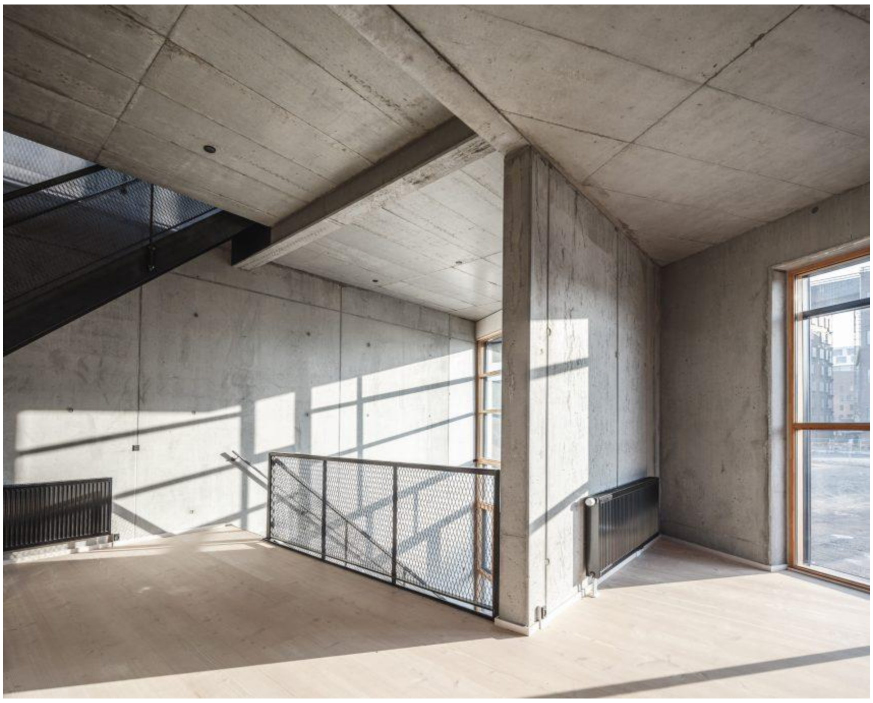

Figure 15: Indoor view of Upcycle Studios, showing the bare upcycled concrete walls and roof, the upcycled windows, and wooden floors made from surplus materials. (Photo by COAST, from Astbury (2019))

Concrete

In Upcycle Studios, 1400 tons of concrete that has been used in the building is upcycled concrete. The upcycled concrete was cast in-situ in Upcycle Studios in the building's foundation, ground deck, inner partition walls, and the floor slab on the deck. In addition to this, virgin concrete (non-upcycled) was also used in parts of the building. Two types of concrete were used − one type for the floor slabs and another type for the interior walls. (Lendager Group, 2021; Sustainability, 2020)

In upcycled concrete, the coarse aggregate consists of crushed “donor concrete” (Sustainability, 2020). The production process for the upcycled concrete as stated in the documentation by Lendager is given in Figure 16. The concrete originated from an ongoing construction of Copenhagen metro. The donor concrete was *in situ* cast, making it different from the precast elements that were reused in Cases A and B. The metro concrete underwent quality and strength testing to determine its suitability for use in new construction (Lendager & Pedersen, 2020). Because the concrete used in the metro construction had high quality requirements, it proved good to use in upcycle concrete. The high quality of the upcycled concrete enabled in-situ casting to a height of 12 meters in Upcycle Studios. (Kargaard, 2018) The donor concrete originated from an ongoing construction, making it an “aggressive” type of concrete that has not yet fully solidified at the time of mixing (Lendager & Pedersen, 2020).

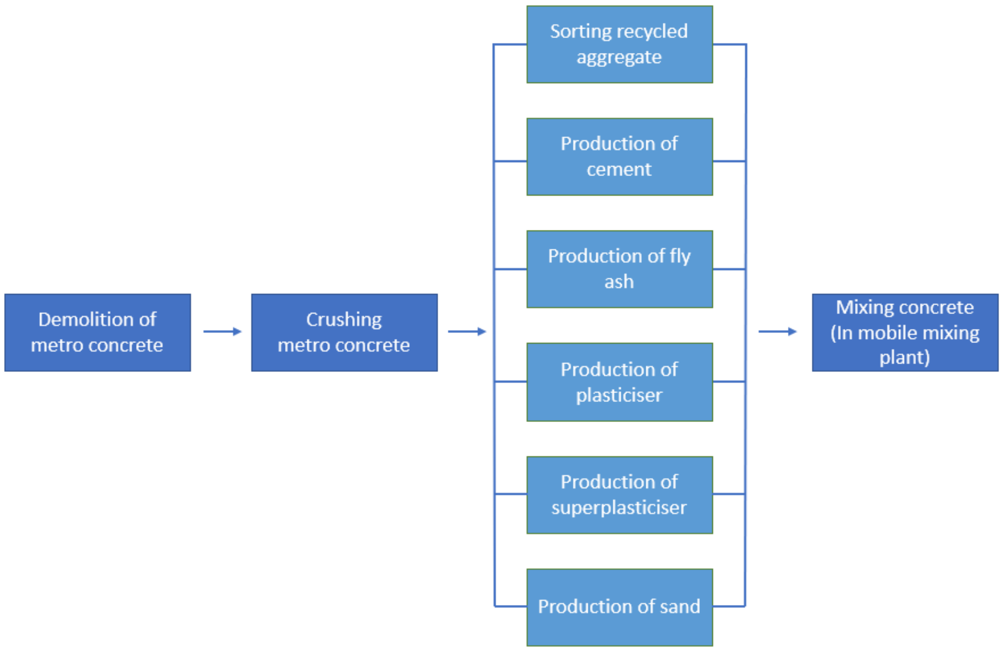

Figure 16: Production process of upcycled concrete for Upcycle Studios (adapted from Lendager & Pedersen, 2020)

In addition, two other types of material were sourced and reused. They are included here, because the secondary material available on the case concerns the building as a whole, hence it would be a threat to validity to omit the other two building materials without knowing the details of the case. Further, including all the secondary materials used provides a richer perspective to the reuse phenomenon in the construction industry.

Wood

The donor wood material consisted of discarded wooden floors gained from the factory of a wooden floor manufacturing company. The upcycled wood material used in Case C was not exactly "reused" because the product was sourced directly from production and was never "used" in the first place. The reuse process for wood is presented in Figure 17.

The reuse process for wood does not involve any virgin material inputs as such. According to the data, the wood material was discarded by the original manufacturer because they were of an unsuitable length or had some fungi infestations, thus not meeting the original quality requirements set by the floor manufacturer. The wood pieces were cut to suitable lengths, but they ended up shorter than wood cladding would normally be, which was seen as an increase in the installation time. (Lendager & Pedersen, 2020)

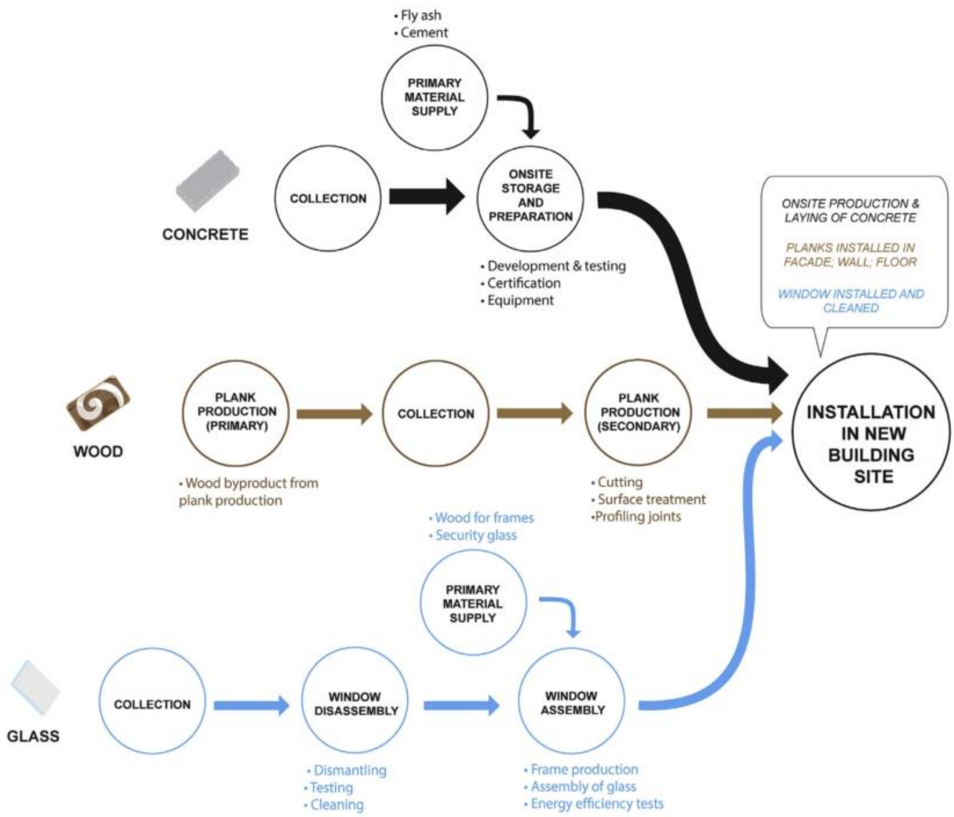

Figure 17: Figure by Nussholz et al. (2020) presenting the reuse (value chain) processes for the three upcycled products in Case C.

The upcycling process for the wood offcuts adhered to the biological cycle of the CE − the products were treated with natural linseed oils, and a black finish for the exterior façade was yielded by a process of burning the wood slightly on the surface. This was reportedly done both for the unique aesthetic appearance but also as a protection for the material. The upcycled wood products were then utilised in both the interior (floors and walls) and exterior of the terrace. (Lendager & Pedersen, 2020)

Windows

57 sets of windows utilised in the receiver building contained up to 50 % secondary materials. The windows were salvaged from an abandoned donor building in Aalborg. The installation of windows was a labour-intensive process done manually, but the project involved volunteer personnel in the deconstruction. The windows themselves were “remanufactured” (Figure 17) and then reassembled and supplemented with new wood frames and an added security glass. The used glass layers were combined into new multi-layer windows so that the windowpanes would meet the current energy demands and gain an “as new” lifespan. (Lendager & Pedersen, 2020)

Figure 17 presents the reuse process for all of the upcycled materials within Case C as illustrated in Nussholz et al. (2020). As can be seen from the figure, the upcycling process requires value-adding activities and even some virgin material inputs (for concrete and wood) so that the high quality of products can be guaranteed.

7.4.3 Value implications to actors involved in Case C

Value creation in Upcycle Studios has been studied in Nussholz et al. (2019) and Nussholz et al. (2020). Economic, environmental and social value have been discussed in the papers, focusing on the point of view of Lendager UP, the firm overseeing the reused materials design and production in Upcycle Studios (Nussholz et al., 2020). Case C is a past project, so just as Case B, the value from reuse is already realised. However, the case includes also value *potential*. Due to limitations of data access, the focus here is on value implications for two sets of actors within the case: the architecture company and the clients.

Architect/Upcycled materials designer

The architect created value in the reuse process both by designing the receiver buildings as well as the upcycled materials and their incorporation in Upcycle Studios (Nussholz et al., 2020). The company had outsourced the production and installation of the upcycled products but was in charge of managing the products’ value chain (Nussholz et al., 2020). The company sources its products from “urban mines”, both secondary and excess goods that can be saved from becoming waste and instead becoming valuable parts of a building. Thus, the company has adopted a design-for-reuse BM on the building level as well as an EPV BM in building product design. The materials producer has been circular from the beginning, and the company aims to be a market leader in sustainable solutions and CE (Nussholz et al., 2019). According to the company website, the motivation for starting the upcycled materials business in addition to the existing architectural business was the realisation that there is not enough supply of upcycled construction products, yet a rising demand for such locally sourced products had been identified (Lendager Group, 2021).

Case C marked an important "success case" for the architecture company. By participating in the development of Upcycle Studios, the company was able to demonstrate the reuse of concrete, windows and wooden floors, and the upcycled products are still in the product portfolio of the company today (Lendager Group, 2021). The company's products create value to building developers by lowering emissions relating to material consumption, while providing the same or even higher performance with regard to current building standards, functionality and aesthetics (Nussholz et al., 2019; Nussholz et al., 2020). In addition, *functional value* was also implied in the data regarding the upcycled products: the concrete used in Upcycle Studios was subject to strict "first-time production" standards, meaning that for legislation to allow using the upcycled concrete in the buildings, it had to not only reach the compressive strength requirements of virgin concrete, but actually exceed them (Sustainability, 2020). The reuse process in Upcycle Studios thus enabled the materials producer to strengthen the value proposition of their existing circular BM.

It was also suggested by the data that within Case C, the architecture company was able to pilot a mobile mixing plant for concrete, which since yielded an opportunity for the company to further develop the crushed concrete upcycling together with a mining company partner (Nussholz et al. 2019).

> "*Through a long trial process, we have amassed a lot of experience as well as very specific knowledge about handling, processing and documentation of concrete waste*." (Lendager Group, 2021)

Regarding the reuse of wood, the company was able to acquire high-quality offcut floors from the premium floor manufacturer free of charge allowing the architect to resell the high-value floors with only small amount of product recovery needed, creating win-win opportunities for itself as well as the client who gains the functional and aesthetic value from the premium wood floors, facades and walls with lower price (Lendager & Pedersen, 2020). The architect often receives suggestions from owners of used products that they could supply materials for upcycling:

> *"- - there's so much quality materials that we unfortunately have to let go. The calls that we get, there's the obvious ones: 'I have a lot of windows, what to do with them, we're taking them down'. But we also get calls from other industries: 'We have no idea what to do with a vast, vast volume of waste, can we do something about it?'"* (CEO, Lendager Group) (Dansk Arkitektur Center, 2020)

The architect focuses a lot on communicating the sustainability benefits and cost implications of its building projects. The company benefits from the recognition of Upcycle Studios, because this may facilitate demand for circular products in the building sector, as customers become aware of the feasibility for cost and environmental efficient closed-loop construction.

The reuse process in Case C marked an important source of information value for the architect in improving its business and managing the business risks involved in closed-loop construction. The company received a subsidy for the costly research and development activities required for Upcycle Studios (Nussholz et al., 2019). Due to the high R&D costs especially regarding the production of reused concrete, the utilisation of upcycled products was yet not considered as profitable as virgin equivalents (Sustainability, 2020).

Clients

The two clients in Case C were a building developer and a real estate investing company working in collaboration. The value the clients gained from reuse had to do with the overall sustainability elements of Upcycle Studios which resulted in low lifecycle costs for the building.

One of the benefits gained in the project had to do with the documented improvement in carbon emissions reduction by substituting the use of virgin products with upcycled products. This environmental benefit was realised by the client who may use the building in their investment portfolio. For example, due to the reuse of concrete in material form, the CO_2 emissions for concrete in Upcycle Studios were realised as 5-8 % lower than virgin concrete. For upcycled windowpanes, the CO_2 savings were 32 %. And for wood reuse, the emissions were decreased by 68-88 % depending on the wood product (Sustainability, 2020).

The clients themselves were able to capture realised value from renting out the apartments in Upcycle Studios. Commercial viability was deemed important for the investing company. For the clients, the project did not end up costing much more than a traditional building of similar quality. (Business Review, 2019)

> "*The project was economically constructed as a conventional row house project, where sustainability actions could not increase the total budget for the development*." (Sustainability, 2020, p. 71)

The client company worked in collaboration with the architect and upcycle materials producer, and they had also worked together previously in another circular building project in the same area (Bertelsen et al., 2020). The real-estate investor has "*a strategic focus on pioneering sustainability solutions*" (Bertelsen et al., 2020), so the reuse process has created value for them in the form of complementing their strategy in this area. The decreased environmental costs may also serve as a type of risk management for the client.

7.4.4 Value capture determinants in Case C

This section discusses what value capture related findings were extracted from Case C. These were rather easy to extract from the secondary data, as both relevant policy interventions, business drivers and barriers (Nussholz et al., 2019) and scale production benefits (Sustainability, 2020) have been discussed in the data. Furthermore, some additional insights have also been examined that may also be considered value determinants − those that have helped or will help generate value to the actors involved.

One of the identified value determinants has to do with the *lack of virgin resources*, which makes them expensive to source. This development, regarding both natural gravel (concrete production) as well as sand (glass production) could make upcycled products from secondary materials cheaper in relation to the transportation costs relating to virgin material sourcing from new locations. The upcycle materials producer has highlighted in their marketing the fact that Denmark is *at risk of running out of natural gravel*, which would support the utilisation of existing concrete in product manufacturing. The comparative cost and emissions analyses provided by the company have concluded that upcycling of concrete may become more profitable as the limited supply of natural gravel makes upcycled concrete relatively more profitable as transportation costs would otherwise get too high (Sustainability, 2020).

However, the *locations of the donor concrete site as well as the receiver building sites* were also seen as crucial so that the economic and environmental cost benefits of upcycled concrete would not be lost in long transportation distances. Thus, *the choice of optimal donor and receiver sites* should be considered to capture value from (concrete) reuse (Nussholz et al., 2019).

One of the barriers for capturing value in the reuse process as found in Nussholz et al. (2019) was that *enough secondary (donor) products and materials are difficult to find* for upcycled materials production. On the other hand, the architecture company is sometimes contacted by potential donor building/product owners who themself suggest that the company could utilise their waste materials in upcycling (Dansk Arkitektur Center, 2020). It was also implied in the data that one of the success factors for reuse in Upcycle Studios had to do with the *creativity of the materials producer* in working with different kinds of materials and their possibility to spend resources in the product development.

Another value determinant is related to the required *scaled production* to make the production of upcycled concrete in particular more profitable. Regarding concrete reuse, Upcycle Studios marks a pilot case in which the actors involved identified that the production needs to be more scaled to offset the high research and development costs that have sunk in the project. The actors estimate that, if economies of scale can be utilised in future projects, crushed concrete reuse becomes more profitable (Sustainability, 2020). Scaled production was also mentioned to decrease costs in the future, because the concrete had to be tested extra carefully during first-time production, which created additional costs in the reuse process. These tests could be avoided in the future if upcycled concrete is utilised more in construction (Sustainability, 2020).

7.5 Cross-case synthesis and comparison

This section summarises the findings gained from the single case studies, with regard to both value capture for the different actors involved in the cases as well as the identified value capture determinants.

7.5.1 Reuse processes for building product reuse

Here, findings related to the reuse processes in each of the cases are discussed and compared. Because the cases were chosen as diverse, the reuse processes were expected to be different at the outset. The reuse processes for each case are shortly reviewed here by examining what kind of donor structures, product recovery operations and receiver structures were present.

Cases A and B were strictly related to the reuse of concrete. The donor structures in both cases were multi-storey buildings: in Case A, the donor building is an office building, while in Case B, there were several donor buildings, all apartment buildings within the same housing area. Both the cases involve the reuse of precast concrete elements salvaged from buildings currently in use. In both cases, the donor buildings, while not designed for deconstruction, contained some properties that made the buildings easy to deconstruct and reuse according to the interviewees. Such properties include suitable floor height (Case A), a beam-post building frame (Case A), having similar apartments stacked on top of each other for sensible building downsizing (Case B), the presence of precast concrete elements altogether (Cases A and B) with existing hoisting gear still intact (Case B). In Case A, the donor building was in possession of the property developer, and in Case B, the building was owned by the housing company.

For Case C, there were several donor materials originating from different locations. The donor concrete was in-situ cast, sourced from an infrastructure construction site, making it different from the other two cases which dealt with precast concrete. Because the donor concrete was not precast, it could not be reused as entire elements − instead the concrete was crushed and reused as part of new in-situ cast concrete. In addition, surplus or unqualified wood products were acquired from a factory producer, and windows were salvaged from abandoned buildings.

All of the cases depicted reuse of concrete in new structures, as was desired when selecting the cases. However, the levels of reuse ambition were different for each case. For Case A, reuse has not yet realised, so accurate information about the receiver structures could not be gathered. However, the case project aims for high-value reuse, and to the realisation of concrete element reuse in new apartment buildings. If a primary receiver building is found for the project, the elements likely end up in reuse as part of a receiver building, together with virgin elements. The same goes for Case C, where concrete was reused in a residential terrace as load-bearing elements, which is a high-value reuse application.

In Case B, due to the nature of the project, the receiver structures were also the donor buildings, when reuse was realised through adaptive reuse of the donor building. Other receiver structures of reuse on the site were the open, outdoor buildings within the apartment building courtyards. The structures had no special health requirements because they were located outside and either open or otherwise not meant for people to stay a long time in. Other receiver structures in Case B were miscellaneous farm buildings that third parties reportedly assembled from the donated elements somewhere else in the region.

Due to the different donor and receiver structures in the different cases, the recovery operations enabling reuse were also different. Case A is characterised by goals for high-value reuse for the deconstructed components because the case project aims to pilot the reuse of concrete elements while retaining as much of the value as possible. The expectation is that the salvaged components need to undergo various testing and possible repair operations which are costly but result in good quality, as-new products as outputs. On the other hand, products that will end up in secondary applications may not require much product recovery, as in Case B when the elements were utilised in their current condition, which made reuse cheap for the construction company and the housing company. In Case C, on the other hand, the products were modified rather extensively, and the reused crushed concrete was subject to strict quality testing. In addition, the windows had to be modified to meet current standards for building energy savings. The salvage of windows was not reported as challenging, whereas window assembly into new windowpanes was regarded a laborious process. Deconstruction, as such, was not evident in Case C unlike the other two cases. Window salvage from buildings was arguably easier and less risky compared to concrete element reuse in the other cases. Especially the utilisation of "waste" concrete meant that the upcycling process did not include the deconstruction phase which was present in Cases A and B.

7.5.2 How value is created and captured in the reuse of building products

The case findings depict several types of value for various actors in the value chains. Value was found to be captured both directly from reuse, resulting in cost savings or revenue gains, and indirectly, through increases in revenue on the longer term through new emerging business opportunities. Value was seen to be captured by actors in the upstream, midstream and downstream of the value chains. Furthermore, value creation and capture manifested in a variety of ways across different reuse pathways. A summary of both realised and potential value for the actors in the cases is presented in categories in Table 8.

Table 8: Cross-case comparison of value related findings

	Case A	Case B	Case C
Overview of value in the reuse process	Ongoing pilot project of deconstruction, element recovery and high-value reuse yielding future business opportunities to several actors.	Adaptive reuse by building downsizing, secondary, local reuse of salvaged concrete elements. Implied realised value for the housing company and the residents.	Reuse by upcycling concrete, wood and windows in the same receiver building. Has contributed to realised environmental costs savings and business opportunity in upcycled materials design/ production
Information value	Value-chain actors can learn which steps in reuse process are value-adding and which are not.	The construction company was able to learn new methods of disassembly	The architect was able to identify demand for upcycled products.

	Property developer can identify demand for circular buildings through reuse pilot projects. Structural designer, element manufacturer, architect and demolition company can learn new value-creating work methods. Value-chain actors can utilise existing competencies in novel ways in the reuse process.	and construction with reused components.	The architect and client proved documented savings in environmental and lifecycle costs through upcycling. The architect gained important insights on upcycled product development.
Cost minimisation and avoidance	Potential tax benefits may lower project costs for construction companies. Construction company may avoid potential future fees directed at virgin material reuse. Construction companies and property developers may benefit from potentially shorter construction times by using existing, dry elements.	The housing company avoided demolition costs for the donor building. The housing company cut down on maintenance costs due to building downsizing. The construction company avoided waste transportation costs by reusing the elements. The housing company saved in material costs in the construction of garage and leisure structures.	Used building products are free/affordable material for the upcycled materials producer. Buildings with upcycled materials decrease building lifecycle costs for clients/investors.
Revenue (direct)	Element manufacturers gain resale revenues from refurbished concrete elements. Property developers gain resale revenues from circular buildings involving reused concrete elements. Structural designers, demolition companies, architects and logistics companies gain revenue from service fees in the reuse process.	The construction company gained direct resale value from salvaged elements. The construction company and architect gained service fees from the housing company.	Architect gains revenues in design service fees.
Revenue (indirect)	Several actors may gain competitive advantage from element reuse process and product development. Several actors benefit from brand value related to adopting circular business practices.	The housing company gained increased rent profits due to decreased vacancy in the donor buildings.	Actors gain brand value which may yield more clients in circular building projects. Client gains revenues from renting out receiver building apartments.
Functional value/ use value/ other value	The element manufacturer gains potential for internalising material and component cost savings	The housing company and residents gained more spacious and durable structures from reused concrete elements.	The upcycled concrete has higher strength than regular concrete. Upcycled products bring unique aesthetic

	from using existing elements. Property developers/construction companies gain potential for building material substitution.	Adaptive reuse improved the image of the neighbourhood, creating value for the housing company. Adaptive reuse retained emotional value of donor buildings for the housing company.	value for prospective residents. Less virgin materials are needed when they can be substituted with existing building materials.
Business opportunities	Refurbished concrete element production by an element manufacturer. Circular building production by a property developer. Deconstruction service by a demolition company. Reuse consulting and assessment services by a structural designer. Design-for-reuse services by an architect and structural designer. Element transportation service by a logistics company.	No clear business opportunities identified.	Architecture company has expanded its business into upcycled materials and circular buildings design.
Value capture determinants	Labour intensity of element salvage and recovery affects the costs and duration of deconstruction for the property developer. Careful and efficient deconstruction reduces need for element repairs and enables resale of elements further along the element reuse value chain. Tax deductions may lower the costs of using reused elements in construction. Specific demand for circular buildings can justify higher sales prices for buildings with reused elements and yield more revenues and reduce risks for the property developer. Suitable measurements of the donor building and sufficient information on the donor building elements enables primary reuse and decreases costs of element salvage. Reusing in an optimised and hierarchical way while limiting unnecessary element recovery	The careful monitoring of deconstruction and reassembly performance indicators by the client ensured cost efficiency of reuse. Bidding competition based on both quality and price. A design-and-build contract with the construction company enabled them to find innovative and comprehensive solutions for deconstruction and reuse. The value chain actors had a common goal and good attitude towards reuse, enabling the project's success. Adaptive reuse of the donor buildings was a driver for element reuse, limiting the need for separate deconstruction for element salvage. Simple design of donor buildings enabled easy and fast deconstruction, minimising costs. Element reuse in secondary structures to	A scale production of upcycled concrete would minimise unit costs of production. The potential local shortage of natural gravel and sand may serve as a driver for upcycled product demand, increasing revenues. Insufficient supply of used materials may hinder value creation from reuse. The creativity of the architecture company in material processing turned waste into valuable products. The architecture had an existing circular BM – no additional costs or risks were thus incurred for the existing business. Location of donor and receiver sites affects the costs of reuse from transportation.

	operations minimises reprocessing costs. Potential scaled processes in element assessment and refurbishment may decrease costs of reuse.	avoid costs related to testing and refurbishment. Reuse project was well-known – finding local demand for elements was easy.	

The findings from the cases suggest several types of value implications of reuse. First, because the case projects were all "pilot" projects in some level, the cases implied *information value* to actors involved in reuse processes. For instance, in Case A, the actors gain information on which activities are value-creating on the longer term and which should only be applied in the pilot project. Furthermore, the businesses receive and opportunity to test the customer reactions to reuse and investigate whether there exists demand for the reuse activities or not. The actors may also utilise their existing competencies in new settings. In Case B, the construction company learned new methods of construction and component assembly which reportedly may have aided them in future projects as well. In Case C, the documented realisation of improved lifecycle costs for upcycled products was important in communicating the environmental value benefits of the architecture company's offering.

The reuse of concrete and other materials was also seen to contribute to cost savings and avoidance of alternative costs. In Case A, the possibility even arose that reused, dry concrete elements might even contribute to faster construction times, although the benefits can be partially offset by the need to have more careful moisture protection plans during construction. Furthermore, it was identified that, in the future, companies may need to face higher costs linked to virgin material use, which would make the reuse of elements a more profitable option, but this was not reality yet. For case B, however, cost savings were a source of significant realised value gained from both adaptive reuse and element reuse. From adaptive reuse, the housing company saved costs relating to demolition and new construction of the donor building when the same functionality could be achieved by adaptive renovation and downsizing existing buildings. In addition, the buildings' maintenance costs were decreased as apartments were no longer left empty. Furthermore, the utilisation of salvaged elements from adaptive reuse in new structures contributed to decreased waste management and logistics costs for the housing company. Material costs were also saved for the housing company when the structures were built with existing elements. Material savings were also linked to Case C, where the material costs for wood were mostly avoided as the upcycled materials designer could source the wood for free at a wooden flooring manufacturer. In general, the upcycled materials productions in Case C was rather costly due to first-time production requirements and lack of scaled processed, but it was also identified that cost savings might be possible once these issues are solved.

Reuse also brought realised or potential revenues, either directly or indirectly, in all cases. In Case A, possibilities for revenues have to do with reselling elements for reuse, either by an element manufacturer or some other actor earlier on in the value chain, as well as increased service fees for the building design and deconstruction operations as it is assumed that these activities might take a longer time. In Case B, some of the elements were reportedly sold by the construction company for external actors. The resale or letting of new buildings which at least partially include reused elements may also bring revenue flows for actors in the downstream of the value chain. For example, in Case A, the property developer identified a possible new clientele for circular buildings. Adaptive reuse in Case B brought increases in rent revenues for the housing company as the overall attractiveness of the neighbourhood increased. In Case C, the client received rent revenues from letting the apartments in the receiver buildings, and the architect received service fees from design of new buildings.

The cases also depicted various forms of functional and use value for reused products. These refer to instances where the product creates (nonmonetary) value during its use, and especially the kind that is unique to the reused material. Use value was a significant form of value for the housing company and neighbourhood residents in Case B, where the salvaged elements that would have otherwise been waste were utilised in covered car parks, gazebos and maintenance buildings. In addition, adaptive reuse enabled utilising existing spaces in the donor buildings, which resulted in more space per resident at no additional expense. The housing company also retained the emotional value linked to the old donor building. Because the salvaged elements were made of concrete and of a given size, they actually allowed for the construction of more numerous, more spacious and more durable structures for the residents than would have been made if virgin materials (e.g., timber) had been utilised. In Case C, functional value was insinuated in the data, because the upcycled concrete had higher strength than virgin concrete which may result to more durable receiver buildings. The most significant use value in the case has to do with the unique aesthetics of the upcycled products, where the circularity of the material is purposefully accentuated which may attract a certain customer base and result to higher revenues. Some forms of potential use value were also identified in Case A, where the value of the concrete elements could be internalised by the element manufacturer who may utilise the materials as inputs in its production process, or by construction companies that may substitute new concrete elements with already existing, salvaged components.

Business opportunities were identified in various phases of the reuse process and links of the value chain. The findings suggest that potential for several types of business opportunities exist at least for property developers, structural designers, demolition companies, element/product manufacturers and designers, architects and logistics service providers. Most of the business opportunity-related findings are from Case A, as it comprised the greatest number of interviewed actors. Furthermore, in Case A, the reuse process was still at its beginning and thus no realised value capture could be identified yet, so focus was on the value *potential*.

Almost all of the actors across cases were expected to gain sustainability-related brand value from developing new kinds of services and products that either directly or indirectly would also translate to revenues. The property developer in Case A identified potential for a new type of customer segment of buyers looking to have circular buildings, where reused building components are utilised. However, challenges were linked to the costly phase of deconstruction. For the structural designing company, it was identified that it can capture value in the reuse process by offering consulting services related to best methods of deconstruction in the form of pre-demolition audits, which also contributes to value creation for the other actors further down the value chain. Additionally, structural designers may also utilise new types of expertise in the designing of buildings with reused products. The element manufacturer may gain business opportunities in the refurbishment and resale of used concrete elements, which would, however, require creating new production line. The demolition company, on the other hand, can expand its expertise in building disposal methods to also provide services in deconstruction for building owners. There may also be business opportunities for logistics service providers which could transport the elements from one worksite to another, additionally also taking measurements and handling a tracking system and possible storage for the elements. Architects may utilise their creativity in the design of buildings so that they include reused elements. It was suggested in the data that architects may even have a more prevalent role in the reuse processes in the future, and they may have more control over the receiver building design than previously. Within Case C, business opportunity for upcycled materials design and production was also identified, where waste products are sourced from worksites and recovered creatively to create high-level product outputs. No clear business opportunities were identified within Case B, because the value gained in the project realised on the project level, and longer-term impacts on companies' BMs did not come up in the data.

Reuse in the cases stemmed from various motivations by the actors. Participation in subsidised project was the direct and indirect motivation behind the reuse of concrete and other building materials in all cases. It was also found that the actors' desire to be ahead of competition and respond to expected demand for circular services and buildings or building products was a motivation for participation in the reuse processes. For example, several actors in their respective interviews in Case A told that their company, in participating in this research project, wishes to gain a competitive edge compared to their competitors. In that sense, they identified that there exists *future revenue potential* with regard to both new products and new services from product lifetime extension. On the other hand, some actors saw that they might miss out on value opportunities if they did not answer to the demands of customers. Thus, reuse BMs may also be seen as a practice contributing to risk management and sustainable competitive advantage.

In addition to identifying business opportunities for actors, the data also suggests several analogies in the companies' current know-how and resources that may aid them in seizing the business opportunities, regarding Case A in particular. The element manufacturer, structural designer and demolition company all had some forms of competencies and existing working processes that might be utilised in a reuse process setting. For example, paper machine disassembly in prior projects and building deconstruction were seen as relatively similar practices by the demolition company. The element manufacturer identified that it may be able to utilise existing processes of element surface treatment as well as equipment for the lifting and space for storage regarding the reused elements. The structural designer can utilise existing processes related to condition investigations and pre-demolition audits when conducting investigations for deconstruction purposes on the donor buildings.

In comparing the reuse processes with the identified value capture findings, interesting conclusions can be made. In Case A, reuse is implemented through a high-value product recovery process for whole elements with a higher number of actors involved. In the midstream of the value chain, cases A and C include the presence of manufacturer who not only retains the existing value of the products but also enhances them (adds new value). The reused materials in both cases A and C become reused in primary applications, and thus the reuse process involves steps which ensure that the products meet the required standards. The element manufacturer in Case A is an established company that has not previously done refurbishing on the component level but is able to make use of existing processes so that such practice would become a viable business in the future. The upcycled materials producer in Case C is already a circular company from the beginning, and thus a realised example of the role that product and resource lifetime extension works in the construction industry setting as well. Cases A and C highlight the need for reverse logistics, where prior to reuse the product needs to be recovered and/or upgraded. These pathways may suggest business opportunities for actors within reused building product logistics and refurbishment. The reuse processes seem to be complex in these cases, making the reuse process overall more cost intensive. However, the reused building product output should be of high quality.

Depicting a more small-scale approach, elements in Case B were reutilised in secondary applications, where high functional and use value was achieved but similar needs for product quality testing or repairs were not needed. Value was captured by the housing company and the construction company. The findings regarding Case B suggest that the role of building owners can be significant in building product reuse, as they can control the chosen methods of building disposal. However, demolition contractors may also operate as “gap-exploiters” and identify demand for building products which have been left with their possession, allowing them the opportunity to capture value in the form of resale profits. In Case B, reuse took place locally and through more “direct” reuse than the other two cases, and while the project involves innovative work methods and creativity, the reuse of elements on the component level was less laborious than expected. These findings are in line with product recovery literature, which states that product recovery options of high labour content contribute to more valuable outputs, whereas direct reuse preserves value but creates little new value-added (Russell & Nasr, 2019).

It was also discovered that value capture potential is achieved in different ways for different actors in a reuse process. It was identified that some forms of captured value are conditional, requiring that certain factors exist in order for value capture to realise for a given actor. For example, some forms of value were dependent on possible tax reductions, or the existence of more demand for reused building products, because the costs of acquiring virgin concrete was seen cheaper than reprocessing reused elements. The value capture determinants are discussed in more detail in the following subchapter.

7.5.3 What determines value capture potential in the reuse of building products

The cases yielded several findings related to how value could be captured from the reuse of building products. These value capture determinants are understood as factors that have a direct or indirect effect on either the revenues or costs for one or several actors. Some of the determinants actually fall into the category of reuse *enablers* or *drivers*. It should be noted that the goal of scoping for value capture determinants was not, in itself, to find out how reuse could be implemented. However, the empirical data suggest that the same factors that enable the reuse of building products are also related to how value can be captured from reuse.

Next, the themes which emerged in the study of value captured determinants for reuse will be reviewed.

a) Strong-willed client

The *strong-willed client* is a subtype of a larger group of value capture determinants related to the demand category. The strong-willed client describes a setting where not only has the focal actor identified existing demand for its offering − but that the demand is pull-type (cp. *push*), where there exists a client that specifically wants a reuse-oriented service or a product. This allows the product or service provider to sell its offering for a potentially higher value that offsets the costs related to the possible extensive processing or lack of economies of scale in the reuse process. Thus, in a way, the strong-willed client can compensate the lack of other value-driving determinants.

Overall, identified demand in the downstream of the value chain was considered as a determinant for value capture. Once there is demand for a building with reused components, there exists also demand for the components themselves, and thus also demand for the used construction components as inputs to the product recovery process. Thus, downstream demand for reused products is expected to yield value opportunities across the entire value chain. The demand value determinant is consistent with studies by van den Berg et al. (2020) and da Rocha & Sattler (2009) which highlight identified and existing demand to be both a driver and a prerequisite of building product reuse.

b) Properties of the donor building and the donor element

The characteristics of the reuse processes themselves were seen as important value capture determinants, because they were seen to dictate the level of product recovery needed, affecting costs incurred in the reuse process. Properties of the donor building refers to the condition, specifications with regard to current building norms and the overall nature of the building or structure or individual element which is to be (salvaged and) reused. It thus more generally refers to the disposer market of the building product reuse process.

Two main conditions for donor buildings to enable value capture from reuse were identified: First, the donor building should be easy to deconstruct or the elements easy to salvage. This may also involve having sufficient information available on the design drawings and the structures of the building. Second, the donor building needs to contain elements that can be reused in receiver buildings given the current building norms.

Regarding the first condition, the multiple case study suggests that buildings of a given type are easier to deconstruct than others. “Beam-and-post” structures were considered easy to deconstruct and easy to reuse according to interviewees and were highlighted in Case A. Columns and beams were also the donor elements that were considered easy to reuse. Easy deconstruction was an important value determinant for the property developer in Case A and both the construction company and building owner in Case B. While in Case A, the deconstruction is assumed expensive and labour-intensive, the costs are expected to be less for the salvage of some elements in the building due to the donor building properties.

The second condition is dependent on the regulatory environment and the durability and quality of the elements. For example, in the study by Huuhka et al. (2015) the authors have considered the building requirements for new buildings in determining reuse potential of concrete elements in the current building stock. If such conditions are not met (e.g., because the elements have lost functionality or are outdated in measurements), this may require (potentially costly) reprocessing so that these conditions are met, or that one settles for a lower-value reuse application.

The significance of donor building qualities was an expected result in the sense that products intentionally designed for deconstruction, as well as standardised and modular components and other functions belonging to the “nature” category have been brought up in a variety of papers focusing on drivers of reuse in construction (Iacovidou & Purnell et al., 2016; Eberhardt et al., 2020) and manufacturing (Gallo et al., 2012; Cox et al., 2013). The notion of buildings being “accidentally” easy to deconstruct despite no deliberate DfD was, however, less expected and not extensively discussed in literature.

c) Properties of the receiver building

Value determinants *b* and *c* are closely interlinked, because their combination is what essentially determines the product recovery activities needed in the reuse process. The receiver building here refers to any structure in which the secondary building products are reused (the reuse market). The receiver building was found to influence the value potential from reuse by dictating the recovery and testing operations required for the reusable building product, both from functional and regulatory sense. In Cases A and C, where the goal was to reuse concrete elements and building materials in high-value applications, extra costs may be incurred from ensuring the safety, functionality and aesthetics of the donor materials. Conversely, in Case B, because the elements were reused on the same lot and in open spaces not intended for living, there was no need to test them in any way which thus enabled value capture through cost reduction by reducing the number of required activities in the reuse process.

In addition, the application of the reused building components and materials affects also the profit potential linked to reuse. Reuse in more advanced structures, such as apartments and workspaces, enables that such buildings (or the components themselves) are resold to sustainably oriented individuals and organisations for a price similar to or even higher than new buildings. For example, the realisation of emissions savings and aesthetic appeal of upcycled products in Case C brought important sustainability value to the client companies. Reuse in secondary receiver structures, such as in Case B, however, creates value in the form of cost avoidance and minimisation as well as use value. The issue comes down to finding suitable demand for the products either from a “high-quality” or “second-hand” reuse market, or something in between these, such as a market valuing product uniqueness. For example, da Rocha & Sattler (2009) identified several types of customers for reused building products, some of whom appreciated the lower cost of products while some were looking for high-quality “antiques”. If the motivation for building product reuse is simply the minimisation of waste handling costs, product donations may also be opted for (*cp.* e.g., Veleva & Bodkin, 2018).

e) Common goal among actors towards reuse

The importance of a common goal and set targets as drivers for reuse value creation became evident in all cases. In Case A, the research project setting provides the actors a safe ground to try out reuse operations as the entire value chain is involved in finding ways to reuse the concrete elements. The entire value chain is thus set towards gaining future value potential instead of seeking short-time profits from reuse. In Case B, the client purposefully chose project participants in a way that they would provide the best solutions for adaptive reuse in the donor buildings and the subsequent element reuse in new structures. The implementing construction company and the designers reportedly had a “good attitude” during the project and the careful monitoring of costs and duration by the client ensured that the reuse project’s success was seen through by all the key actors involved. In Case C, both the client companies and the architecture company were invested in the goal of having reused materials in the receiver building. Having a separate client for reuse provided the opportunity for the upcycled materials producer to present commercial viability of a circular construction project on a large scale. The literature has also identified that *social* aspects like trust and willingness to promote reuse are drivers of building component reuse (Rakhshan et al., 2020).

f) Contractual agreements

Contractual agreements were found to determine both whether value creation can be achieved and who may capture that value. Case B depicted the importance of choosing the right type of contract form that provided the combination of risk avoidance and value capture maximisation for the donor building owner. In addition, the design-and-build contract enabled the construction company to also get its share of value from reuse by minimising costs through resale and donation of the excess construction elements. In Case A, the discussion on value capture potential for various actors led to the conclusion that the division of "benefits" from reuse will be determined largely by the formation of the value chain − who is the supplier for whom, for example, and whether there will be additional players in the reuse process. This value capture determinant is linked to the discussion in Chapter 4 on the role of demolition contractors as promoters of reuse, and how they may choose to salvage and resell building components for their own value capture even when not instructed to do so (van den Berg et al., 2020).

g) Legislation, policy and public guidance

The role of legislation and guidance was highlighted by many actors especially in Case A. This determinant category involves both the suggested tax benefits given to actors operating in the downstream of the reuse process to minimise costs related to product recovery, as well as some form of penalties or taxes for the use of virgin materials. It was the actors' own perception that policy changes should be made in a way that the reuse of goods would be more affordable to the actors when compared to construction using virgin building products. Furthermore, it was also implied that policy changes may be needed to better enable the communication of environmental impacts of reused products to potential customers. The general consensus among interviewed actors seemed to be that the involvement of regulations to artificially make reuse profitable should only be a tool utilised in the beginning of the shift towards circularity and reuse in construction, but on the longer term, the supply and demand for reused building products should be driven by market-based profitability. In addition, possible obstacles stemming from regulatory processes created for a linear economy should be addressed so that reuse is, at minimum, not hindered. Legislative/regulatory factors have been identified in literature both as barriers to be addressed, such as bureaucratic processes (Rameezdeen et al., 2016) as well as drivers for increasing reuse of building products, such as incentives (Rakhshan et al., 2020).

h) Experience, optimisation and economies of scale

Last but not least, experience, optimisation and/or scaled processes were also evident at least in some way in all of the cases. The presence of expected high research and development costs was identified in cases A and C for the product manufacturer and the upcycled materials designer. All of the cases represent pilot projects, so the reuse value chains are not yet optimised for maximum value creation, but it was identified that the product manufacturers and designers might benefit from a larger scale production so that individual components and materials would not have to be so carefully examined or processed separately as this was considered costly.

In addition to scaled production and services, experience was also found to be a value determinant in some form in all of the cases. In Case A, the project actors gain information value throughout the project regarding best methods for, e.g., element deconstruction, tracking, testing and transportation. Through a learning process, this information value can translate to economic value for the actors by them being able to, e.g., omit redundant phases of the reuse process and optimise element salvage and processing so that only the necessary and valuable activities remain in the value chain. In Case B, accumulated experience throughout the project by the construction company allowed them to try out different techniques for deconstruction at the beginning of the project, which made the subsequent reuse of elements in later phases of the project successful. In Case C, the pilot project of Upcycle Studios marked an important step for both the clients and the architect in developing other circular buildings jointly in the future.

7.6 Discussion

The empirical setting of this study combined the multiple cases together to reveal interesting findings regarding value creation from building product reuse. Reflecting with circular BM research, this study showed that EPV BMs are seen as potential paths for circular value creation also in the construction industry setting. It is interesting to see where companies from demolition contractors to property developers, product manufacturers to architects will position themselves once the circular transition towards the construction industry finally realises on a larger scale.

Regarding reuse processes for building products, several value creating pathways were discovered − even within the single cases. Distinctions were found along the entirety of the reuse process − the source of the used products (disposer market), the product recovery process, and the receiver structure (reuse market). The sources for products in the studied cases ranged from in-situ cast concrete in a worksite, windows in abandoned houses and surplus wood from manufacturers to pre-cast concrete elements in existing buildings still in use. The receiver structures in the reuse market were also varying, consisting of both open and closed structures with varying building requirements.

Regarding value creation and value capture potential in reuse processes, it was found that companies in the upstream of the reuse value chain − that is, donor building owners, demolition companies, pre-demolition consultants and waste transporting logistics companies, may capture value from reuse by reselling building components along the value chain, or simply by minimising the cost effect of waste handling either to themselves or their value chain partners, depending on the contractual relationships.

The findings of this study suggest that business opportunities may exist for companies in the midstream of reuse value chains. Companies like precast element manufacturers, upcycled materials producers, building product refurbishers and resale platform service providers can exploit gaps presented by the new supply of salvaged building materials in need of testing, checking, refurbishment, certification and distribution for reuse. Similar to findings in Yrjölä et al. (2021), Whalen (2019) and Ertz et al. (2019), such intermediating actors are needed in bridging the supply and demand of secondary building products together, while minimising transaction costs that may hinder their reuse.

Finally, the reuse side of the process involves potential for construction companies, property developers and investors in realising their sustainability, risk management and brand image goals as companies may either choose to stand out from competition by reuse of building materials − or by following the “sticks” and “carrots” issued by policy makers.

Regarding value capture determinants in a reuse process, the findings of this study mainly follow the same line as prior studies within construction industry on the enablers and barriers of reuse. For example, need for legislative instruments was not a surprising finding. In addition, similar results were found that design-for-deconstruction and standardisation of elements is needed to make reuse more profitable, as in, e.g., Iacovidou & Purnell (2019) and Adams et al. (2017). Within the first of the studied cases (Case A), overall, the deconstruction phase was deemed costly and seen as limiting the profit potential for the property developer. Surprisingly, deconstruction was not deemed very expensive or challenging in the second of the studied cases (Case B), which challenges the prevalent view that deconstruction is often costly and unprofitable for the old building stock not designed for deconstruction (Tatiya et al., 2018).

The final case (Case C) demonstrated that value-retaining reuse options are possible for buildings without deconstruction, when instead of utilising whole components in construction, waste is utilised creatively by upcycling. Similarly, as in the processual chart by Cai & Waldmann (2019), it is proposed that current buildings and structures made of concrete but deemed unfit for reuse on the component level might find secondary uses from creative approaches and upcycling. The buildings where such upcycled materials would be utilised should be designed so that reuse on the building or component level might be possible in the following cycles of building use. Drawing from this, an opportunity exists for *cascading* reuse for materials also in the technological cycle of the CE diagram. Technologies could be developed that better enable a cheap case-by-case examination for reuse potential within a certain building to hierarchically determine whether reuse could take place on the building, component or material level.

The focus in this study was on cases which employ the *nurture* strategy for buildings and building elements, i.e., focusing on extending the value of the product during its mid-use and end-of-use (Cox et al., 2013). Cases strictly employing only the *nature* strategy (but no secondary material reuse) were not considered, yet determining factors were found in the donor buildings' design that served as enablers of reuse and value capture − even when a specific nature strategy had not been implemented. This notion supports the view that the existing building stock can be reused, but also denies the before-established notion that DfD would be prerequisites of value-capturing reuse. However, the findings should be approached carefully as all of the cases within this study included value chains where some form of financial support was granted in the construction projects.

The transitional phase towards CE provides opportunities for building owners and construction companies to reuse concrete elements and gain certain benefits and advantages. If it is assumed that reusing (concrete) building elements is feasible, but challenging (i.e., it creates costs in relation to demolishing or virgin construction), then there arguably exists a business opportunity for an actor able to minimise such costs. For example, if donor buildings are not designed for deconstruction, provision of a service in demanding deconstruction or design is a value-creating activity. However, if buildings do become more easily deconstructable even from their design, this means that deconstruction is theoretically very simple, and a special service is no longer needed. This shift in properties of the building stock would arguably change which services and products are needed for future reuse processes, and business opportunities are then expected to shift towards designing buildings for disassembly from standardised components, as well as maintenance services that extend building and component lifecycles.

8. CONCLUSIONS

This final, concluding chapter provides remarks for the key findings, originality, practical implications, and limitations regarding this study as well as ideas for future research.

8.1 Key findings

This exploratory study on building product reuse in construction projects yielded several interesting findings. Here are some highlights of this study:

- Value-creating forms of concrete reuse can occur on the building, component and material level, and with varying amount of product recovery needed.
- Construction industry actors can capture value from reuse in the upstream, midstream and downstream of reuse processes. Value capture from reuse can manifest in information value, use value, cost minimisation, and direct and indirect revenue increases.
- Business opportunities within building product lifetime extension were identified, e.g., element refurbishment, upcycled materials design and production, deconstruction services and reuse consultancy.
- Key value determinants of reuse include incentivising regulatory instruments, suitable donor and receiver building properties, common goals towards reuse among actors as well as suitable contract models for reuse, and process efficiency through experience, optimisation and scaled production.

Within this multiple-case study, it was found that building product reuse provides several opportunities for value creation and value capture to the actors involved in such reuse processes. Some forms of value (e.g., use value, resale value) can be realised within individual project settings, whereas the efficient adoption of reuse BMs can require more efficient scale economy and a nudge from policy makers. It was found that reuse is still hindered by costs related to deconstruction, donor product testing and reprocessing, but in the right circumstances, even small-scale reuse can be profitable.

8.2 Contributions to theory

This study contributes to several streams of literature because of its multisectoral nature. The three major research areas that were advanced through this study were: 1) research on reuse and product recovery processes, 2) research on circular value creation and (product lifetime extension) business models, and 3) research on circularity in the construction sector.

First, this study contributed to the priorly scattered knowledge base of product reuse processes and their implications to value creation and value capture. Existing literature was utilised from multiple sectors (e.g., ICT, furniture, construction product and lab equipment reuse) focusing on various types of reuse (direct reuse, refurbishment and remanufacturing). In addition, the existing framework of a product recovery process (Fleischmann, 2000) was utilised in a novel setting of building product reuse, together with the more recent construction industry reuse framework by Jayasinghe et al. (2019). This study combined these prior findings to visualise how reuse processes are formed in different types of (concrete) building product reuse in the empirical multiple case setting. While this study focused on reuse in the construction sector, the empirical findings shared some similarities to studies in other sectors. The findings from literature regarding the value created from reuse to suppliers (e.g., Veleva & Bodkin, 2018); focal firms (e.g., Hopkinson et al., 2020) and final customers (e.g., Alexander & Smaje, 2008) in various links of the value chain were evident also in this multiple case study, thus strengthening these theoretical findings. For example, similarly to earlier reuse studies, this study suggests that labour costs related to product recovery are an important value determining factor in reuse, as well as the initial condition of the object of reuse (e.g., Rahman et al., 2019; Geyer & Doctori Blass, 2010). Novel findings were also gained from this study – for example, a careful consideration of alternative ways of reuse in secondary applications had not been highlighted in prior reuse literature. Overall, factors determining value capture from reuse have not been discussed much in literature, so this study paves the way for this emerging concept.

Second, this study expands the CE research from the point of view of circular BMs, circular value chains and circular business strategies. This study increases understanding on the “reuse” part of the 3R concept of reduce, reuse and recycle, and its implications to value creation and value capture for different actors in various reuse value chains. As was suggested by literature, also this study found that value implications of reuse consider several types of actors and forms of value. This study contributes mostly to the economic value gained by actors from reuse – environmental (and social) value are considered only to the extent to which they generate indirect economic value, and thus this study contributes less to these value aspects of reuse, even if they were identified and highlighted in reuse literature (e.g., Zacho et al., 2018). This study identified value creation and capture from building product reuse in the form of revenue increases and cost minimisation, but also functional value to customers. In fact, functional value from building product reuse was a surprising finding which has not been discussed much in circular value creation or reuse studies.

Within this study, new types of EPV BMs within building product reuse were discovered, for example deconstruction services and reuse consulting services, as well as refurbished concrete element production and resale, and upcycled building product design and resale. These business models expand the research on EPV BMs conducted by, e.g., Ertz et al. (2019), Yrjölä et al. (2021) and Whalen (2019). These studies have described CE BMs from the point of view of individual circular businesses and their value creation logics in relation to their customers. However, in this study, it was found that a value chain perspective is needed where the value creating activities are dependent on other businesses, and more links in the value chain should be considered in addition to the immediate suppliers and customers of the object of reuse. The results of this study indicate that research on the reuse of building products may require value considerations expanding beyond the traditional circular business strategy and circular BM research. For instance, it was found that value chains of reuse in the construction sector involve contractual aspects which determine who is able to capture value from reuse, and that incentives are perceived by industry actors as required for value capture from reuse. Overall, the results of this study indicate that circular value creation and capture in the construction sector is driven more by project-level value chains than circular business model changes within an individual business. While these construction sector-specific aspects of reuse value chains can be found in construction industry research (e.g., Chileshe et al., 2016; Rakhshan et al., 2020), they did not come up in CE research papers focusing on other sectors. Through a practical research approach, this study contributes to the knowledge of how reusing building products translates to realised value and value capture potential across the reuse value chain. This enables picturing what the CE looks like and could look like in different settings, even outside the direct business setting.

Third, this study builds on and contributes to circular construction research involving reuse. Existing studies in the construction industry were found to have a technical focus on reuse, mostly limiting to individual pilot projects of deconstruction (e.g., Tatiya et al., 2018) and reuse, or reverse logistics for construction products (e.g., Rameezdeen et al., 2016), or design methods to enable future reuse of building products (Iacovidou & Purnell, 2016). The point of view of reuse value creation has also been that of the donor building owner or the demolition contractor. As earlier studies predicted, deconstruction was found also in this study to be a key phase in the reuse process with regard to value creation and capture, and several value determinants were found to be linked to deconstruction activities. However, while prior studies have indicated that DfD is required in order to capture value from building product reuse, this study suggests that existing buildings without DfD may also be profitably reused. In addition, findings from da Rocha & Sattler (2009) on reuse value chains in the Brazilian construction industry and van den Berg (2020) on the demolition contractors' perceived value potential of building product reuse in Netherlands are complemented by this study from a Finnish construction industry value chain perspective.

Concrete has not been studied earlier as an object of reuse from a value perspective, so this study was able to explore this topic through combining three case projects involving concrete reuse to draw some common findings. This explorative study benefits future research by yielding results on value creation and value capture opportunities in circular construction involving concrete. More understanding has been gained as to how reuse processes enable the formation of new types of circular value chains, both temporally within distinct construction projects as well as providing potential for organisations in assuming more permanent shifts in their role in construction.

8.3 Practical implications

This study provides insights for various practical implications for both businesses as well as the public sector. Firstly, this study implies that individual actors within a construction project may capture value from reuse even within individual projects. Thus, building owners and demolition companies should keep an open mind and try to scout for demand for reusable building elements and materials. It is also important to decide early on the method of building disassembly and who has the ownership of reusable elements and has thus the opportunity to gain either use value or resale value from the products.

One of the most significant remarks of this study is that even now, when CE is not a mainstream practice yet, companies and building owners have several opportunities to capture value from reusing building products. This study has gathered together and reviewed three diverse construction projects where concrete was reused. These cases can be benchmarked to gain inspiration how to implement reuse of building materials still in the absence of a circular BM, and on the other hand, provide inspiration on what type of BMs might be needed in the future. Construction companies, product manufacturers, real estate developers, demolition companies and many more firms in the construction industry can gain tips on how they might capture value from reuse. For example, building owners should, in some cases, reconsider their desire to destructively demolish undesired buildings, because there may be actors willing to utilise the valuable elements in the building. The collaboration of project teams towards reuse is also important.

Architects may suggest the incorporation of reused materials in new buildings and use their expertise to identify creative ways to even upcycle waste. Product manufacturers may examine potential supply of used elements from building owners, demolition companies or logistics service providers.

Concrete cascading may be a useful step in the transitional phase of CE. The most profitable type of reuse may vary depending on the project. Crushed concrete is still needed for cases when e.g., buildings will destroy from natural disasters or other accidents. In these cases, it is good that there are ways to utilize this concrete. The value creation potential as depicted by the upcycling case in the utilisation of crushed concrete in the making of new concrete should not be underestimated. The different types of reuse of concrete and other types of building materials can complement each other.

Another important implication was the potentially essential role of the client. This goes for both deconstruction and reuse projects. The client may determine that the new building should include certain reused elements and is prepared to pay more for such a building. This would create demand and allow innovative construction companies to stand out in bids for projects. In deconstruction projects, the client should state early on, which elements need to be saved and for what purpose if it wishes to capture value for itself in the reuse process.

Legislation should better enable building component reuse. A key factor for the cost effectiveness and profit potential of building product reuse was legislative guidance. This same finding was predicted from the literature as well. This calls for changes in the way that companies need to deal with risks related to reuse. A suggestion was that tax reductions or enforcements should be directed downstream in the value chain, towards the construction of new buildings. It was suggested that building product reuse should be artificially made more profitable for construction companies before the reuse process may become established and more efficient − and ultimately lead to market-based profit.

8.4 Originality and limitations

This study contributes to the growing research area of reuse in construction. Reuse of other building materials has been studied from economical perspectives, but during the research process it became evident that concrete is a special type of building material to reuse since it is currently still largely downcycled. While reuse of concrete has been studied from environmental and technical perspectives, a research gap was identified related to value capture potential in concrete reuse.

The combination of three cases for this multiple case study was purposively selected in a way that the cases complement each other in a novel way. While data sources for two of the cases relied largely on existing research due to practical reasons, the three cases were analysed utilising a novel framework. In addition, one of the cases chosen represents an exceptionally valuable contribution due to its ongoing state and ex ante perspective, which provides an excellent initial inspection into the possibilities of value in concrete reuse. These cases have not previously been subjected to cross-case comparison with each other. Thus, this multiple case study on three diverse types of concrete reuse in building projects and their giveaways for potential value capture opportunities to different actors is a valuable contribution to CE literature. Chapter 8.6 describes how this research could be expanded in future studies.

As an explorative case study, the findings on this report can be generalised only to a limited extent. For example, some limitations stem from the choice of merely Nordic cases for the empirical study. The geographical and regulative setting is thus limited to Finland and Denmark, but, with caution, conclusions may be drawn to other western countries as well. Some value capture determinants, for example, may be more present in other geographical areas, such as due to different labour costs or limitations in building material supply. Limitations to the generalisability of the study are also linked to the time horizon of the cases – the cases contain findings dating up to over 10 years in the past, meaning that changes to the research setting may have occurred during this time and thus caution should be exerted when applying the findings in other research settings.

This study focused on a rather “niche” research area by basing the case selection on concrete reuse alone. Rather ironically, due to the scarcity of such available cases, this setting created the challenge of diverse cases where the only common factor between the chosen cases was that concrete in some form was reused. This meant that case bounding had to be done in a flexible manner, and thus the generalisation of findings should also be approached with caution. The accuracy and generalisability of the findings of this study can be improved by gathering more cases for analysis and verifying the realised value creation and value capture by doing follow-up of the ongoing Case A.

8.5 Future research

This exploratory multiple case study provides a good starting point for further research, since the reuse of concrete has not yet been studied from a value point of view extensively – the phenomenon is still rather rare and value-related findings undocumented and unstudied. However, collection of data showed that reuse in building materials is estimated to be increased in the future, and it may even become the norm in the industry. Hence, it was necessary to provide preliminary glimpses into what value could be gained by the industry actors, and future research thus should aim to add to this knowledge.

The role of donor building owners as clients of deconstruction projects should be examined further, as it was identified that these actors may have a lot of power regarding whether building products are reused or not. The role of the deconstruction phase was found to be important, so ideas for further research includes, for example, an interview study with several demolition contractors/companies to find out their views on deconstruction and selective demolition, and what business benefits they might gain from these practices, i.e., how they could capture value from the reuse process. It would be interesting to expand the research done by, e.g., van den Berg (2020) on demolition contractors to involve also considerations as to why certain concrete building elements are chosen to be recovered or not. This could involve several actors' perspectives and possibilities remain to utilise decision-making frameworks developed for remanufacturing contexts (e.g., Goodall et al., 2014).

Another interesting group worth studying is the several platforms selling used or excess building products. With the changing construction product legislation, it would be insightful to see what kind of roles these service providers might take. A hypothesis would be that platform providers could act as intermediators, reducing the uncertainty related to the supply-demand dilemma that developers interested in reuse face, which would decrease the friction of the reuse process that hinders reuse becoming a more prevalent practice. Further studies on individual companies' BM impacts are also needed regarding building product lifetime extension. It would be interesting to know what "reuse" type BM strategies might emerge in the construction sector in addition to recycling-type BMs and second-hand retailers of used or surplus building products.

Further research is also needed in the form of case studies to effectively determine the value impacts of reuse. Research on reuse within construction could benefit from a project management perspective. It would be important to identify why some reuse cases have failed, since most case studies on reuse tend to be about success cases. In addition, the construction industry also needs further research regarding reverse logistics. The existing research stream in that area largely stems from a strictly South Australian context, so more geographical diversity is needed. Currently most of the research is conducted from a deconstruction and design-for-deconstruction setting, but for a comprehensive view, more research should be undertaken across the entire value chain.

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