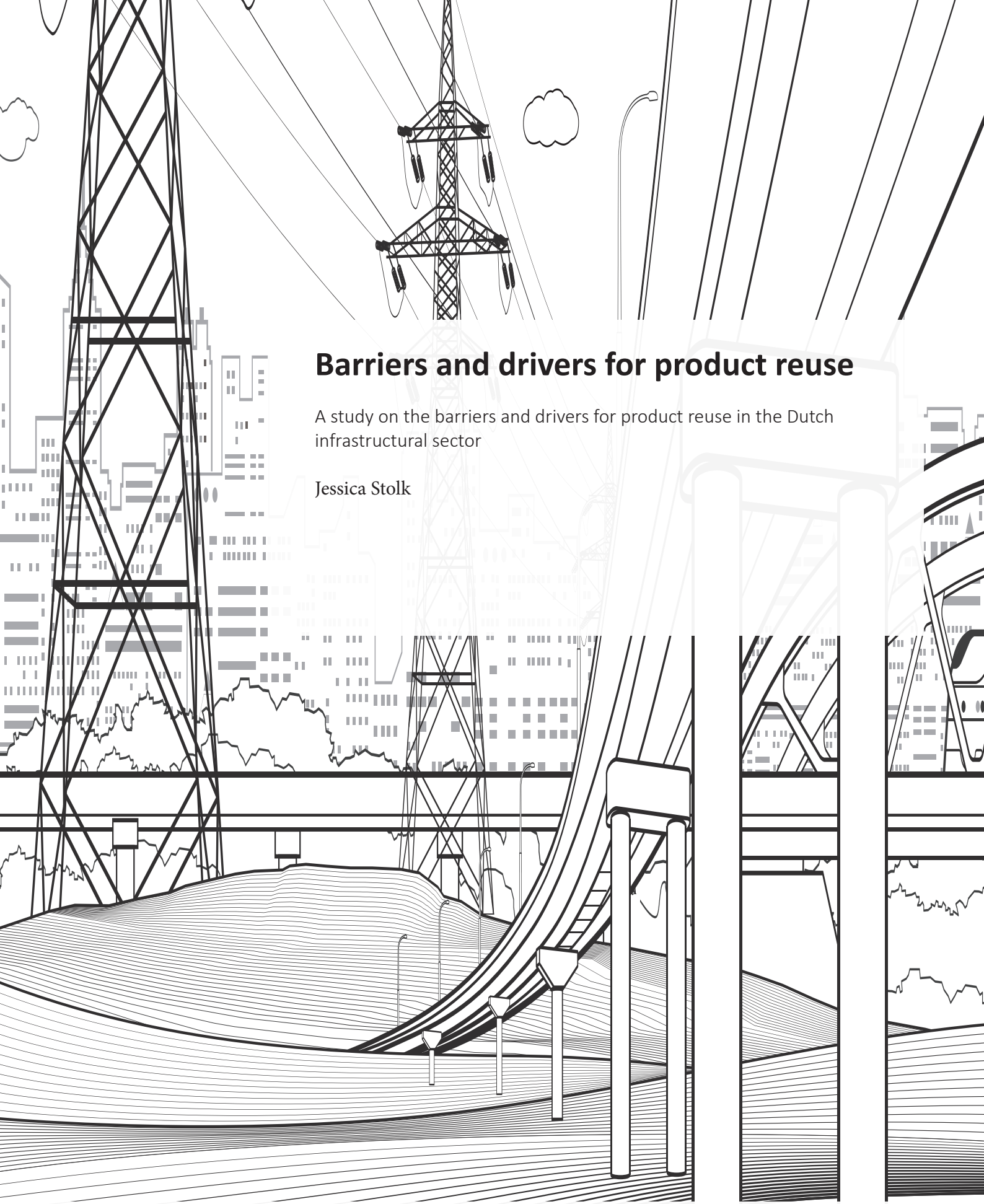

Barriers and drivers for product reuse

A study on the barriers and drivers for product reuse in the Dutch infrastructural sector

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Barriers and drivers for product reuse from assets in the Dutch GWW sector

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PREFACE

In front of you lies the result of a five-month research in partial fulfilment of the requirements for the degree of Master of Science in Metropolitan, Analysis, Design and Engineering of the Delft University of Technology and Wageningen University and Research. Two years ago, I started this master programme and enjoyed the programme a lot! Working together with students from different backgrounds taught me a lot about interdisciplinary research. However, these past five months it was up to myself to formulate my research. This thesis period I l earned a lot about myself and conducting research. It was a rollercoaster ride, with many ups and downs but I can proudly say that I finished my research.

The past five months and this research would not have been so interesting without the help of some important people: my mentors, the interviewees, my internship company and my family and friends. First, I would like to thank my supervisors Yawei Chen and Karen Fortuin, for their support and interesting insights throughout the whole research process. Their positive feedback and enthusiasm guided me through the difficulties and made every graduation meeting helpful and fun. Second, I would like to thank all the interviewees and experts that participated in my explorative interviews and case studies. Without their insights, knowledge, and stories this research would not have been a success. Lastly, I would like to thank my internship supervisor Florinde Vessies and Witteveen+ Bos Consultancy and Engineering, who gave me the opportunity to experience an urban area development process in Dutch practice. Furthermore, I would like to thank Witteveen+ Bos for using their. This research is the last step of my student career and by completing this research I will obtain my Master of Science degree.

ABSTRACT

The built environment in the Netherlands is responsible for 50% of the national raw material usage and 36% of national CO2 emissions. Moreover, almost 40% of all the waste in the Netherlands is related to the construction- and demolition sector. Reuse of construction products has the potential to reduce resource depletion and CO2 emission. Although in literature and practice, attention has been given to the importance of reusing products to close material streams in the built environment, the implementation of reuse in practice is limited. There are still many barriers to implementing product reuse in practise. Attention has been given to what these reuse barriers and drivers are in the building sector. However, limited attention has been given in literature and practice to barriers and drivers for product reuse from infrastructural assets in the urban context. Moreover, only a small number of studies focused on barriers and drivers in different countries, but no studies were found that examined the Dutch context. Therefore, this research aimed to identify the barriers and drivers to reusing products from assets in the Dutch infrastructural sector. This research was divided into three phases. Firstly, existing literature and theories about the barriers and drivers for the reuse of products in the built environment were studied. Afterwards, it was evaluated if the barriers and drivers identified in literature also applied in practice in the Dutch GWW sector by conducting semi-structured interviews with different actors. Next, a case study was performed in the final phase of this research to gain a more in-depth and practical understanding of the barriers. The results indicate that many barriers found in literature for the building sector also apply to the Dutch infrastructural sector. The barriers identified in this research that apply to the Dutch context are (1) not recognising the environmental and economic value of reused products, (2) additional cost for reuse, (3) lack of a reuse market, (4) difficult time planning, (5) strict contractual agreements, (6) lack of communication and collaboration along the value chain, (7) lack of information, (8) strict certification, (9) Handboek voor Openbare Ruimte. The drivers that crystallised from the findings of this research are: (1) case studies, (2) setting high ambition by formal alderman, (3) making a material inventory, (4) physical or digital market place, (5) involving the contractor and management department early on in the design process, (6) use contracts that support collaboration between actors, (7) iterative nature between the feasibility and design phase, (8) material passports, (9) willingness of the project leader to take risk and (10) financial incentives.

Keywords: reuse - barriers - drivers - infrastructure - built environment - urban area development

GLOSSARY

Grond, Weg en Waterbouw - The Grond, Weg en Waterbouw (GWW) sector is involved the realisation and maintenance of infrastructural assets in The Netherlands. The clients in the GWW sector are often public institutions, such as municipalities, provinces, water authorities and government task organization ProRail.

Reuse - Reuse is a circular strategy to extend the lifespan of products. In this research reuse is defined based on the 9-R waste hierarchy model by Reike et al. (2018) and could be either repurposing, remanufacturing, refurbishing, repair, or direct reuse.

Handboek voor Openbare Ruimte - Many interests are involved in the design of public space. The municipality divides these interests into three domains: management, design and use. The public space manual provides an assessment framework in which the interests from these three domains are represented. By using the manual, when making plans for the public space, the municipality already takes account of its 'performance' in the future. In this way, unnecessary maintenance, unsafe or undesirable use is prevented.

ABBREVIATIONS

UAD - Urban Area development

CUAD - Circular urban area development

CE - Circular Economy

DfD - Design for Deconstruction

DfAD- Design for Adaptability and Deconstruction

EoL - End of life

EoU - End of Use

GWW - Grond, Weg en Waterbouw

W+B - Witteveen+ Bos Consultancy and Engineering

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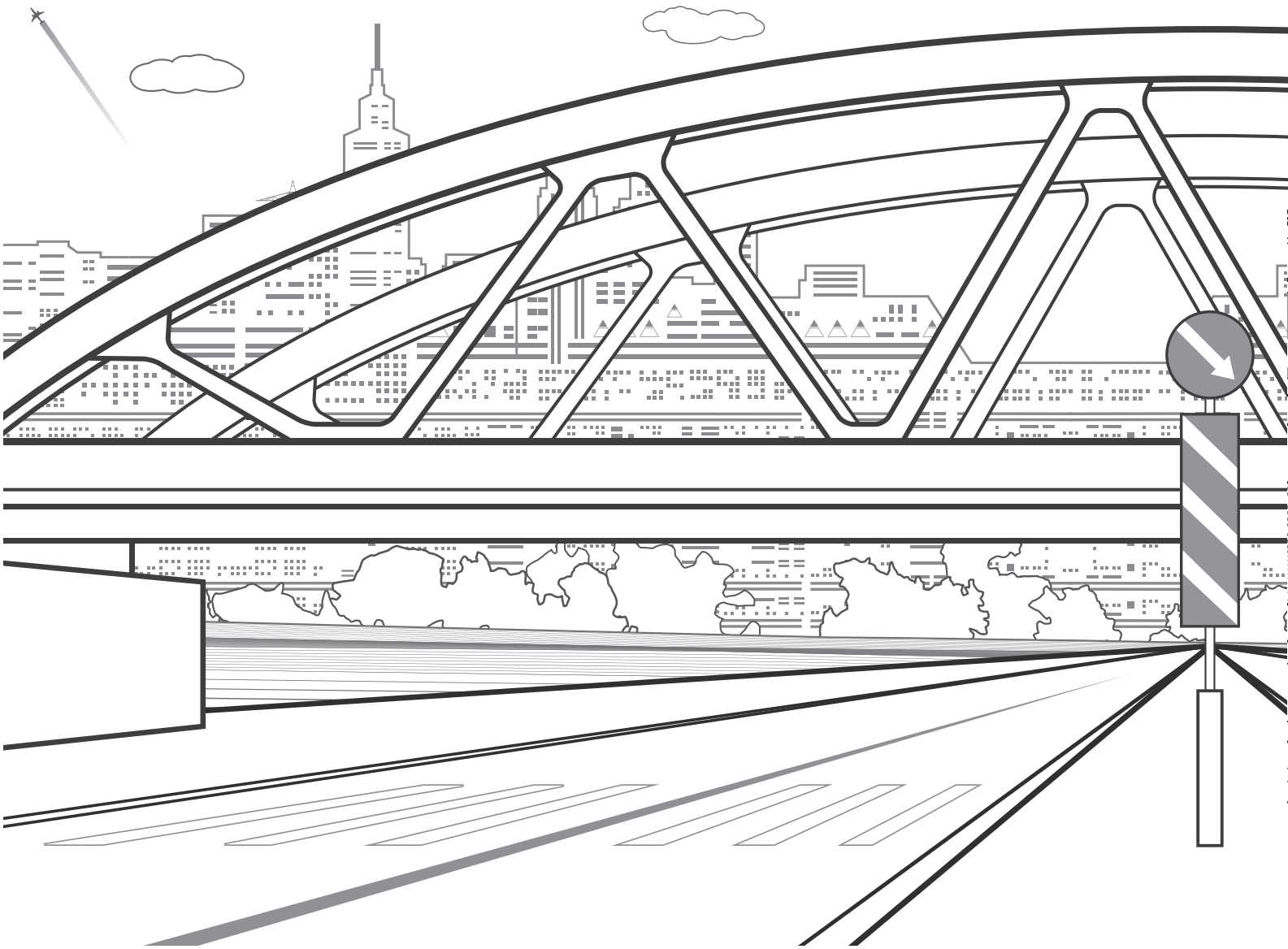
1. Introduction



1.1 Resource depletion

Industrial development and globalization has brought us enormous economic growth. However, this growth resulted in pressure on our planet's resources. The global product consumption has increased existentially over the past hundred years and is likely to be tripled by 2050 (Krausmann et al., 2009). This way of depleting natural resources cannot continue. To combat the negative effects of the raw materials use and CO2 emissions, the concept of a circular economy (CE) has gained momentum both among scholars, politicians and practitioners. The importance to transition towards a CE has also been recognized for the built environment. The built environment in the Netherlands is responsible for 50% of the national raw material usage and 36% of national CO2 emissions (Rijksoverheid, 2018). Moreover, almost 40% of all the waste in the Netherlands is related to the construction- and demolition sector (Rijksoverheid, 2018). The Dutch government has recognized that this way of depleting natural resources cannot be continued. They have therefore introduced a nationwide programme stating that the Netherlands should be 100% circular in 2050, designating the construction sector as one of the five critical sectors that need to switch to a circular approach (Rijksoverheid, 2016).

Urban areas form an important part of the built environment according to van Bueren (2012) and Heurkens (2018). The importance to transition towards a CE has therefore become increasingly important for urban areas. The implementation of the CE concept in urban area developments asks city managers (including policy-makers, urban planners, mayors) to take the lead and to implement CE principles at the urban scale (K. B. J. Van den Berghe & Verhagen, 2021; K. Van den Berghe & Vos, 2019; Zhijun & Nailing, 2007). Some city managers have taken this step by adopting the CE principles into urban area development plans.

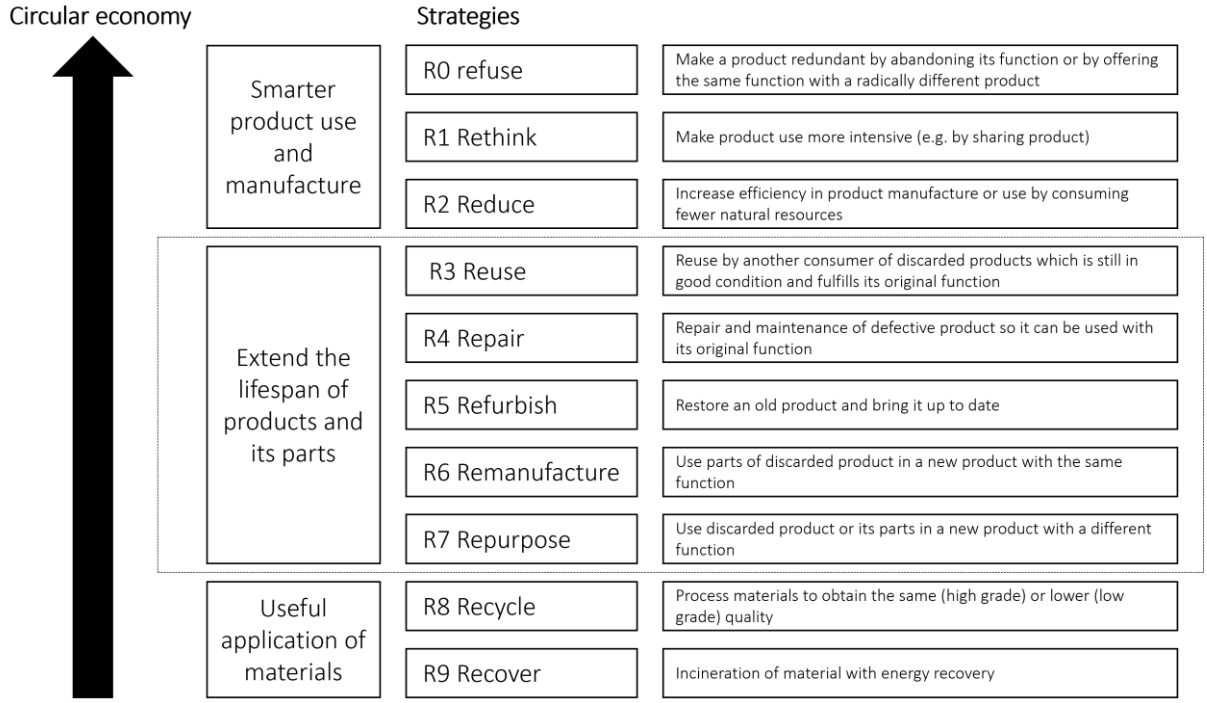
1.2 Circular Economy concept

It has been recognized, that to realise a 100% circular built environment, urban area developments have to implement the CE concept. It needs to be noted that the need to transition to a CE has been recognized by practise and academics, however there is no consensus yet about the definition for the CE. A study done on defining the CE concept by Kirchherr J. et al. (2017) discovered 114 different CE definitions. In their study they defined CE as "an economic system that is based on models which replace the 'end-of-life' concept with reducing, alternatively reusing, recycling (3R-framework) and recovering materials to accomplish sustainable development.". This definition highlights the importance of closing the materials stream in realising a CE. In addition to the definition proposed by Kirchherr J. et al. (2017), MacArthur (2013) identified five principles for CE which are – (1) design out waste, (2) build resilience through diversity, (3) rely on energy from renewable sources, (4) think in systems, and (5) waste is food. These principles do not only highlight the importance of closing materials stream, but also recognize the importance to transition to sustainable energy and show the importance of thinking in system. When implementing the principles of the CE concept on the urban area scale this means realising a flexible and adaptive built environment (Schmidt, Deamer & Austin, 2011), efficient energy systems (Pomponi & Moncaster, 2017b), which are based on renewable energy sources. But also closing water systems and reusing and collecting household waste at the urban scale (Pomponi & Moncaster, 2017).

1.3 R-ladder waste hierarchy

The definition of Kirchherr J. et al. (2017) and the final principles - waste is food - by MacArthur (2013) highlights the importance of closing material streams in realising a CE. To decide which strategies need to be implemented to close material streams, the waste R-hierarchy model is often applied in practise and academics. In the literature, there are many R-ladder waste hierarchy frameworks, ranging from 3, 4, 5, to 10-R. These frameworks show the priority order for reducing primary resources and energy consumption throughout the product life cycle (Reike et al., 2018). The 10-R framework is applied in this research and is shown in figure 1. This 9-R ladder shows that smarter product creation and use (R0-R1) is favoured above strategies to extend the lifespan of products and its parts (R3-R7). In a CE, material recycling, energy recovery from incineration, and re-mining are given the lowest priority to waste management strategies (Government of the Netherlands, 2016). This hierarchy shows that the value retained through reuse is more than the value retained through recycling. In literature and practice, attention has been given to recycling of material streams in the built environment (Gebremariam et al., 2020; Kibert et al., 2000; Obiadi, 2020). However, limited attention in practice and research has been given to reusing products in the built environment (Mhatre et al., 2021). Research shows that reusing materials is thought to be one of the best waste management strategies for closing the material cycles (Minunno et al., 2018; Nussholz et al., 2019). When reusing materials, in comparison to recycling materials, less energy, CO2 emission and raw materials are used (Akanbi et al., 2018; Gorgolewski., 2008; Sassi, 2008).

Figure 1. The 9R Framework. (Source: Adapted from Reike et al. (2018))



1.4 Material streams in the built environment

To close material streams in the built environment, waste strategies to extend the lifespan of products and its parts are preffered over recycling strategies. The materials stream in the development of urban area consist of materials used for the development of buildings (residential and non-residential) and infrastructure. These infrastructural assets with large material demand and environmental impact are roads, civil constructions (bridges, locks, tunnels, subways), and sewages (Kok et al., 2022). These infrastructural assets are in the Dutch context often referred to as the GWW sector. The materials used in these assets are mainly concrete, steel, bricks, asphalt and wood (Kok et al., 2022).

1.5 Problem statement and research question

Although In literature and practice attention has been given to the importance of reusing products to close material streams in the built environment (Arora et al., 2020; Foster, 2020; Geldermans, 2016; Kok et al., 2022; Rahla et al., 2021), the implementation of reuse in practice is limited. There are still a lot of barriers to implement products reuse in practise (Hart et al., 2019). Attention has been given to what these reuse barriers and drivers are in the building sector (Hart et al., 2019; Knoth et al., 2022; Rakhshan et al., 2020). However, limited attention has been given in literature and practice to barriers and drivers for product reuse from infrastructural assets (Rakhshan et al., 2020). Moreover, only a small number of studies focuses on barriers and drivers in different countries, but no studies were found which examined the Dutch context (Huuhka & Hakanen, 2015; Tingley et al., 2017). Therefore, this research aims to identify what the barriers and drivers are to reuse products from assets in the Dutch GWW sector.

This results in the following main question to be answered in this research:

What are barriers and drivers to reuse products from assets in the Dutch GWW sector?

To following sub-research questions will be answered in this research:

1. How does the building process with reused products differ from the building process with new products?
2. What are the products that could be reused from infrastructure?
3. What are the barriers and drivers for product reuse in the built environment?

1. 5 Readers guide

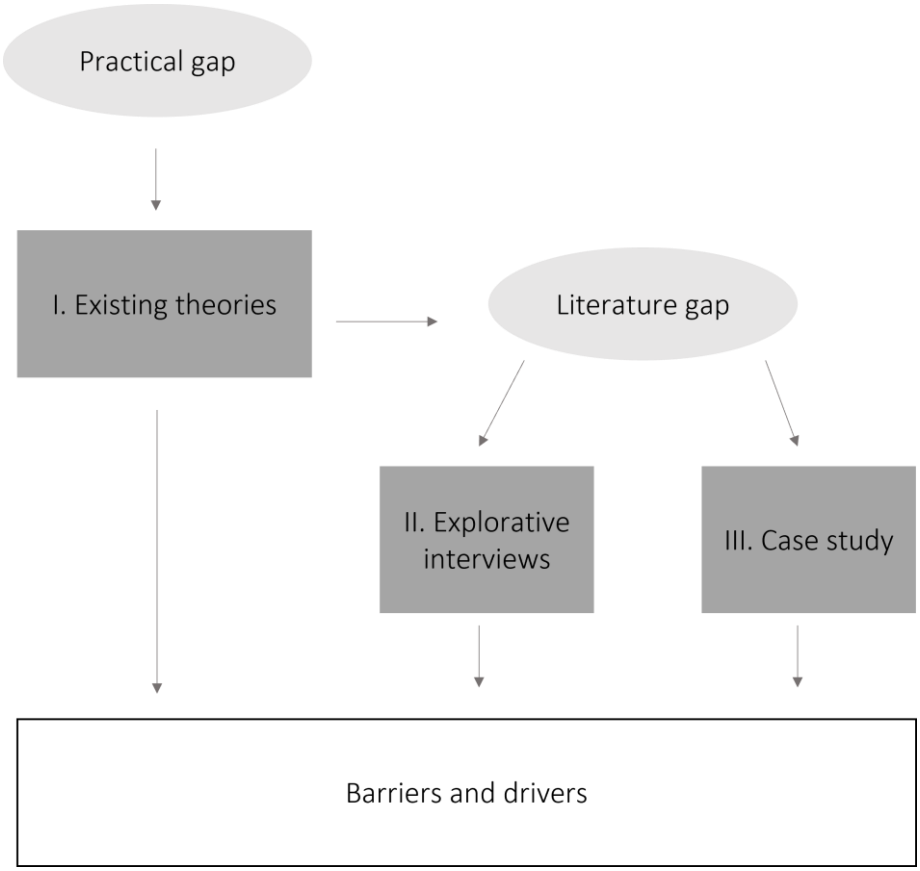
Chapter 1 has introduced the topic by showing the societal and academic importance of this research. The second chapter describes the methodology, interviewee profiles and data analysis. Chapter 3 provides the theoretical background for this research by showing the results of a literature study conducted in this research. In chapter 4, the empirical results from the first explorative interviews are given. In addition to the explorative interviews a case study is performed in this research. The outcomes of this case study are given in chapter 5. The final chapters of this thesis discuss the empirical results and give a conclusion of this study.

2. Methodology

2. RESEARCH METHODOLOGY

This research methodology is divided in three phases, as shown in figure 2. The aim of this research is best to be answered by using qualitative research methods. This research is not about counting or measuring but about the meaning, experience and perspective from the standpoint of the participant, and therefore quantitative methods are not used in this research (Hammarberg et al., 2016). This research is divided in three phases, as shown in figure 2. Firstly, existing literature and theories about the barriers and drivers for reuse of products in the built environment that have been written by previous academic authors have been studied. This was done by conducting literature review. Afterwards, it was evaluated if the barriers and drivers identified in literature also applied in practice in the Dutch GWW sector. According to Hammerberg (2016), to seek views on a focused topic with key actors can be best researched using semi-structured interviews as a qualitative research technique. Therefore, after conducting a literature review semi-structured interviews were conducted with different actors in UAD process. The literature study and explorative interviews gave insights into the general barriers and drivers. To gain a more in-depth and practical understanding of the barriers and drivers in the UAD a case study is performed in the final phase of this research. In this case study a document analysis is performed in combination with semi-structured interviews with different actors involved in the case study. The outcomes of phases one, two and three will answer the main research question. The sub-research questions will be answered individually by input from all three phases in this research.

Figure 2. Research design (source: author)



2.1 Phase 1 - Literature study

A systematic academic literature review to identify barriers and drivers for reuse as a end-of-life management (EoL) strategy for the management of CDW was conducted based on four steps. This literature study has formed the basis of this empirical research and identified further research gaps. Relevant articles were identified in Scopus using the keyword “reuse”, “barriers”, “ challenges”’, “CDW”, “construction and demolition waste”, “roads”, “infrastructure”, “building components”, “product components”, “construction sector’’ and Built environment’”. These keywords were selected based on scanning abstracts of several articles and were combined in multiple ways. The review included papers written in English during the previous ten years (2012-2022). This time frame was chosen due to the increasing awareness on the aspect of circularity and end-of-life management in CDW. After the initial search, identified articles were screened for eligability using two criteria. First (1), the articles were focused on identifying barriers and drivers for CDW. Second (2), the circular strategies that were described in the studies must be related to reuse strategies for the end-of-life management of CDW. Scanning for eligibility was performed by reading titles, abstracts and keywords and resulted in a remaining number of 8 articles. The outcomes of this literature study resulted in categorised table of barriers and drivers for the reuse of products from CDW and has served as input for the empirical research. Besides a systematic academic literature review other sources are used to gain insights into the materials that could be reused in the Dutch GWW sector. For this analysis policy documents and consultancy reports on the circular economy in the GWW sector have been analysed.

2.2 Phase 2 - Explorative interviews

Semi-structured interviews were conducted to reflect upon the insights gathered during the literature study to see if the barriers and drivers identified in academic literature also are in practise in the Dutch context. A snowball sampling method was used to find respondents for the semi-structured interviews. This research was part of a graduation internship at W+B. Therefore, the practitioners in practice were all employees of WB, expect the actors from the municipality who work on implementation of the circular economy in the built environment. An interview protocol was designed prior to the interview that focused on core topics derived from the literature study. The interview protocol consisted of a combination of closed- and open-ended questions, often followed by *why* and *how* questions. All interviewees were asked the same questions. The interview protocol for the semi-structed interviews in the explorative interview phase can be found in appendix A. Below is described which stakeholders have been interviewed in this explorative phase and why these stakeholders are relevant for this empirical research.

Interviewees' profile

All interviewees are actors involved in the UAD process in the Dutch GWW sector. The aim was to cover a range of different practitioners in the Dutch context. Interview participants have various backgrounds and hold different roles with the UAD process. Table 1 provides a list of interviewees in this study.

1. Project leaders (urban infrastructure) - Project leaders in UAD have been interviewed because they are often involved in multiple phases of the UAD process. These project leaders were involved in different infrastructural projects in the GWW sector. This was chosen to get a better understanding on the general barriers and drivers to reuse products. All the project leaders are employed by W+B.

2. Urban planners - Urban planners are involved mainly in the initiation phase of urban area development. They often set ambitions for the UAD and create a visually appealing design. They are an important stakeholder to consider regarding the reuse of materials since they can set ambitions regarding the reuse in materials in a very early stage of the project. They can hereby influence until what extent the reuse of materials is considered in the initiation phase

3. Circular economy advisor (municipality) - The municipality is often the client of infrastructural projects. Therefore, they play an important role in addressing the importance of reuse. They are usually involved during the initiation- and definition phase of the urban area development. As a client and owner of most reusable materials they play an important role in the implementation of reuse of materials from CDW.

4. Contractors - In this explorative phase one contractor has been interviewed. A contractor is usually involved in the realisation phase. It is required from contractors in urban area development to apply reusable materials in the realisation. They are therefore important stakeholder to understand their perspective on reuse of materials from CDW.

Table 1. Interview list explorative interviews

Interviewees		Company/public institution	Expertise
Project leader N=3	Stephanie Lamerich	W+B	Involved in bridges and dykes
	Tjeerd Kamerling		Inner-city road development
	Barbara Dopper		Quay walls and playgrounds
Urban planner N= 2	Donald Boing	W+B	Public space
	Tom Lodder		Public space
Municipality N=2	Marie-Louise Gasseling	Amsterdam	Circular economy advisor
	Annelein Ouwerkerk	Harderwijk	Circular economy
Contractor N=1	Rob van den Burg	Dura Vermeer	Infrastructural projects

2.3 Phase 3 - Case study

A more in-depth and multi-faceted understanding of the barriers and drivers in a real-life and natural context must be researched. According to Crow et al., (2011) this is best done by performing a case study. Therefore, a case study design was performed in the final phase of this research. The purpose of the case study is to identify what barriers and drivers are along the processes of UAD. By connecting the barriers and drivers to phases in the UAD a more in-depth knowledge was generated to add onto the insights generated from the explorative interviews.

The case study selected in this research is the Croeselaan in Utrecht. This research was performed during a graduation internship at WB. It was therefore convenient to select a case study in which W+B was involved in. Because of W+B involvement in this project it was easier to contact the stakeholders engaged in this project. Moreover, the Croeselaan was selected since it is now at its final exploitation-management phase. To understand barriers and drivers during the UAD process it is important to select a case that has passed all these stages. The methods used in this case study design were document analysis and semi-structured interviews. Information about the case study is gathered by reviewing documents about the Croeselaan project. These documents were reports from WB and the municipality of Utrecht. Multiple stakeholders are identified that were involved in different phases of the urban area development. The interview questions were different for every stakeholder involved in different parts of the AUD process. The interview protocol for all interviewees can be found in appendix B. The actors interviewed in this case study are listed in Table 2. Semi-structured interviews were conducted with all interviewees. The questions for each interviewee were different based on their involvement in the Croeselaan project. The interviews were analysed and barriers and possible interventions were identified along the process linking them to involved stakeholders.

Table 2. Interview list case study

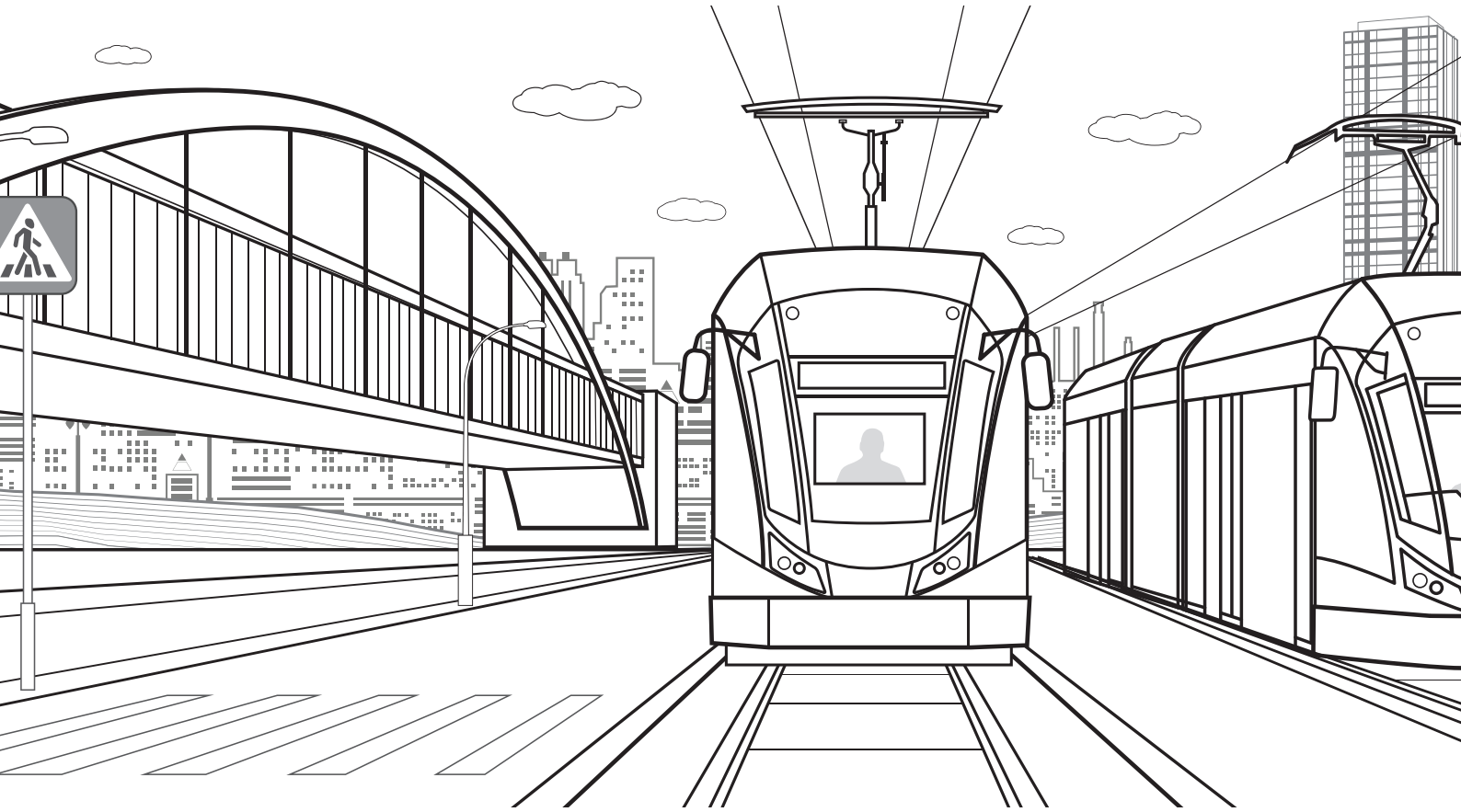
Name	UAD phase	Company/public institution	Role
Sara Rademaker	Initiation	Municipality of Utrecht	Sustainability advisor
Maarten Schaffner	Definition/realisation	W+B	Project manager
Bart Jonkman			Contract/operational manager
Carla Groot	Definition/realisation	Definition/realisation	Sustainability advisor
Stefan de Kruijf	Definition/realisation	Dura Vermeer	Project manager
Ronny Roomenburg	Exploitation/management	Municipality of Utrecht	BING comission

2.4 Data analysis

The results from the semi-structured interviews were coded using Atlas.Ti software. The explorative interview data was used to test and verify the theory derived from the literature study. Therefore, a deductive approach was used in this data analysis. A theoretical framework was derived from literature to categorize the barriers and drivers that resulted from the semi-structured interviews. The themes used in organising the codes were: economic, social, organisational, legal and technical.

As a first step, the interviews conducted were transcribed. Afterwards, an open coding method was used to code recognizable aspects regarding barriers and drivers for product reuse. This open coding method was use to gain first insights into barriers and drivers mentioned by the interviewees. As a second step, axial coding was applied, where similar codes were clustered. The results of the axial coding process are shown in appendix C. As a final step, selected coding was performed where the codes remaining were classified according to the themes identified from literature. The codes identified in the axial coding process formed the identified subcategories within the themes derived from the literature. It must be noted that some barriers and drivers could not be classified under one specific category. Therefore, some barriers and drivers were listed under multiple categories. The same coding process was used to code the semi-structured interviews from the case study.

3. Literature study



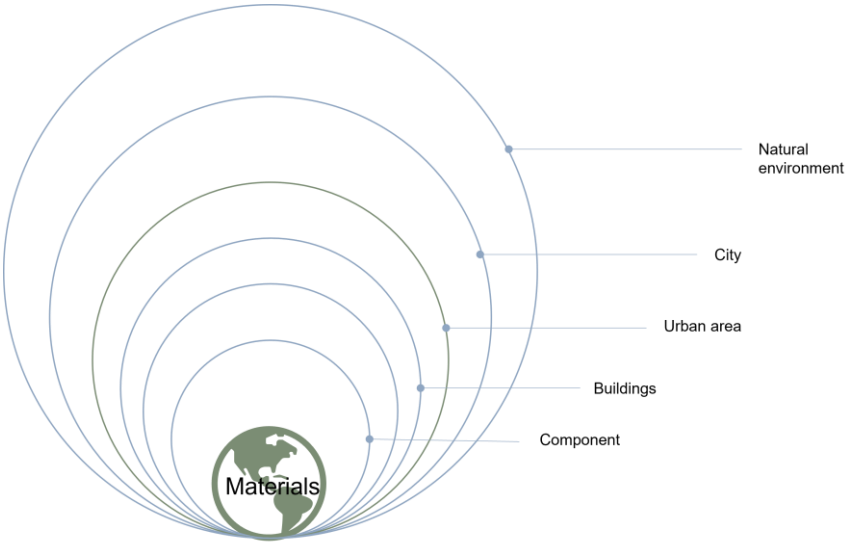
In this chapter, scientific and practical literature is reviewed, which forms the theoretical framework for this research. First, the concept of what circularity entails in the built environment is elaborated on. Second, an overview is given of the material streams and product reuse in the GWW sector. Third, the building process for using reused material is explained. This literature study ends with a review of barriers and drivers for the reuse of products in the built environment.

3.1 Circularity in the built environment

The aim of this research is to identify barriers and drivers for reusing products from assets in the Dutch GWW sector. Assets in the Dutch GWW sector such as roads, dykes and bridges are in the urban context realised or redeveloped during the urban area development process. The aim of this research hereby contributes to practical and academic knowledge on the implementation of circular strategies in urban area development. However, CUAD is not only about closing material streams. It is about the development of urban areas based on the principles of the CE. The following sections will explain what the implementation of CE principles entails in the context of urban area development and will elaborate on the CE principles this research focuses on. This is done to contextualise the findings of this research and evaluate what the contribution of this research is to the practical and academic knowledge of CUAD. The following sections will explain what CUAD entails by applying the five CE principles - (1) Design out waste, (2) Build resilience through diversity, (3) rely on renewable energy sources, (4) Thinking in systems, and (5) Waste is food- by MacArthur (2013) in the context of urban area development.

The CE principles relevant to this research are “think in systems” and “waste is Food”. The first principle “thinking in systems” is defined as: “the ability to understand how parts influence one another within a whole, and the relationship of the whole to the parts” (MacArthur, 2013). The built environment consists of different scales ranging from material to component, product, building, urban area, city and the natural environment, as shown in figure 3 (Pomponi & Moncaster, 2017a). The urban area operates between the city and the building scale. Figure 3 shows the importance of the materials, components and products used in the design of the urban area. It shows that actions on a smaller scale have an impact on the higher scales as well. Using newly manufactured products from non-renewable resources hereby influences the circularity of the built environment and the urban area. Figure 3 illustrates how reuse of products that form the urban area could benefit to circular urban area development.

Figure 3. Scales in the built environment from a circular perspective (Source: Adapted from Van Bueren, 2018; Pomponi & Moncaster, 2017).



The second principle introduced by MacArthur (2013) is “Waste is food” which is defined as: “the ability to reintroduce products and materials back into the economy through improvements in quality” (MacArthur, 2013). These principles together with thinking in systems highlight the importance of reintroducing materials and components when they have reached their End-of-Use phase (EoU). The urban area can be understood as a system of two life cycles: the use cycle and the cycle of its components after use. When assets in the urban area reach the EoU phase there is a potential to extract these materials, components and products for their residual value. So, the urban area can be seen as reservoirs of materials and components that can potentially be used again for the next cycle.

However, circularity in the urban context is not only about the principles “think in systems” and “waste is Food”. In circular urban area development, different components are realised, such as buildings, but also elements of the public space and underground infrastructure. When applying the CE principles “Design out waste”’, proposed by MacArthur (2013), this means in the built environment to design for deconstruction (DfD). The goal of design for deconstruction (DfD) is to close the construction and component loops (Iacovidou & Purnell, 2016). This is done by building new structures in such a way that structural components and their related value can be easily recovered. In addition to DfD, the CE principle ‘’Built resilience through diversity” highlights the importance of a diverse system with multiple connections and scales (MacArthur, 2013). These systems are more resilient in the face of external shocks than systems built simply for efficiency. This principle is about designing the components of the urban area in a modular, versatile and adaptive way. This ensures that when the urban area context changes, the function of assets in the urban area can easily be adapted to current needs. This makes for a spatially adaptive urban area which hereby contributes to a circular built environment. It should be noted that when the principle Design out Waste is implemented, it makes it easier to extract resources from the environment. This illustrates that these principles are interrelated. However, this research does not contribute to knowledge on the implementation of this principle.

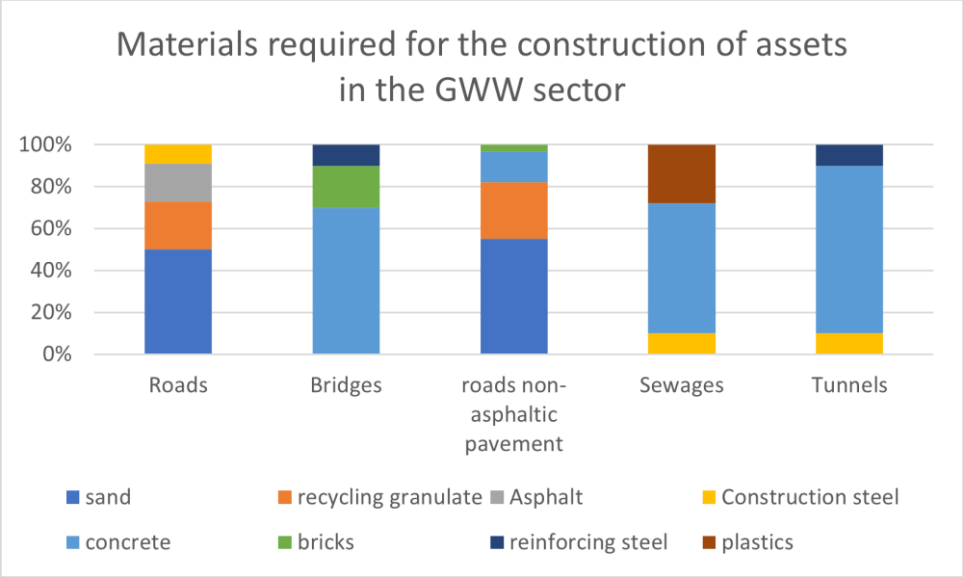
Moreover, according to MacArthur (2013) a CE Systems should ultimately aim to run on renewable resources. In a circular urban area, all elements should therefore rely on energy from renewable energy sources. Which energy system is suited depends therefore largely on the type and orientation of buildings and public space.

3.2 Material streams and product reuse in the GWW sector

The previous sub-chapter has illustrated the importance of closing material stream to realise circularity in the built environment. This sub-chapter elaborates on the materials and products used in assets from the GWW. This information is given to understand of the products and the materials, the barriers and drivers identified in this research refer to.

The GWW has a great diversity of assets however, not all are related to the urban area context. Based on the categorization of GWW assets made by Kok et al. (2022) the following assets in the GWW sector are related to the urban area context. These assets are (1) roads, which are distinguished as asphalt, brick roads, cycling path and walkways, (2) civil constructions such as bridges and tunnels and (3) sewerage. The materials used in these assets are shown in figure 4. The material most used for roads in the GGW sector is fill sand. Concrete is most used in civil constructions, such as bridges. It needs to be noted that most materials used in the GGW sector are bulk material streams like grind, sand and concrete (Kok et al., 2022). Construction steel and wood are other materials that is often used in civil construction. In non-asphalt paved roads, bricks are the materials most used. At this moment 93% of waste from the GWW sector is being recycled, the rest of the materials are burned or landfilled (Timmermans et al., 2021).

Figure 4. Materials GWW sector (Source: Adapted from Kok et al. (2022)).



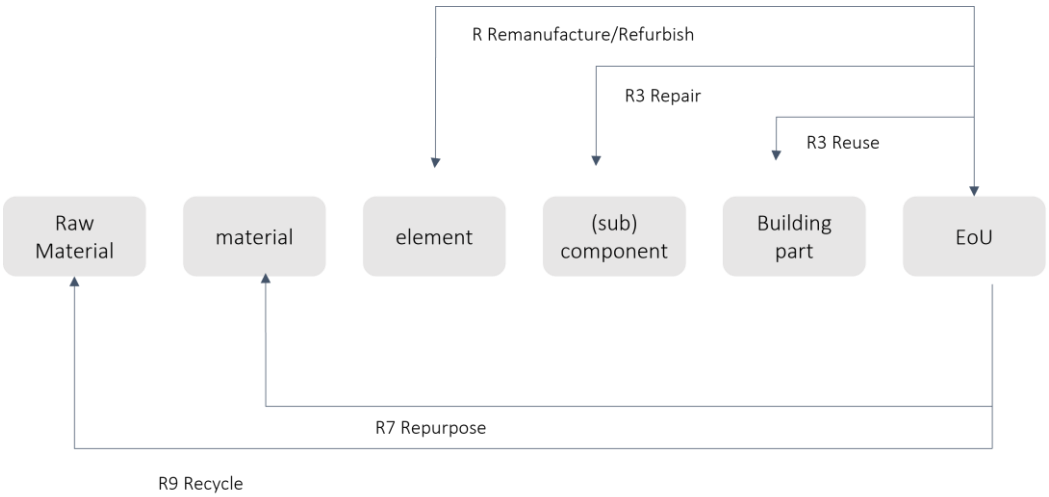
To implement waste strategies at higher levels of the R-hierarchy ladder it is important to understand how products are classified and how this classification relates to the waste strategies. Building products are build up from different layers. It starts from raw materials and goes until the building complex, as shown in Figure 5 (Durmisevic et al., 2017).

- Material - the base ingredient without any further shaping or treatment such as sand in concrete
- Standard material - the intermediate goods which are available in standard sizes such as bricks
- Commercial Material - a material shaped specifically for a product or a project
- Elements - different commercial materials are assembled to form an element
- Sub-component - a closed assembly of elements with a single function such as a window frame

• Component - an independent functioning unit built up from several elements and assembled offsite, such

• Building Part - a collection of elements and components with the identical technical primary function, like benches used in public space

Figure 5. Reuse strategies for product classifications (source: author)



Materials that offer the possibility to be repurposed are concrete, steel and timber (Iacovidou & Purnell, 2016). This research showed that components such as beams, columns and slabs have the potential to be repurposed. However, it should be noted that limited research is conducted into the reuse potential of an element, component and building part in the GWW sector. A research conducted by Timmermans et al. (2021) highlighted the importance of conducting more research into the reuse potential in the GWW sector. However, new initiatives like the Bruggenbank in the Netherlands offer entire bridges to be directly reused (Kuipers, 2022). Moreover, projects like the "Tweede Leven Brug'' exposed at the Floriade 2022 shows how bridges can be constructed entirely out of secondary materials. However, these are mainly pilot initiatives. Moreover, there are also products used in the design of public spaces like trash bins, pavement tiles, playground equipment, kerbstones, bicycle stands, streetlights, benches offer potential to be reused on component or product level (Gemeente Amsterdam, 2021). Although limited research has been conducted into the reuse potential in the GWW, research has been conducted into potential indicators to evaluate the reuse potential of components reuse. These indicators are:

Ease of deconstruction - The less effort required for procurement (deconstruction / selective destruction), the more feasible it is. It takes less effort when minimal construction site equipment, machine time, transportation, storage, and work is required.

Embodied energy - It is vital to reuse and reclaim materials and products with higher embodied energy from an environmental standpoint, as the savings can greatly reduce the negative impact (Gorgolewski & Morettin, 2009)

Lifespan - the longer the lifespan of products are, the more potential they have the be reused. If elements are reused with a limited remaining lifespan the products will maybe have to be disassembled sooner in comparison to using new materials. The energy needed to deconstruct the product might be higher than the energy gains from reusing the elements (Gorgolewski & Morettin, 2009).

Quantity - Another factor to consider when reusing a product is its quantity, which has a direct impact on the amount of waste that would be caused (Gorgolewski & Morettin, 2009). Reuse can be scaled up from a specific design case to an industrial scale by using materials available in big numbers (weight or volume).

3.3. Building process

To understand what the barriers and drivers are to reuse products it is important to illustrate how the traditional building process when using new products, is different from building with reused products. Therefore, this sub-chapter gives information on the process steps needed and the actors involved to reuse products.

3.3.1 Building process using new products

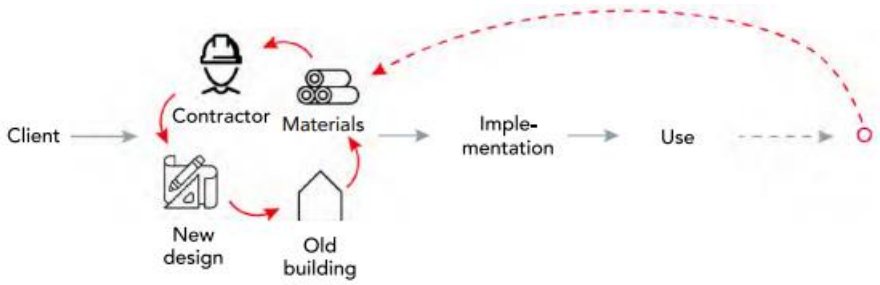
In the traditional building process the client, which is often a public institution in the Dutch GWW sector, comes up with an assignment. Based on this assignment the designer draws up a design. The contractor is responsible to realise the design and for purchasing the new materials as proposed by the designer. After the use cycle has ended, the assets are demolished(Tingley et al., 2017). Figure 7 shows the building process using new products in the urban area development process.

Figure 6. The building process with new products (source: author)

3.3.2. Building process using reused products

Reuse requires a different way of working which is illustrated in figure 6. Before the demolition process begins, inventories are done to determine the availability and reusability of infrastructural components. As well as information on their quality and value (Kabirifar et al., 2020). The information required for the inventory is determined by the material's future use. Therefore, communication between material users (architects, engineers, manufacturers) and material extractors (demolition firms, building strippers) is critical. When working with reused components the designer should base the design on the products available. This requires the contractor to be involved early in the design process.

Figure 7.The building process with reused products (source: author)



When the material inventory is made, and information is provided about the products that can be reused the products will need to be harvested. Harvesting is the process of retrieving items from a structure once an inventory has been done (Kabirifar et al., 2020). After the products are harvested, they will need to be distributed. Transportation, sorting, processing, and retail are all part of the logistical process of getting harvested components to architects, manufacturers, and consumers. If the reuse is known ahead of time, it can be carried straight to the location for temporary storage until it is needed, cutting transportation costs. This is an opportunity-dependent approach that is typically carried out when architects and engineers are involved in the deconstruction process before it begins. It enables

the infrastructural design to be modified in response to material availability. The second option is to submit the harvested products to a manufacturer who will restore and remanufacture them before reselling them. In most cases, this strategy preserves the product's reuse value. However, there is no relationship between demolition businesses and original producers or manufacturers in the Netherlands. It's because the product's ownership has shifted from the maker to the user. Harvests that have no specific destination are transported to the marketplace to be held until they are sold. The harvest is made available through a collaboration between demolition companies and secondary material dealers, and the process is more logistically oriented. In this case, the reuse value cannot be predicted and is entirely dependent on the person who reuses the goods.

3.3.3 Actors involved in building with reused products

Various stakeholders are involved in procurement, whose roles and participation vary with a change in scale, type of reuse, and economic benefits attached to the harvest. The most important stakeholders have been identified based on previous research conducted by (Shooshtarian et al., 2020) on the procurement process described in the previous chapter.

• Public institution - For a project in the GGW sector the clients are often formal public institutions. In inner-city road developments the client is often the municipality, for highways in the Netherlands, this is Rijkswaterstaat or the province. Sewerage and bridges and dikes or owned by Water boards. The client plays a significant role in deciding the retail channel for harvest. A demolition company is not always necessary. And most materials can be stocked in municipal material hubs.

• Demolition Companies - For large-scale projects, demolition companies are hired to identify the inventory and proceed with the deconstruction process. Depending on the economic benefits attached to the project, the companies can get involved in the harvest and retail process as a side business.

• Secondary Companies - Demolition companies hire secondary companies to dismantle the reusable materials. Their function is to process the waste for demolition companies (harvest) and provide a construction market for designers and engineers. The companies operate under demolition and renovation projects and are dependent on them for commission.

• Retailers - They are responsible for creating a commercial channel for selling the materials to different users.

• Architect - An architect can be pre-involved for the direct reuse of the secondary material on another site. Their role involves the identification of reuse opportunities based on the given inventory.

• Manufacturer - For remanufacturing or refurbishing the building products, manufacturers can collect their products and prepare them for reuse elsewhere.

3.4 Barriers and drivers for product reuse in the built environment

This sub-chapter shows a literature-based reuse barriers and drivers categorization framework. This framework is developed to categorize the barriers and drivers found in the empirical results of this study. This sub-chapter furthermore identified the existing academic knowledge on barriers and drivers for product reuse in the built environment.

3.4.1 Barriers and drivers categorization framework

To categorize the barriers found in this study a framework proposed by Rakhshan et al (2020) is used. Here they identified six categories to allocate the identified barriers to product reuse in the building sector. These categories are: economic, organisational, social, legal and technical. These categories are chosen since Rakhshan et al (2020) listed the most extensive list of barriers and drivers in comparison to other authors. Which articles have been reviewed and which categories they identified are described below.

Potential barriers to reuse products in the construction industry have been documented by multiple researchers. A systematic literature review has been performed by Hosseini et al. (2015) who looked into the barriers and advantages of reverse logistics. Moving goods and resources from salvaged structures to a new construction site is referred to as reverse logistics in the construction industry (Hosseini et al., 2015). In principle, reverse logistics is similar to reusing building products since the materials are harvested at the construction site and reused at the new construction site. Hosseini et al. (2015) categorised the barriers by industry-specific and organisational barriers. Hart et al. (2019) conducted a further comprehensive analysis of the literature with the goal of identifying drivers and constraints for the circular economy in the built environment. This research has identified four categories of barriers and enables namely: financial, cultural, regulatory, and sectoral. Another systematic literature review on product reuse in the building sector is performed by (Rakhshan et al., 2020) who identified the following categories for barriers: Economic, environmental, organizational, regulatory, social and technical. It needs to be noted that the review performed by Rakhshan et al (2020) merely focused on component reuse in buildings sector.

Next to extensive literature reviews on the topic of product reuse in the built environment research has been conducted into barriers and drivers in a national context. Knoth et al. (2022) conducted research on the barriers, drivers and perspectives for the reuse of building products in building in Norway. This research used the following categorization for reuse barriers: reuse Infrastructure, legal framework, business frameworks and mindset and knowledge. Another research conducted by Tingley et al. (2017) looked into the barriers of structural steel reuse in the UK. This study did not categorize barriers. There were no additional barriers found in this article in comparison to the systematic review performed by Rakhshan et al (2020). The article by Tingley et al. (2017) mainly showed that the barriers to structural steel reuse are similar to common barriers in the building sector to reuse products. The latest study conducted by Rakhshan et al (2020), included all the barriers which were also identified by Hart et al (2019), Hosseini et al. (2015), Rakhshan et al. (2020), Knoth et al. (2022) and Tingley et al. (2017).

3.4.2 Barriers for products reuse

The section of the literature review presents the barrier and drivers identified in the literature by previous academic authors. The literature-based framework as described above is used to categorize the barriers and drivers. A more detailed description of all the barriers identified in literature is given in table 3.

Economic barriers

These barriers refer to the challenges that companies or governmental organizations face in the distribution and selling of reused products. These include logistical and market challenges. The cost of building with reused products is currently higher due to the cost of storage, transportation and a more labour intensive deconstruction. This all results in that fabrication cost of reused products are higher than that of new products from raw material (Knoth et al., 2022) (Tingley et al., 2017) (Hosseini et al., 2015) (Rakhshan et al., 2020). Additionally, there isn't a developed market for reusable goods. However, the market for these items could expand if there is a rise in the demand for reused building products (Knoth et al., 2022). On the other hand, there may not be a need for repurposed products, which raises doubts about the potential profitability of reused products (Rakhshan et al., 2020).

Organizational barriers

The reuse potential of building products is affected by a lack of reused component knowledge, experience, and expertise. Deconstruction, as opposed to demolition, needs enough space for sorting, storage, and handling of the harvested products. However, an unskilled contractor is unable to accurately predict the amount of space needed to store the harvested parts after deconstruction. Due to limited storage space, the recovered components must be transported to and stored at a different site (Hart et al., 2019) (Knoth, Fufa, and Seilskjær 2022)(Huang et al., 2018) (Rakhshan et al., 2020). Moreover, lack of systems thinking, ownership and integrating reuse in the design process obstruct reuse (Hart et al., 2019) (Hosseini et al., 2015) (Rakhshan et al., 2020). Furthermore, a lack of good case studies is considered an organizational barrier to implementing reuse (Knoth et al., 2022) (Hart et al. 2019) (Rakhshan et al., 2020).

Social barriers

Reuse may be hindered by stakeholder's negative perceptions of reused products. One explanation for this is the visual appearance of reused products, which could be mistaken for being of poorer quality when compared with new products (Hosseini et al., 2015) (Rakhshan et al., 2020). Furthermore, there is unawareness of the economic and environmental advantages of reuse products which act as a social barrier (Hart et al., 2019) (Hosseini et al., 2015) (Tingley et al., 2017) (Rakhshan et al., 2020). Moreover, the implementation of reuse is limited due to a lack of trust in the supplier of repurposed products. This results often that clients do not support reuse (Hart et al., 2019) (Tingley et al., 2017) (Rakhshan et al., 2020).

Regulatory barriers

The fact that current legislation does not allow deconstruction and reuse is one of the barriers that obstructs reuse. The reuse of the recovered components is hindered even after obtaining permissions for deconstruction because current regulations do not permit the storage of the harvested products and consider them as waste (Hart et al., 2019; Hosseini et al., 2015). Additionally, reuse may be hindered by a lack of quality certificates for the reusable products. In many situations, all the parts need to be tested to validate their quality. This is because often it is not possible to trace back where the reused components originate from (Rakhshan et al., 2020).

Technical barriers

These technical barriers refer to the technical capabilities of reused products. Possible damage during deconstruction could occur due to exposure to nature or during dismantling, storage and transportation (Rakhshan et al., 2020). Furthermore, it might be difficult to design with reused components since the remaining capacity of the reused component is unknown.

Table 3. Barriers identified in literature

Economic Barrier	Explanation	References
Deconstruction for reuse is more labour intensive	Deconstruction instead of demolition requires additional steps such as the need to evaluate which products can be reused. After, selective dismantling needs to be applied. These steps results that deconstruction is more labour intensive and raises the costs of reuse.	(Knoth et al., 2022) (Tingley et al., 2017) (Hosseini et al., 2015) (Rakhshan et al., 2020)
Higher costs for design with reused components	There is no established reuse market that ensures product availability. Therefore, the design team needs to spend extra time to research what products are available to be reused. Furthermore, since the delivery time or reused products can't always be guaranteed the design needs to remain flexible.	(Hart et al., 2019) (Knoth et al., 2022) (Hosseini et al., 2015) (Tingley et al., 2017) (Rakhshan et al., 2020)
Cost of storage	If harvested products can't be directly reused at a new building location they will have to be stored. These storage facilities cost raises cost for reuse.	(Hart et al., 2019) (Knoth et al., 2022) (Hosseini et al., 2015) (Tingley et al., 2017) (Rakhshan et al., 2020)
Cost of transportation	Harvested materials that can't be directly transported to a new building location will have to be transported to a storing facility. After, the materials will need to be transported from the storing facility to the new building site. All these extra transportation movement raises costs for reuse.	(Hart et al., 2019) (Knoth et al., 2022) (Rakhshan et al., 2020)
Fabrication cost of reused products are higher than new elements	Often, harvested products can't be directly reused. The products will need to be prepared for reuse which requires extra time, labour and machinery. Moreover, reused products will need to be tested and certified. These additional steps make the current cost of reused products higher than for new elements.	(Hart et al., 2019) (Knoth et al., 2022) (Tingley et al., 2017) (Rakhshan et al., 2020)
Lack of established market	There isn't a developed market for reusable goods. However, the market for these items could expand if there is a rise in the demand for reused building products (Knoth et al., 2022). On the other hand, there may not be a need for repurposed products, which raises doubts about the potential profitability of reused products (Rakhshan et al., 2020).	(Knoth et al., 2022) (Huang et al., 2018) (Tingley et al., 2017) (Tingley et al., 2017) (Rakhshan et al., 2020)

Short term profit	The building sector is often accused of prioritizing short term profits over longer term environmental and social outcomes with longer financial payback time.	(Knoth et al., 2022) (Rakhshan et al., 2020)
Low cost for disposal of materials	Due to the low cost for materials disposal the building industry is not stimulate to implement waste strategies.	(Hosseini et al., 2015) (Rakhshan et al., 2020)
Organizational barriers	Explanation	references
the lack of skills, experience, and knowledge in deconstruction	Deconstruction requires a new way of working. Without skills, experience and knowledge of deconstruction the reuse potential lowers.	(Hart et al., 2019) (Knoth, Fufa, and Seilskjær 2022) (Huang et al., 2018) (Rakhshan et al., 2020)
Lack of systems thinking, ownership and the integration of reuse in the design process of the new projects.	The traditional design processes using new materials requires limited collaboration. However, when working with reused products it is more important to understand where the material comes from. A supply driven design is needed which requires integration and ownership.	(Hart et al., 2019) (Hosseini et al., 2015) (Rakhshan et al., 2020)
Lack of supply chain coordination and integration	The supply chain of reused products requires new collaborations. When there is a lack of coordination and integration of the reused supply chain between the demolished building and new construction site might obstruct reuse.	(Hosseini et al., 2015)
Lack of information about existing structure and materials - traceability and quality	To identify which products can be harvested it is important to have information about the existing structure. Without this information it is hard to effectively dismantle a building. Moreover, when the products have been harvested it is crucial to know their quality and be able to trace back where the materials came from. This is to ensure the safety of buildings constructed from reused products.	(Hart et al., 2019) (Rakhshan et al., 2020)
Social/cultural barriers	Explanation	references
Awareness about the economic and environmental benefits of reuse	Often, there is a lack of awareness about the economic and environmental benefits of reuse by actors. Without recognizing these benefits further upscaling of reuse is limited.	(Hart et al., 2019) (Hosseini et al., 2015) (Tingley et al., 2017) (Rakhshan et al., 2020)
The negative perception of the stakeholders of the visual appearance	Reused products might have some damage a lower visual appearance. However, this does not mean that reused products are of lower quality.	(Hosseini et al., 2015) (Rakhshan et al., 2020)

Liability and fear, lack of trust to the supplier of the reused components.	An unestablished reuse market results in fear, lack of trust to the supplier of reused components.	(Hart et al., 2019) (Tingley et al., 2017) (Rakhshan et al., 2020)
Reluctant to take risk	The building sector is often perceived as reluctant to take risk. However, since reused requires a new way of working it is important to experiment and take risks to further implement reuse.	(Knoth et al., 2022) (Rakhshan et al., 2020)
The client does not support reuse	The client might not support reuse. This might be due to a number of reason as listed in this table.	(Rakhshan et al., 2020)
Conservative way of thinking	A conservative way of thinking is present in	(Knoth et al., 2022) (Rakhshan et al., 2020)
Regulatory barriers	Explanation	References
Rigid contract/procurement process	The building sector is known for strict contracts/procurement process leaving minimal space for flexibility and new collaborations. These rigid contracts are used to minimize financial risk.	(Knoth et al., 2022) (Rakhshan et al., 2020)
existing regulations do not support deconstruction and reuse.	Reused products often have to be stored, however current regulations don't allow harvested products to be stored. This obstructs further implementation of reuse.	(Hosseini et al., 2015) (Rakhshan et al., 2020)
Lack of quality certificates for the reused components	New materials are certified to ensure quality. When reused products are harvested and no information is available from the donor structure about the materials regulation ask for quality certificates from reclaimed components.	(Hart et al., 2019) (Hosseini et al., 2015) (Rakhshan et al., 2020)
individual testing fails to certify the reused components.	Test to certify reused components based on the same regulation as new materials fail.	(Rakhshan et al., 2020)
Lack of supporting regulations	There are no supporting regulation to further stimulate reuse.	(Knoth et al., 2022) (Rakhshan et al., 2020)
Technical barriers	Explanation	References
Damage reused products	Damage could occur when product are disassembled, stored or transported which limits the reuse potential.	(Rakhshan et al., 2020)
Difficult to design with reused components	Design with reused components is difficult cause often information about the quality and origin of the product is unknown.	(Rakhshan et al., 2020)

Additional health and safety precautions necessary	When dismantling a building extra health and safety regulation might be needed.	(Hosseini et al., 2015) (Rakhshan et al., 2020)
Buildings not designed for dismantling	DfD is a relatively new concepts, that has not been applied in practise often. This means that buildings are not designed in a way that they can be easily dismantled this obstructs reuse.	(Hosseini et al., 2015) (Rakhshan et al., 2020)

3.4.3 Drivers for product reuse

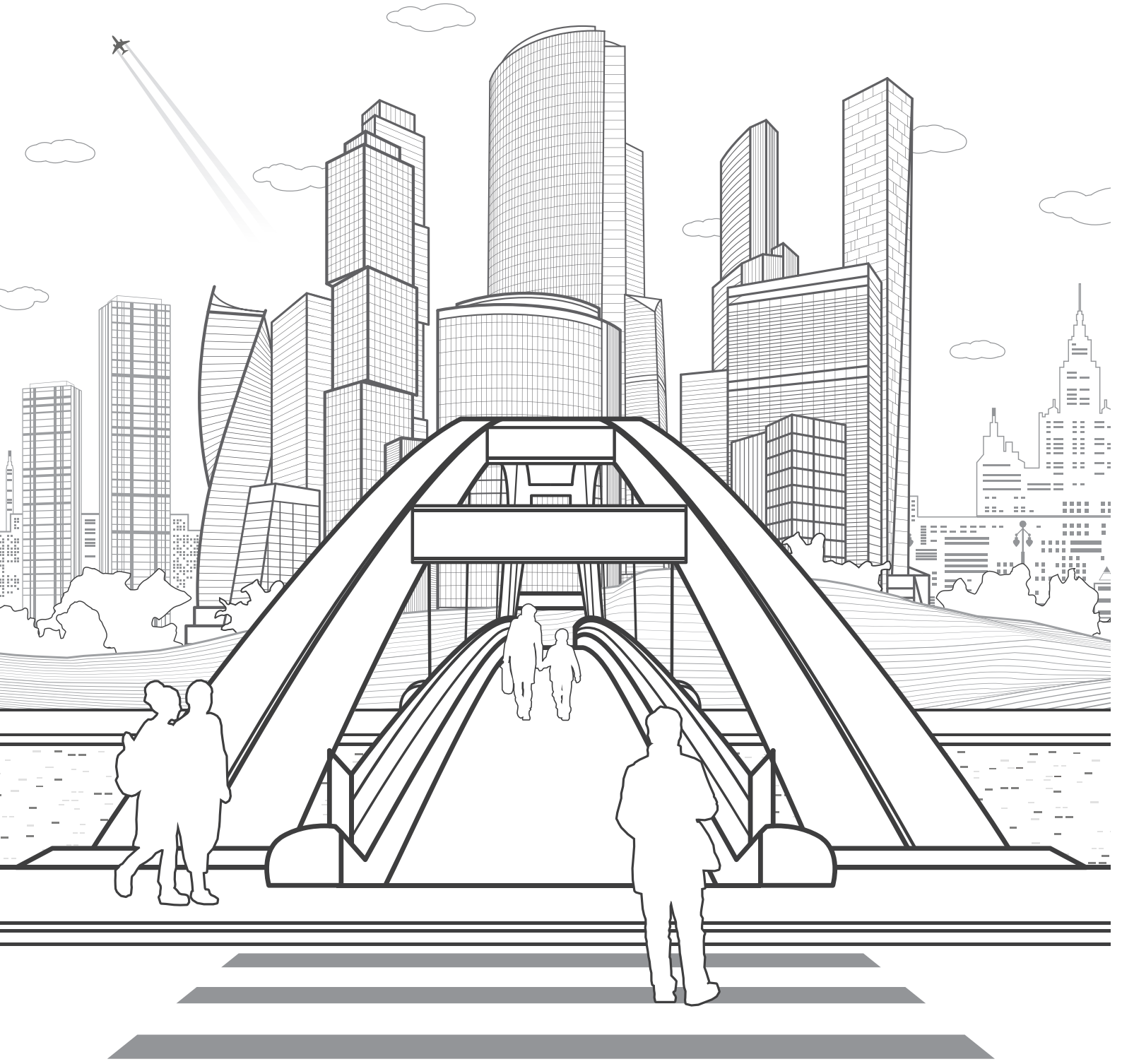
For this research, the drivers are not categorised. Since one driver might be linked to multiple barriers in different categories. The most frequently proposed drivers in the literature are described.

A first driver would be multiple good example case study initiatives to show how reuse of products could be successfully implemented (Knoth et al., 2022; Tingley et al., 2017). Moreover, the development of market places, materials storage locations and product repairing facilities is seen as an important driver (Hart et al., 2019; Hosseini et al., 2015; Knoth et al., 2022; Tingley et al., 2017). These developments could reduce practical concerns regarding product reuse. In addition to a digital market place, the literature review by Rakhshan et al. (2020) highlights the importance of a harvested products management coordinator and a list of reusable products, which could be used in the beginning of the design phase. This list can be realized by collaboration between the owners of the demolition site and the new building.

Furthermore, Rakhshan et al. (2020) suggested including reuse in the design stage of projects. Moreover, several papers claim that by having reuse as a contractual requirement reuse rate will rise (Hart et al., 2019; Hosseini et al., 2015; Knoth et al., 2022; Tingley et al., 2017). Additionally, it's important to involve the manufacturers. They are in a unique position when it comes to material knowledge. They have an in-depth understanding of the material structure, endurance, and other product features. Quality certifications and guarantees from manufacturers for used products could promote the development of reuse practices (Rakhshan et al., 2020). Furthermore, more awareness of the potential to reuse products will be realized by connecting manufacturers with those involved in the actual reuse processes in construction projects.

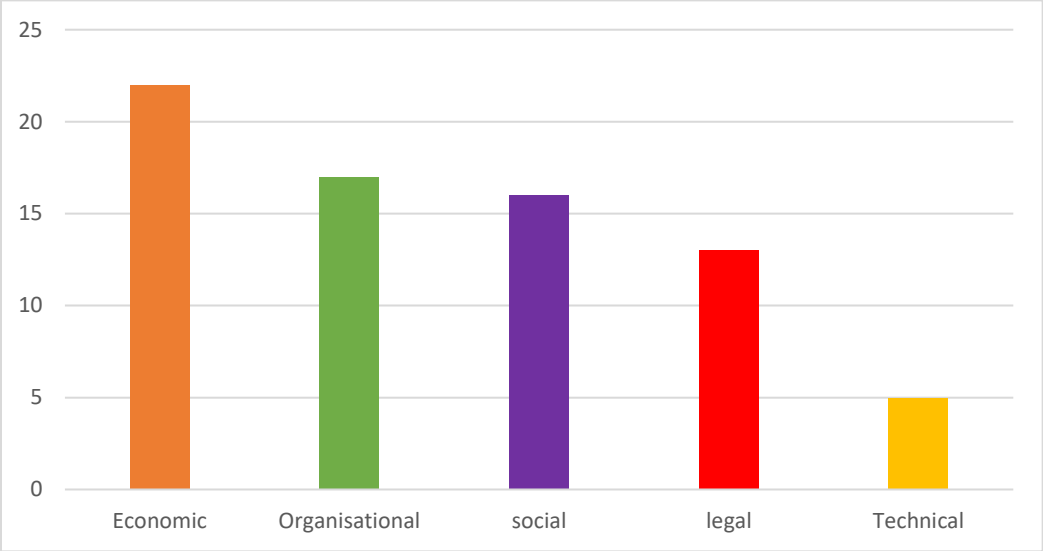
Additionally, aspects such as the rising environmental concern of society or the increased stakeholder awareness of the benefits of reuse might stimulate product reuse. Moreover, positive perceptions and willingness of the stakeholders such as clients, designers, and contractors to integrate reused components into their projects are important drivers. This positive perception can be sparked by Informal and positive stakeholder interactions which can help to encourage reuse (Rakhshan et al., 2020). Last but not least, the existence of regulations supporting product reuse as well as the availability of financial and regulatory incentives to encourage deconstruction can stimulate the further implementation of reuse.

4. Results explorative interviews



In this chapter, the findings of the explorative interviews, with multiple actors involved in UAD are discussed. This chapter is divided into several sub-chapters based on the different themes derived from literature to categorize the barriers and drivers. The themes used to categorize barriers in this research are: economic, organisational, social, legal and technical. In total 8 interviews have been conducted. To highlight the importance of every sub-category, figure 8 shows the number of quotations for every categorised barrier. This figure shows that the interviewees mentioned economic barriers most often, followed by organisational, social, legal and technical barriers. An overview of the different barriers within these categories is shown in table 4.

Figure 8. Number of quotations reuse barriers



Furthermore, table 4 shows which barriers were mentioned for every interview conducted.

Table 4. Barriers mentioned in the interviews conducted

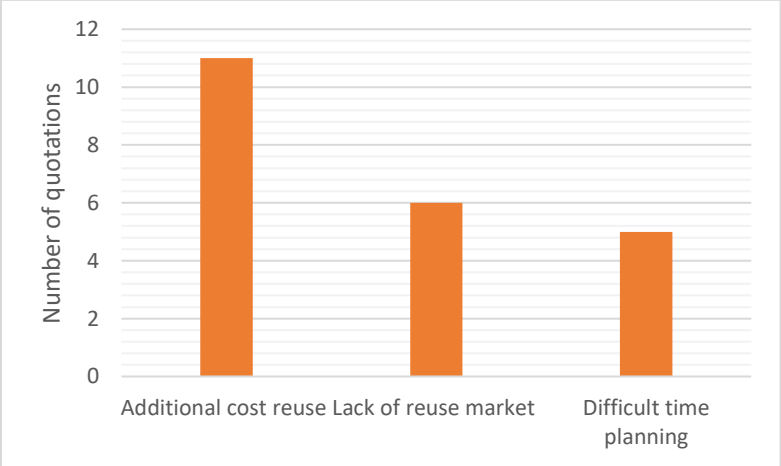
	Contractor	project leader	project leader	Project leader	Urban planner	Urban planner	municipality	municipality
Economic barriers								
Additional cost reuse	x	x		X			X	X
Lack of reuse market	x	x	x	X	X			
Time planning	x	x		X				X
Organisational barriers								
Lack of reuse market	X	X		X			X	X
Collaboration and communication	X	X	X				X	X
Lack of information	X	X	X	X			X	
Social barriers								
Aesthetic				X	X	X		X

Negative perception client	X			X				
Mindset	X		X				X	X
Legal barriers								
Certification	X			X				X
Handboek openbare ruimte	X	X	X	X	X		X	
Strict contractual agreements	X					X		

4.1 Economic barriers

The first key theme discussed from concerns economic barriers. These barriers, in the context of this research, are barriers related to costs associated with reuse, but also the effect reused products have on the market for new products. As shown in figure 8, economic barriers are mentioned 22 times in the 8 interviews conducted. The specific sub-category identified for the economic barriers and the frequency of mentioned barriers in the interviews conducted is shown in figure 9. Based on the answer given by the interviewees the economic barriers could be categorised as (1) additional costs for reuse, (2) lack of reuse market and (3) difficult time planning.

Figure 9. Number of quotations for economic sub-categories



4.1.1 Barrier: Additional cost reuse

Figure 9 shows that the current additional costs for reused products was mentioned most in the interviewees conducted. The additional costs arise due to (1) storage, (2) transportation, (3) cost for, material processing, (4) labour costs for processing materials, (5) additional time needed for deconstruction and sorting of reused materials at the project location, (6) certification and (7) quality assurance. A contractor stated: "*At project locations, it is more financially attractive to take everything to the scrap yard in one go than to take it apart and to see which products can still be reused. Dismantling takes more time, which means that a road must be closed for longer. This increases the costs for a contractor. There is no time to selectively demonetize your materials"* (R. van der Burgh, personal communication, May 3, 2020). All these additional costs make the current price for reused products higher than new products. One interview respondent remarked ''*in theory reuse should be cheaper*'' (M. Gasseling, personal communication, May 25, 2022). At this moment this is true for products that

require limited to no quality testing, processing and are directly reused at the deconstruction site. The additional costs for storage, transportation and material processing are in this situation not applicable. This makes reused products financially more attractive. An example of a product that is financially attractive to reuse is bricks used for inner-city road redevelopment projects. Since bricks have a lifespan of over 150 years they can be easily reused. The bricks are sorted, processed and quality checks are performed at the project location. This makes reuse of materials financially attractive and is therefore widely applied in the Dutch road development projects. However, for most of the products, the current price for reuse is higher than for new products. Due to current higher prices for reuse clients currently have minimal financial incentives to reuse products.

4.1.2 Barrier: lack of reuse market

A lack of reuse market has been mentioned in the interviews conducted as an economic barrier as shown in figure 9. This barrier was mainly mentioned by actors who have an influence on the products that are used, such as urban planners, contractors and the municipality. An urban planner stated: " *We also did a project a while back, where we had circular ambitions, but the material that we wanted were not available"* (T. Lodder, personal communication, April 24, 2022). A lack of demand or uncertainty about the need for reused products could cause doubt about the revenue of reused product sales. This limits the possibility to expand the reuse market. Furthermore, the supply chain is still fragmented and information regarding supply and demand cannot be shared in an underdeveloped reuse market, which further reduces reuse rates.

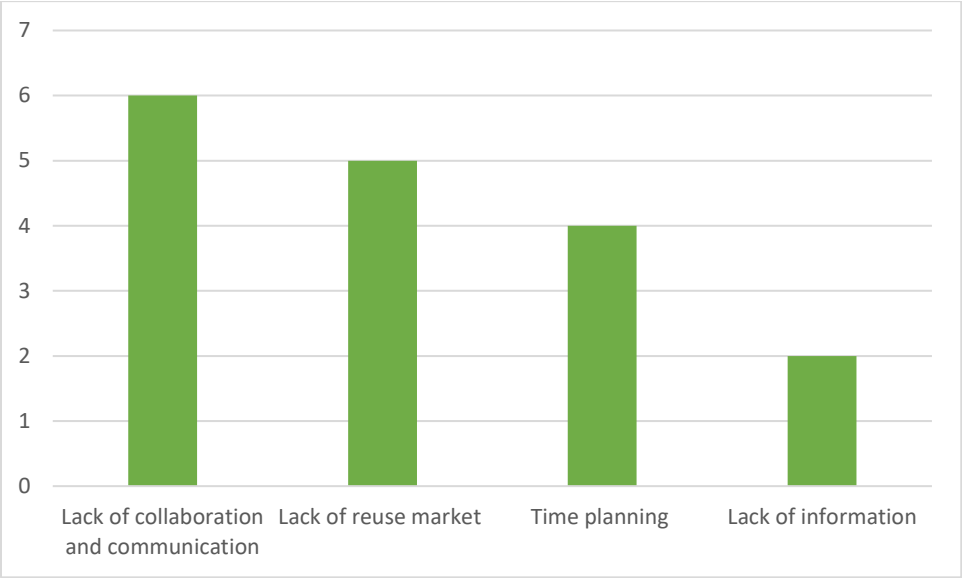
4.1.3 Barrier: Difficult time planning

Timing is a critical consideration for urban planners, clients, and contractors. It might not always be possible to disassemble a donor structure at the exact time when those components are needed for the construction of a new building or infrastructural assets. The time planning for working with reused products is therefore difficult. Moreover, storage spaces are often not at the same location where the harvested components are needed. This causes extra transportation time, which could further increase difficulties in planning resulting in higher costs. A contractor experienced this first-hand: "The *rent of your storage costs time, money, effort, commitment. The moment something is lying around for too long it will cost too much money. You lose money instead of making it financially attractive to reuse products. It is easier for projects to say, I buy it new, so I have a guarantee about delivery time to a certain extent."* (R. van der Burgh, personal communication, May 3, 2022).

4.2 Organisational barriers

This section shows the results from the interview data concerning the organisational barriers. The organisational barriers relate to the current organisational process of the different phases in urban area development and how these phases influence reuse potential. A Lack of collaboration and communication is mentioned six times in the interviews conducted, followed by lack of reuse market, time planning and lack of information.

Figure 10. Number of quotations for organisational sub-categories



4.2.1 Barrier: Lack of collaboration and communication

Collaboration and communication in the value chain is an aspect considered important by almost all group of actors. One urban planner reported a positive experience during an urban area development project including the contractor in the design process: *"It is preferable to involve the contractor as early as possible in the design process. This prevents design ideas from not being possible to implement. By collaborating early in the design process, you will certainly come a step further and there is still a lot to be gained from this"* (S. Lamerichs, personal communication, April 24, 2022). Furthermore, when actors are involved earlier in the process the acceptance of reuse could increase and scepticism of individuals not yet familiar to working with reused products can be reduced. The project progress can be negatively influenced due to lack of collaboration and communication, which was pointed out by a project leader: "Currently *we work in different project phases. If we want to implement reuse it would require all actors to make this decision in an early stage."* (M. Gasseling, personal communication, May 25, 2022).

4.2.2 Barrier: Lack of information

A lack of information about various remanufacturing procedures and lack of information about the quality of the harvested products was mentioned as a second important barrier. This is a barrier that is applicable for structural assets, such as bridges. At this moment there are just a few example project who worked with reused products which leads to limited experience in practise. Project leaders from W+B mentioned that repurpose of products is typically dependent on a "trial and error" process, making reuse a more time-consuming and solution.

4.2.3 Barrier: Time planning

Timing is besides an economic barriers also perceived as an organisational barriers by the interviewees in this research. Timing is a critical consideration for urban planners, clients, and contractors. It might not always be possible to disassemble a donor structure at the exact time when those components are needed for the construction of a new building or infrastructural assets. The time planning for working with reused products is therefore difficult. Moreover, storage spaces are often not at the same location where the harvested components are needed. This causes extra transportation time, which could further increase difficulties in planning. A contractor experienced this first-hand: "The *rent of your storage costs time, money, effort, commitment. The moment something is lying around for too long it*

will cost too much money. You lose money instead of making it financially attractive to reuse products. It is easier for projects to say, I buy it new, so I have a guarantee about delivery time to a certain extent." (R. van der Burgh, personal communication, May 3, 2022).

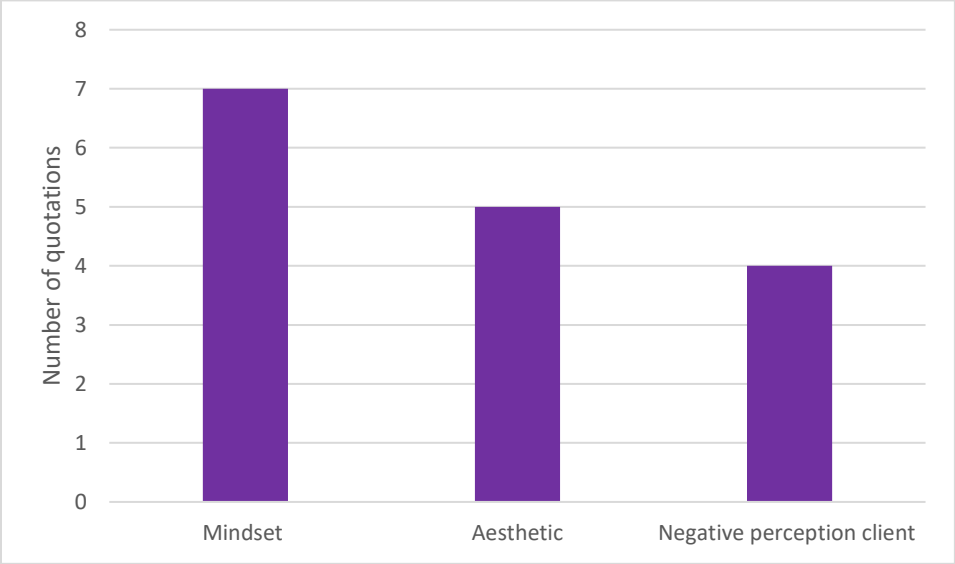
4.2.4 Barrier: lack of reuse market

The lack of a reuse market is not only considered an economic barrier by the interviewees but also an organisational barrier. At this moment there is no designated actor in the Dutch GWW sector taking the lead in facilitating a reuse market. Different actors are pioneering in offering reused products. A contractor stated: *"We are still quite pioneering in the sense that we are still investigating what the material flows are where there are enough sales that you do not leave them in storage forever"* (R. van der Burgh, personal communication, May 3, 2022). Currently, contractors and municipalities are pioneering with offering a marketplace for reused products. The municipality of Amsterdam stores and processes products used in the design of public space. The municipality is responsible for the procurement of all materials used in the design of public space. Therefore, the municipality of Amsterdam argued that it is logical to be responsible for the EoU treatment for the products they procured. However, it needs to be argued that not every municipality in the Netherlands can facilitate this material hub. A circular economy advisor from the municipality of Harderwijk mentioned they would like the contractor to take the lead in facilitating materials hubs and a marketplace.

4.3 Social barriers

The third theme discussed in the interview data concerns social barriers. These barriers, in the context of this research, refer to the mindset of stakeholders regarding reuse, but also possible cultural perspectives from actors. The social barriers are together with the economic barriers most often mentioned by the respondents.

Figure 11. The number of quotations for social sub-categories



4.3.1 Barrier: Mindset

As shown in figure 11, de mindset is referred to as a social barrier by all different actor groups respondents. This shift in mindset regards a lack of knowledge about the environmental and possible economic and environmental benefits of reuse. Without actors recognising the value of products, they would remain in their old ways of working where products are often demolished and recycled.

Moreover, the municipal circular economy advisor highlighted that it is often hard to ensure think about which materials they use and what the environmental and economic impact is of these materials. It was stated: *"It is already a challenge to get colleagues to think at all about what materials are being used. "* (A. Ouwerkerk, personal communication, April 24, 2022).

4.3.2 Barrier: Aesthetics

Moreover, the negative perception of reused products by clients and urban planners was mentioned as a barrier. Clients could associate reused products with minimized quality, aesthetics, and functionality. In the interviewee with the municipality stated: "You *have to frame it properly if you want to work with reused materials. You have to show in advance how beautiful these materials can be, reused product does not mean less quality*" (T. Lodder, personal communication, April 26, 2022).

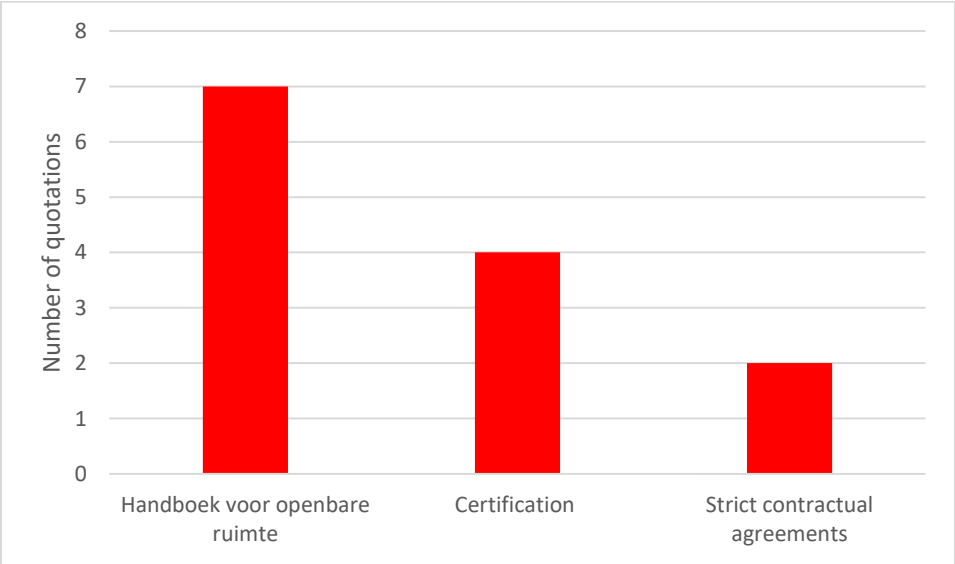
4.3.4 Barrier: Negative perception of clients

The urban planners interviewed in this research however did highlight that they are often striving for reusing materials as much as possible but see the negative perception of clients regarding the aesthetics of reused materials as a barrier: "*The municipality can have a very clear vision for a certain area, it needs to have a certain appearance. Municipalities often perceive reused materials with lower aesthetics, and therefore reused materials are not preferred in projects."* (M. Gasseling, personal communication, May 25, 2022). Lack of knowledge and good example projects was also highlighted as a reason why reuse often receives criticism, especially by clients; mainly the project leaders and the clients experience that a conservative linear approach to realizing assets in the Dutch GWW context is still present.

4.4 Legal barriers

The fourth category discussed are legal barriers identified in the explorative interviews. These barriers, in the context of this research, refer to possible regulations that might hinder the reuse of products in infrastructure.

Figure 12. Number of quotations for legal sub-categories



4.4.1 Barrier: Handboek voor openbare ruimte

Regarding the design of public space the interview participants mentioned the guidelines proposed by the municipality in the manual for the design of public space (handboek voor openbare ruimte) as a barrier to reuse products. In this manual, certain design principles are proposed to ensure a uniform

appearance of the public space in the city. These manuals highlights which material should be used in public space for different parts of the city. Project leaders mention that this manual is often outdated and can hereby hinder circular ambitions: "*The guidelines for material use of 20-30 years may be different from those currently used. Then the question is whether you are going to deviate from the current guidelines for reusing these materials or whether you are going to purchase new materials. This sometimes works against each other*'' (T. Kamerling, personal communication, March 31, 2022).

4.4.2 Barrier: Certification

Certification is often needed to ensure the quality and safety of products. However, it was noted that certification also poses a legal barrier. When products, such as bricks are reused, they are often compared and evaluated based on the requirements for new products. This results that products being sometimes rejected to be reused, while they are still of good quality to be reused again. Products that often still have the potential to be repurposed or refurbished become unnecessary waste. The following was noted: "'*In principle when you buy a product new, it also has all kinds of requirements or product characteristics and properties. It would be nice if we could go to a lower standard for several components in the inspection of reused products."* (M. Gasseling, personal communication, May 25, 2022).

4.4.3 Barrier: Strict contractual agreements

Another regulatory barrier mentioned are the rigid Rationalisatie en Automatisering Grond-, Water- en Wegebouw (RAW-contracts). These contracts are widely used in the Dutch GGW sector but are not the right type of contract if you want to stimulate reusable products. In these contracts, the client has specified what is exactly the desired solution, after which the contractor implement the design. Rigid RAW contracts can be seen as a barriers since these contracts leave very limited possibilities to have input on the materials used: *"'The space really has to be there, especially when you start looking at RAW contracts, it is often boarded up in such a way that the possibility is very limited to give it your own interpretation with recycled or reused materials"* (R. van der Burgh, personal communication, May 3, 2022).

4.5 Technical barriers

This section outlines the results from interview data concerning technical barriers. These barriers, in the context of this research, refer to technical capabilities of reused products. Barriers identified in literature related to possible damage during deconstruction due to exposure to nature or during dismantling, storage and transportation were mentioned as important barriers. To the question what are barriers for product reuse none of the participants mentioned technical barriers. After specifically asking if there were any technical barriers, the respondents did recognize that the technical barriers mentioned in this list could occur, but they did not see them as real barriers to product reuse. Testing of quality assurance and certification did get mentioned as a barrier, but this was more related to the additional costs associated with certification and quality testing as confirmed by: *"in principle, there are many technologies for completing residual life certification, etc. There are, but they are still too expensive financially compared to the primary standard work process"* (R. van der Burgh, personal communication, May 3, 2022).

4.6 Reuse drivers

Funding programs and financial subsidies to stimulate the reuse markets are essential to overcome the additional costs of reuse. Therefore, they are seen as a key driver for further implementation of reuse by clients and project leaders in particular: "*To implement reuse, we'll need certain financial incentives.*" (R. van der Burgh, personal communication, May 3, 2022). It needs to be noted that almost all respondents commented that with the rising raw material prices, the reuse market should get more interesting. With this price increase of raw materials, the reuse prices will hopefully get financially more attractive compared to new products. However, most interviewee participants stressed that it is important to stimulate reuse until this tipping point has been reached. Another driver to lower the price of reused products is upscaling of the reuse market. The following was stated by a contractor in this research: "*When you look at scaling up. This is where the greatest opportunities lie, and in view of the lead time when something is temporarily stored. If you can share that with the entire Dutch contracting industry, the throughput will be much greater, which also increases the chance of success for a successful financial model"* (R. van der Burgh, personal communication, May 3, 2022).

To increase communication and collaboration, involving the contractor and management-exploitation department early in the design process could benefit reuse. Contractors often have more material knowledge, and should therefore be included in the design process. By involving the contractor early in the process you hereby reduce the risk of prescribing materials that are unavailable or can not be reused. The same applies to the management-exploitation department. Furthermore, to have more information about the reuse potential of products, it is important to establish a material passport to stimulate future reuse.

Another organisational driver is flexibility in the process and planning of the realisation. Reuse is often obstructed due to the uncertain delivery time of products. It was mentioned by a contractor that sometimes you discover reuse possibilities later in the design process. New products could, in this case, already be ordered. A flexible planning process is therefore an essential driver for reuse. All interviewees mentioned that a need for a marketplace where materials can be ordered and product inventory stocks are listed. Preferably, this information is listed on a digital platform. This marketplace is needed to link the supply and demand of reusable products. It would be beneficial to have the option to pre-order products that will become available at a specific time. The possibility to pre-order products would help to make reuse more predictable and enable early planning and design with reused products.

Moreover, almost all interviewee participants mention good case study projects as drivers. Reuse of products is not an established practice in the Dutch GWW sector, and pilot initiatives ensure that all actors get more familiar with and gain experience in working with reused products. Another success factor in promoting reuse is the willingness of project leaders and contractors to take the risk and innovate. Taking risks is needed because at this moment reuse is not the standard way of working and therefore requires a willingness from stakeholders involved. Furthermore, the interviews stated that some degree of flexibility regarding the manual for design could facilitate more reuse of products. Moreover, using UWVGC contracts or construction teams could stimulate collaboration and communication in the design process, stimulating reuse.

5. Results case study

This part of the results chapter describes the outcomes of the case study. Background information is first given to introduce the case study selected for this research. This information is based on document analysis. In the second paragraph, a reconstruction of the Croeselaan project is described based on the insights gathered from the semi-structured interviews conducted in this case study.

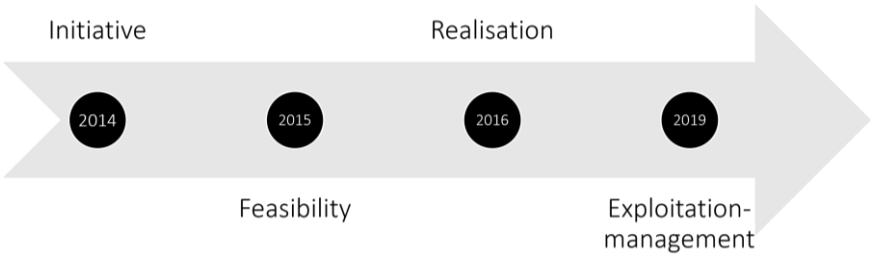
5.1 Background information - Croeselaan, Utrecht

A renewal of the station area was necessary, with more space for cyclists, pedestrians, and public transport and with more sharing mobility. The Croeselaan is a connecting link in this. This central location required its own character with pleasant living space for residents, passers-by, and workers (source document). The municipality of Utrecht had formulated the ambition for the Croeselaan to be the most sustainable street in Utrecht. It was furthermore stated that the Croeselaan needed to be an area that can be seen as a forerunner and inspirational sustainable project. Where sustainability measures have been taken that can also be applied in other areas.

5.1.1 Planning

The initiative phase of the Croeselaan project started in 2014, as shown in figure 13. The feasibility phase started in 2015, in which a temporary design (VO), final design (DO) and Programma van Eisen (PVA) were developed. After finalizing the DO the municipality set out a tender to find a contractor to realise the Croeselaan. The Croeselaan was finalised in the spring of 2019. After which the exploitation and management of the Croeselaan were transferred to the municipality.

Figure 13. Planning Croeselaan



5.1.2 Stakeholders Croeselaan

The stakeholders in the different phases of the urban area development of the Croeselaan have been identified and are shown in figure 13 (B. Jonkman, personal communication, April 25, 2022). This figure only shows the internal stakeholders that were involved in this project. The stakeholders involved in the initiation phase were the alderman from the municipality of Utrecht in collaboration with the sustainability advisor and the programme manager. In the feasibility phase, WB worked together with the engineering firm Advin, the sustainability advisor of the municipality of Utrecht and the contract manager. The contractor responsible for the realisation of the Croeselaan was Dura Vermeer. In the realisation phase WB, and the sustainability advisor of the municipality were still involved. However, they were operating more in the background. In the final phase of this research, the Beheer Inrichting Openbare Ruimte (BING) commission of the Municipality of Utrecht is responsible for the exploitation and management.

Table 5. Internal stakeholders Croeselaan redevelopment

Initiation	feasibility	Realisation	Exploitation-management
1) Alderman municipality	1) W+B	1) W+B	1) BING commission
2) Program manager municipality	2) Program manager municipality	2) Program manager municipality	
	3) sustainability advisor municipality	3) sustainability advisor municipality	
	4) Contract manager W+B	4) Dura Vermeer	
	5) Advin		

5.1.3 Material inventory Croeselaan

Based on confidential documents received from W+B a material inventory is made to identify which products were reused for the redevelopment of the Croeselaan. The results of this material inventory are shown in table 6. Besides researching what products can be reused table 7 shows what products have been newly purchased. From these results can be concluded that the street furniture and light poles from the old Croeselaan were not reused in the redevelopment. Moreover, newly purchased play equipment was purchased, instead of realising a playground from repurposed products.

Table 6. Product reused for the redevelopment of the Croeselaan

dismantling	10R hierarchy	Destination	% reuse
Confinement bands	reuse/recycle	Croeselaan	80%
Concrete pavers parking area and roadway	Reuse/recycle	Croeselaan	85%
pavers	Reuse	Croeselaan	85%
Granite tires	Reuse/repurpose	Croeselaan	80%
Road foundation	reuse/recycle	Croeselaan	50% reuse
Street furniture	Repurpose/refurbish/recycle	Croeselaan	100%

Table 7. Products newly purchased for the redevelopment of the Croeselaan

Purchase	Amnout	Origin
Lightpoles	27	Supplier
Street furniture	8	Supplier
Play equipment	4	Supplier

5.2 Result semi-structured interviews case study

This section explains the results from the interviews conducted with different stakeholders involved in the different phases of the Croeselaan project. The most important findings are discussed per phase in urban area development namely: initiation, feasibility, realisation and management-exploitation. In every phase is discussed which reuse barriers were recognized by the interviewees and how these barriers were tackled. Based on this analysis reuse drivers are highlighted. Also is evaluated what the influence was on reuse potential by the decision made in previous phases and actor participation.

5.2.1 Initiation phase

This sub-chapter describes the barriers and drivers identified in the first phase of the UAD process. The actor interviewed in this phase was the sustainability advisor from the municipality of Utrecht. Based on the outcomes of this interview could be stated that in the initiation phase the client of the Croeselaan already recognized the environmental and financial benefits of reuse. The interviewee stated: *"There was already awareness that the application of reuse percentages, for example in asphalt mixtures, saves a lot of environmental costs. And also of course if you clean sidewalk tiles and turn them around one more time, they can easily be reused which will save a lot of environmental impacts" (*S. Rademaker, personal communication, May 13, 2022). Recognising the value of reuse by the clients is an important driver.

This awareness about the environmental and financial benefits of reuse was also recognized by the project leader from the municipality. In this initiation phase, the client stated that the Croeselaan needs to become the most sustainable street in Utrecht. This ambition was formulated by an alderman of the municipality of Utrecht. It was recognized by the client early in the initiation phase that reusing products should be considered. The fact that this ambition was stated by a formal governmental administrator gave a real push to innovate and come up with sustainable solutions. The sustainability advisor from the municipality of Utrecht stated that this was a big success factor for the project: *"It helps if a government administrator aspires, this should be a very sustainable project, especially in a fairly traditional organization with a lot of technicians who just want to do their job well and with good quality and where sustainability was not always the first priority at the time " (*S. Rademaker, personal communication, May 13, 2022).

However, the interviewee noted that the negative perception of the client regarding product reuse is still present in the legal framework posed by the municipality of Utrecht. This was mainly related to convincing the municipality to change their standard way of working as described in the RAW bestek, which are contractual agreements that are used often in the GGW sector. It is recognized that it is especially difficult to change the perspective of the municipality regarding these contractual agreements, where the client exactly prescribes what materials need to be used and how they should be realised. The sustainability advisor stated: *"Very technical prescribing of exactly which mixtures should be placed there I really had to drag on to be allowed to do a pilot with a different type of asphalt or reusing products" (*S. Rademaker, personal communication, May 13, 2022).

According to the outcomes of the interview, there were no things that had to be organized differently in this initiation phase to better stimulate reuse of products. Furthermore, since the initiation phase is the first step in the UAD process no previous decision had been made that might have influenced the reuse potential for this project.

5.2.2 Feasibility phase

In the initiation phase the most important stakeholder was the municipality of Utrecht, being the client of the Croeselaan project. In the feasibility phase, W+B provided guidance in the design process and setting up the UWVGC contracts. During the feasibility phase W+B, in close collaboration with engineering firm Advin and the municipality of Utrecht came to the final design. An overview of the actors interviewed in this phase is given in chapter 5.1.2. This section describes the barriers and drivers for product reuse in the feasibility phase for the Croeselaan project.

As described in the previous section it was chosen for the Croeselaan products at the project location. No material inventory of products that could be reused from the surrounding area was made. This decision was purposely made to be less dependent on the reuse market. However, it needs to be noted that the reuse potential was diminished by not reusing materials surrounding the area. In the interview was stated that at the time of the feasibility phase in 2015 there was less attention to reusing products from the surrounding area.

The material inventory analysis furthermore showed that street furniture and fitness playground equipment was newly purchased. In an ideal reuse situation, the existing street furniture would be reused, and fitness equipment would be repurposed from the products harvested when dismantling the Croeselaan. In the interviews was stated that the Croeselaan forms an important connecting road between the central station and the city centre of Utrecht. The aesthetics of the area was therefore an important factor to consider in the redevelopment of the Croeselaan. In the Croeselaan project, all the street furniture such as benches, trash bins, playground equipment and fitness equipment were therefore newly purchased. It was mentioned that this was done since the Croeselaan should have a more luxurious appearance. Therefore, it could be concluded that the aesthetics of reused products was an important barrier in the Croeselaan that was not overcome.

However, there were also important drivers in this feasibility phase by the interviewee participant. In the GGW sector in the Netherlands clients often work with standard RAW bestekken. The Croeselaan project was purposely chosen for a UWVGC contract, in which the contractor is already involved during the feasibility phase. In the interviews was stated that contractors often have more material knowledge and should therefore be included in the design process. By involving the contractor early in the process, you thereby reduce the risk of prescribing materials that are not available or can not be reused. So, these UWVGC contract was an important enabling factor in the redevelopment of the Croeselaan to stimulate reuse.

Another important step taken in the feasibility phase was the early involvement of the BING commission, who are responsible to test the design based on the principles stated in the Handboek voor Openbare ruimte. Implementing reused materials into a design is not the standard way of working and might ask for deviation from these guidelines. In the interviews was stated that it is important to consult the department of management and exploitation early in the feasibility phase, to ensure that your design is not rejected. The project leader from WB stated the following: "*You have to have management on board with your design, so you have to make sure that you involve them early. In case of the Croeselaan, we said on these points we deviate from the design manual of the municipality of Utrecht? And we want to go further than usual"(*M. Schaffner, personal communication, May 13, 2022).

A final driver that stimulated sustainable and circular ambitions was the willingness of the project leader. The project leader was prepared to go beyond the standard way of working and formulate a different tender strategy. The circular procurement advisor from the municipality stated: "*This project leader who dared to. That gave us confidence as a team, too. To enter the market with high ambition. But yeah, It's just strong leadership"(*C. de Groot, personal communication, June 3, 2022)

Additional recommendations in the feasibility phase

The interviewees got asked to think about what they would have done differently to promote reuse of products. The circular procurement advisor stated that you preferably want the contractor to stay responsible for maintenance and the performance of materials over the longer term. This would eliminate risk for the municipality when implementing reused materials into the design. The client had chosen not to include maintenance in the tender strategy. When reflecting upon this strategy the circular procurement advisor stated that this was something that could have benefitted the circular performance of the Croeselaan. Moreover, when reflecting upon the action taken by the municipality regarding the feasibility phase it was mentioned in the interviews that the reuse rate could have been higher if the municipality would have made a material inventory, before contracting a contractor, to research the material potential in the area. This material inventory would have shown where the materials come from and how they can be reused. The municipality could have used this material inventory to also steer more in the tender requirements and realisation of the Croeselaan.

5.2.3 Realisation phase

Clear ambitions had been stated for the realisation of the Croeselaan. In the feasibility phase, the ambitions formulated in the initiation had been translated into a final design. In the realisation phase, the contractor Dura Vermeer was responsible to realise the proposed final design. It needs to be noted that once the final design has been decided upon by all stakeholders, there is a limited influence in the realisation phase regarding reuse.

However, in the interviews was stated that a success factor that promoted circular initiatives was the iterative nature between the feasibility and realisation phase. When a drawback occurred, there was the possibility to take a step back in the process. The contractor was willing to come up with alternative sustainable solutions. According to the project leader, it was unusual that a contractor was willing to innovate even after the final design had been decided and contractual agreements were made.

In the feasibility phase clear ambitions had been formulated regarding circular principles. The registration guide for the contractor tender stated the following:

> "The municipality wants to realise a circular Croeselaan that is designed in such a way that the use of new raw materials is prevented as much as possible during the entire life cycle of the road. In this tender, the focus is on high-quality reuse, future-proof design and transparent/learning path"

Contractors had to specify in their offer how they would give substance to the following questions:

a. High-quality reuse

I. To what extent do you apply elements from the existing Croeselaan or otherwise already existing materials and raw materials in the new Croeselaan?

II. During the further elaboration of the design and during the materialization, how do you ensure that the road, or its components, will be returned to the highest possible quality when the function is finished? be reused?

III. How do you ensure the highest possible application or repurposing of the materials that are released from the existing Croeselaan?

The original offer of the contractor translated this ambition into a design for a cycling path designed from baked paving stones. Based on the above-mentioned requirements for the circular principles the baked paving stones cycling path seemed the best solution since the life cycle of brick paving stones is over 150 years and offers easy deconstruction and hereby a modular design. However, the brick paving stones cycling path did not get realised. This was because this cycling path would make too much noise according to research conducted by Arcadis Engineering firm. Eventually a cycling path of asphalt was chosen. The ambitions formulated to reuse materials hereby did not result in what was stated beforehand.

Although the transition between the feasibility phase and the realisation was fluid and of an iterative nature it needs to be noted that most important decision regarding reuse are made in the initiation and feasibility phase. However, the sustainability advisor from the municipality of Utrecht did mention as a final recommendation that it would have been beneficial to set up working conditions for the contractor in the realisation phase of the project. It was noted that realising circular ambitions needs clear guidance along all the process steps. Since if involves often new ways of working

5.2.4 Management - exploitation phase

This final phase in the UAD process is the management and exploitation phase. The actor interviewed in this phase is part of the BING commission from the municipality, which are responsible for testing and evaluating if the final design meets the requirements of the design guidelines proposed by the municipality of Utrecht.

It was recognized by the actor interviewed that the design guidelines stated in the Handboek voor Openbare Ruimte acts as a barrier to reuse. However, it was noted that alteration to these guidelines also proposes opportunities for further implementation of reused products. The guidelines proposed could stir more towards sustainable material use by for example stating percentages reused products that need to be implemented in the design. The actor interviewed stated the following: "' *sustainable solutions can be stimulated by imposing stricter requirements from the management department. So not only whether it is maintainable, but also how many materials must be reused. In this way, ambitions are also made concrete in design principles*" (R. Roomenburg, personal communication, June 13, 2022).

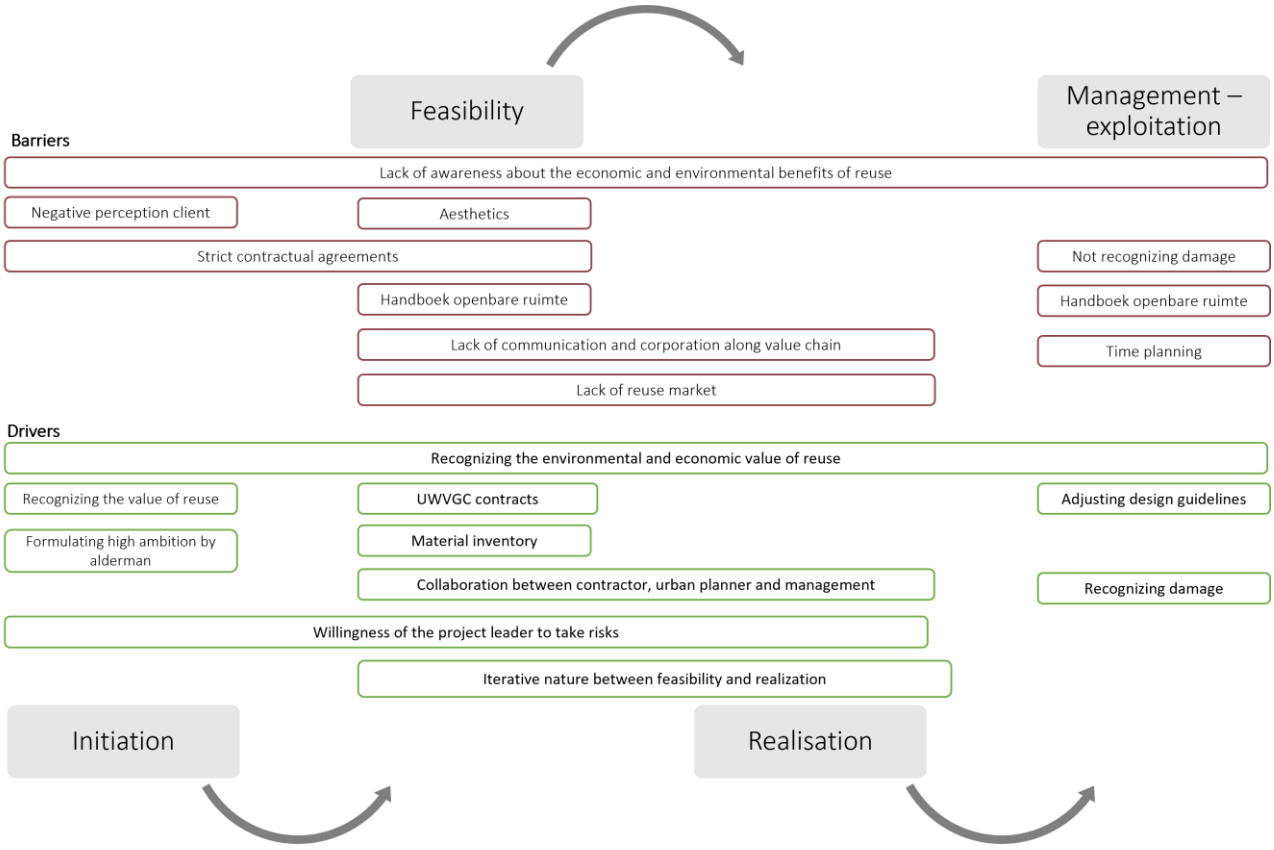
The findings from the interview conducted with the actor involved in the management-exploitation phase furthermore highlight the importance of involving the management department early on in the feasibility phase. It was stated in the interview: *"I think it's important to start an open dialogue at an early stage, involving management to evaluate the requirements for reuse. Especially in the early phase of the project, it is important to agree on a good process and to see what is feasible. We have a lot of knowledge and also data and information in our systems. So we can also indicate whether or not it is feasible to reuse the paving bricks"* (R. Roomenburg, personal communication, June 13, 2022). It was furthermore noted that often the risk in regard to reused materials is higher in comparison to new materials. To evaluate what the risk of a design is with reused components takes more time. This is another reason why alignment early in the UAD process is necessary.

It was furthermore recognized that reuse requires a new way of working and that an important driver to stimulate reuse which was predominantly present in the Croeselaan was the willingness to innovate. The interviewee in this phase stated: "*I communicated to the project leader that I was willing to investigate the possibilities for reuse, and that I was willing to evaluate the requirement the products must meet to ensure the quality of the products*" (R. Roomenburg, personal communication, June 13, 2022). However, since reuse requires a new way it was noted by the interviewee that it is important that the management department is aware of the materials used. And the performance needs to be evaluated. The actor stated that when they are aware of implementation of reused materials, they can act in time to recognize damage.

5.2.4 Conclusion barriers and drivers case study

This case study tried to identify which barriers and drivers for product reuse were present in the redevelopment of the Croeselaan in Utrecht. The barriers identified in the case study and how the barriers are connected to every UAD phase is shown in figure 14. It needs to be noted that certain barriers are spread out over multiple phases in the UAD process. This is because certain barriers are reoccurring in different phase or are ongoing along the different phases. Figure 14 shows the drivers identified in the case study.

Figure 14. Barriers and drivers identified in case study



6. Discussion

This research aimed to identify what the barriers and drivers are to reuse products from assets in the Dutch GWW sector. To answer this aim, a literature study was conducted to research what barriers and drivers have been identified in literature by previous academic authors. Secondly, explorative interviews were conducted with different actors involved in the urban area development process for GGW sassest. This was done to identify barriers and drivers in the Dutch context. Lastly, these barriers and drivers were validated, sharpened or new insights were gained through a case study analysis. The first part of the discussion will show the scientific implications of the empirical results by explaining how the findings of this research fit, deviate or add onto the existing academic knowledge about reuse barriers and drivers. The second part of the discussion will highlight the practical implications of the empirical results by explaining what the results mean and why the results of this study are important for the Dutch GWW sector, Circular urban area development, actors in urban area development and the urban area development process.

6.1 Reflection of academic debate in the Dutch context

In this part of the discussion the results from the empirical data are compared with the findings from literature. Table 5 shows what barriers have been identified in literature, and if these barriers were verified in the explorative interviews and case study. No additional barriers were identified in the explorative interviews and case study. However, some existing regulations do not support reuse which was derived from the explorative interviews. Which showed that existing regulations do not support reuse. Interviewees mentioned the Handboek voor Openbare Ruimte as a legal barrier, which was not stated in previous literature. It could be argued that legal frameworks differ for every national context and this is hereby a logical addition of a reuse barrier in the Dutch context. There were also barriers listed in the literature study that were not confirmed by the empirical data of this research. The barriers low cost for disposal of materials was not mentioned by interviewee participants in this research. This could be since in the Netherlands a lot of attention in the GWW sector has been given to recycling of materials over the past decade, and hereby that barrier low cost for disposal was already overcome for the GWW sector. Additionally, literature stated that higher cost for design with reuse is an economic barrier. However, the interviewees stated that that design for reuse is not necessarily more costly, but that prices rise because the reused components are more expensive than new materials. Furthermore, literature stated that quality testing was seen as a regulatory and technical barrier, however the empirical data suggest that this barrier is just an economic barrier due to additional cost of quality testing. The technical barriers that were not mentioned by the interview participants in this research are (1) difficulties to deconstruct components, (2) damage that occurs during dismantling of products, (3) additional health and safety precautions and (4) difficulties to design with reused products. The reason that the interviewees didn't mention technical barriers could indicate that elements or product used in the GWW sector are easier to dismantle, hereby limiting technical barriers. Possibly, interviewees might not have mentioned these technical barriers since they believe that the economic, social and organisational barriers are more pressing. On the other hand, it could be that the interviewees lacked technical experience and knowledge, to cause ignorance of the technical barriers by the interviewees. It needs to be noted that this research does not suggest that there are no technical barriers for product reuse in the GWW. They just have not been identified in empirical data of this study. Table 5 furthermore shows that there were no additional barriers identified in the case study on top of the literature study and explorative interviews. Remarkably, interviewees from the case study did not identify social barriers such as (1) reluctance to take risk, (2) client does not support reuse, (3) conservative way of thinking and (4) short term profit. This might be because the case study selected was a redevelopment project where high circularity ambitions were formulated and the project needed

to become an inspiring sustainability showcase project for the remainder of the municipality. So, it could be argued that by stating such ambitions the risk, involvement and reuse would have to be accepted by the client to realise these ambitions. Furthermore, the results from the empirical research indicates that certain barriers can not be categorised under one specific theme. The barriers lack of reuse market and time planning are categorised both as economic and organisational barriers. These results suggest that certain reuse barriers are interconnected, and barriers could only be overcome by finding solutions for both barriers. Proposing barriers according to the literature framework, in which the categories economic, organisational, social, legal and technical were identified, may have hindered to find interconnected barriers and drivers.

Table 5 shows which drivers from literature are verified in the empirical data of this study. Table 5 furthermore shows which additional drivers have been identified in the explorative interviews and case study. The drivers identified in literature, who are not verified by the empirical data of this study, are mainly drivers regarding the dismantling process of buildings. These drivers might not be verified since the actors interviewed in the research are not directly involved in the building process. Regarding the drivers identified there was one prominent driver that crystalized from the literature findings but was not confirmed in the empirical data of this study. Literature by (Knoth, 2012), who investigated barriers and drivers for the reuse of building components suggests the need for getting manufacturers involved in facilitating the reuse infrastructure. They recognized that the manufacturers have detailed knowledge of material composition, durability and other product characteristics hereby putting them in a unique position when it comes to material knowledge. However, the importance of product manufacturers was not highlighted by any of the interview participants. This could be because the actors interviewed in this study do not work with the manufacturers often, besides the contractor. Or the impact of manufactures was perhaps not recognized by the interviewees due to the fact that most assets in the GWW are owned by public institutions. Collaboration between the manufacturer and private parties might be easier than for public institutions.

Table 5. Comparison barriers identified in literature, explorative interviews and case study

Barriers identified in literature	verified in explorative interviews	Verified in case study	Comment
Economic			
Additional cost for reuse due to transportation, storage, fabrication, processing, and disemantling	yes	Yes	
Lack of established reuse market	yes	yes	This barrier was in the explorative interviews also mentioned as an organisational barrier
Low cost for disposal of materials	no	no	
Higher cost for design with reuse	no	no	Design cost for reuse are not higher, however additional costs arise due to storage, transportation etc. making reused products more expensive than new materials
Short term profit	yes	no	For the Croeselaan specific sustainable ambition were formulated where short term profit was not a key driver
Organisational			
the lack of skills, experience, and knowledge in deconstruction	yes	yes	
Lack of systems thinking, ownership and the integration of reuse in the design process of the new projects.	yes	yes	
Lack of supply chain coordination and integration	yes	yes	
Lack of information about existing structure and materials - traceability and quality	yes	yes	
Lack of good case studies	yes	yes	
Social barriers			
Lack of awareness about the economic and environmental benefits of reuse	yes	yes	

The negative perception of the stakeholders of the visual appearance	yes	yes	
Reluctant to take risk	yes	no	
The client does not support reuse	yes	no	
Conservative way of thinking	yes	no	
Legal barriers			
Rigid contract/procurement process	yes	yes	
existing regulations do not support deconstruction and reuse.	yes	yes	Existing regulations mentioned in the interviews obstructing reuse is the Handboek voor Openbare ruimte
Lack of quality certificates for the reused components	no	no	
individual testing fails to certify the reused components.	no	no	
Lack of supporting regulations	no	no	
Technical barriers			
Damage reused products	no	no	
Difficult to design with reused components	no	no	
Additional health and safety precautions necessary for	no	no	
Buildings not designed for dismantling	yes	yes	

Drivers identified in literature	verified in explorative interviews	Verified in case study	Comments
Good case studies	Yes	Yes	
Development reuse infrastructure: market places, material storage facilities upcycling facilities	yes	yes	
Coordination between the owners of the demolition site and new building	no	no	
Reclaimed component management coordinator	no	no	
List possible reusable components	yes	yes	
Training for effective deconstruction	no	no	
Knowledge and experience using reuable components	no	no	
Integrating reuse in the desing process	yes	yes	
Integrating reuse in contractual requirements	yes	yes	
Involving manufacturers for component reuse	no	no	
issue quality certificates and guarantees for second-hand materials by suppliers	yes	yes	
Connecting manufacturers with actors involved in the reuse processes	no	no	
Awerness creation and promoting of reuse in public debate	yes	yes	
Regulatory incentives	yes	yes	
Financial incentives	yes	yes	
Material paspoorts	yes	yes	
Additional reuse drivers identified in explorative interviews			
UWVGC contracts			
Involving contractor in design			
Involving management and exploitation department in design			
Foster collaboration with construction teams			
Early damage control by municipal management			
Additional reuse drivers identified in explorative interviews			

Iterative nature between feasibility and realisation phase
Willingness of project leader
Setting high ambitions in initiation phase

6.2 Practical interpretations and implications

GWW

The results of this research show that most of the barriers identified in literature for the building sector also apply for assets the Dutch GWW sector. The Dutch government stated to aim for a fully circular built environment by 2050. To achieve this ambition the Dutch GWW sector needs to overcome the reuse barriers. The result of this study furthermore indicate that the building sector and the GWW sector might not be that different in regard to reuse barriers. These overlapping barriers and drivers could mean that strategies to overcome these barriers are similar for the building sector and the Dutch GWW sector. It is important to recognize these similarities because strategies to overcome these barriers in the building and GWW sector might strengthen each other. The results of the case study furthermore showed that the barriers in the procurement process such as making an inventory, harvesting the materials and the distribution are linked to the UAD process. This study hereby demonstrates the importance of recognising and possibly integrating the procurement process in urban area development.

Circular urban area development

The theory on CUAD has shown how the different principles of the circular economy can be applied in the built environment. This research contributes to the circular principles “waste is food”, which highlights the importance of closing material- and waste streams in the urban context. The principle “waste is food” furthermore recognizes the importance of seeing waste as valuable products. It needs to be noted that the waste streams from the GWW sector are not the only material streams in the urban context. This means that the barriers and drivers in this research can not be generalised for all material streams in the urban area. Furthermore, this research focused on strategies to extend the lifespan of products and its part by either reusing, repairing, refurbishing, remanufacturing, or repurposing products. However, the R-ladder hierarchy shows that applying strategies to refuse or reduces product usages should always be considered before other EoU strategies. Moreover, it needs to be noted that in realising a circular urban area not only the principle “waste as food” should be applied. The other circular economy principles such as relying on energy from sustainable sources, as well as building resilience through diversity are principles that should be realised in the built environment before it is possible to speak of a circular urban area development. This means that the outcomes of this study only contribute to the academic and practical knowledge of part of realising a CUAD.

Actors in urban area development

The research aimed to identify key barriers for reuse of products from assets in the GWW sector. The empirical results have shown barriers perceived by different actor groups. Table 4 showed that the frequency of mentioned barriers and the type of barriers mentioned differ per actor group of actors. For example, contractors more often mention economic barriers in comparison to urban planners. These results could mean that actors perceive reuse barriers differently based on their tasks and responsibilities in the UAD process. Furthermore, Table 4 shows that the municipality least often mentions legal barriers. This result might indicate that actors can overlook barriers in their own work field, and only see barriers caused by other actors in the value chain. These results indicate that not all barriers can be generalised for every group of actors.

Urban area development process

Furthermore, when reflecting upon the reuse barriers identified in the UAD process it should be noted that most reuse barriers are apparent in multiple phases of the UAD process. These results may indicate that reuse barriers should be considered continuously throughout the UAD process. Overcoming a certain barrier in the first initiation phase might not guarantee that this barrier might not pose challenges again in the next phases of the UAD process. This could indicate that barriers should be evaluated and reflected upon in every phase of the UAD.

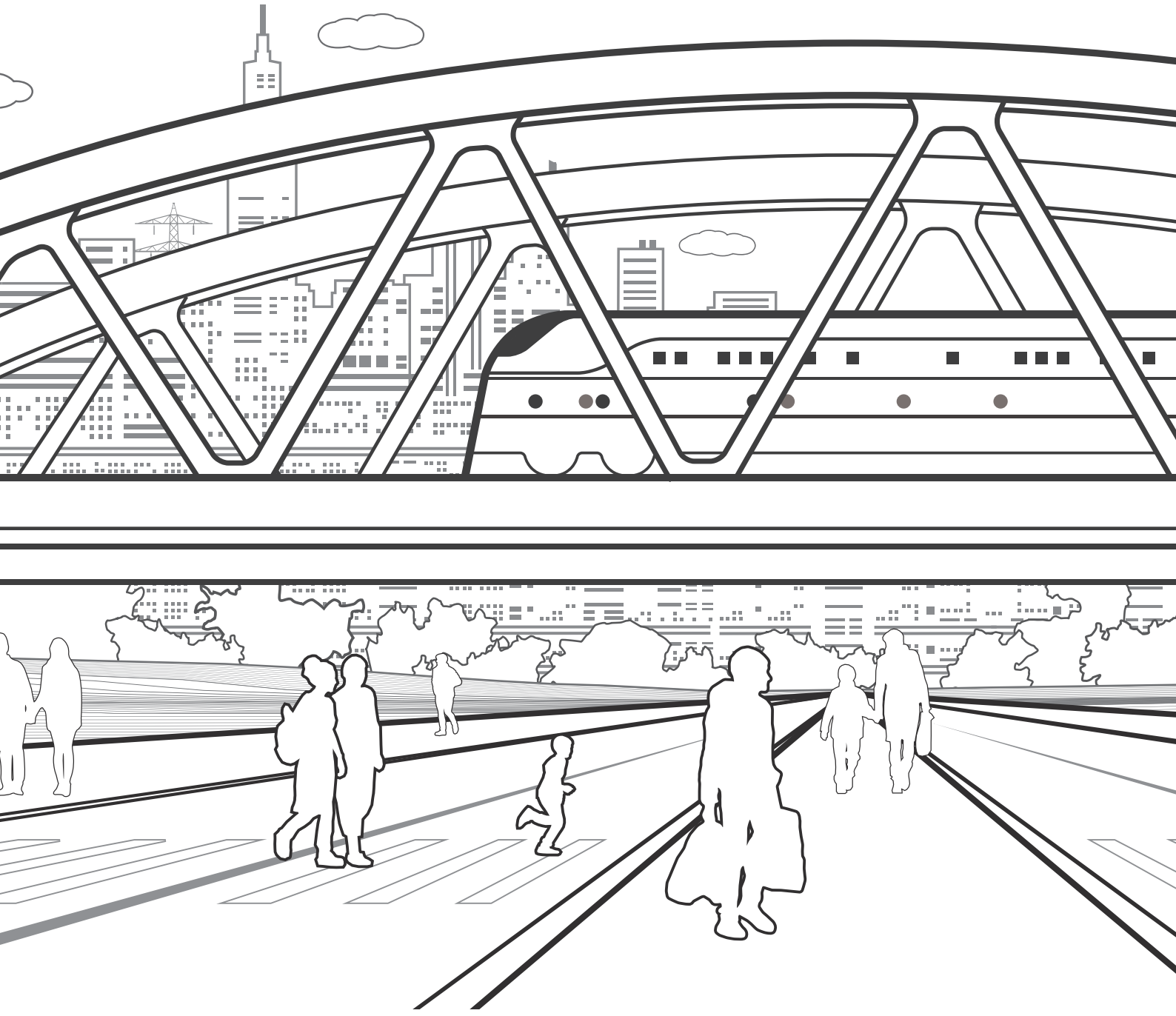
6.3 Limitations and recommendations for future academic research

A limitation of this research was the geographical and organisational context of the municipality selected for this case study, the redevelopment of the Croeselaan in Utrecht. The municipality of Utrecht is one of the biggest municipalities in the Netherlands, with substantial capital to make a claim to realise the most sustainable street of Utrecht. This context influenced which barriers and drivers were identified in the realisation of the Croeselaan. If a smaller municipality would have been selected the outcomes might have been different. So, the outcomes of this research can not be generalised for small to mid-size municipalities in the Netherlands. It is therefore recommended that more case studies are conducted for small to mid-size municipalities to identify barriers and drivers.

The results of this study might have been influenced by an uneven distribution of actors in the explorative interview phase. The interview respondents in the explorative interview phase included three project leaders, two urban planners and two municipalities and one contractor. The contractors were underrepresented. This might have influenced the barriers identified, and the frequency of mentioned barriers in this research. Furthermore, for this research only actors that are involved in UAD have been interviewed. This research did not consider the barriers and drivers of actors perceived by actors involved in harvesting the materials such as demolition companies, secondary companies, manufactures, and retailers. The neglection of barriers and drivers perceived by these actors could have influenced the barriers identified in the research. It is therefore recommended that further research is conducted into the barriers and drivers perceived by these actors, and to understand how these barriers and drivers fit into the Dutch urban area development context.

Finally, the empirical results of this study suggested that actors in UAD perceive barriers and drivers differently. This study did not aim to understand why actors perceive barriers differently. However, the empirical results of this study suggest that there might be a correlation between the responsibilities of actors in the UAD process and how they perceive barriers and drivers for product reuse. It is therefore recommended to conduct further research into how different actors perceive barriers and drivers for product reuse.

7. Conclusion



This thesis aimed to identify what the barriers and drivers are to reuse product from assets in the Dutch GWW sector. This research hereby tried to answer the following research question:

What are barriers and drivers to reuse products from assets in the Dutch GWW sector?

The barriers identified in this research to reuse products from assets in the Dutch GWW sector are:

- Not recognising the environmental and economic value of reused products - Products that are still suitable for reuse become waste when the economic and environmental value of reuse is not recognized by actors. Reusable products are by actors still associated with lower quality, inferior aesthetics, and diminished functionality which obstructs reuse.
- Additional cost for reuse - At this moment the price for reused products is often higher than using new products. The additional costs arise due to needed storage, transportation, cost for certification and quality assurance, material processing, labour costs for processing materials and additional time needed for deconstruction and sorting of reused materials at the project location.
- Lack of a reuse market - A lack of reuse market makes it for designers complicated to implement reusable products in the design. Moreover, lack of a reuse market causes uncertainty about the supply of reusable products which obstructs reuse.
- Difficult Time planning - When new materials are purchased the contractor has some guarantee over the delivery time and quality of the product. However, when working with reusable products the time planning becomes difficult. Deconstruction projects are often delayed, which result those products might not be on time available to be reused in new projects.
- Strict contractual agreements - In the Dutch GWW sector rigid contracts are used, in which the client has specified what is exactly the desired solution and what products should be used, after which the contractors implement the design. However, these are not the right type of contract if you want to support reuse.
- Lack of communication and collaboration along the value chain - Lack of communication and collaboration is between the urban planner/designer and contractor. Contractors are often to late involved in the buildings process. Reuse require supply driven design, often the contractors have a lot of material knowledge, and are aware of reusable products available at the project location or surrounding the project location. Moreover, regarding the design of public space, the management department, who should ensure the quality and uniformity of the public space, should be involved in the design process. Also, this is important because these actors have material knowledge.
- Lack of information - If there is no information provided about which element infrastructural assets are composed off, it becomes difficult to access their reuse potential, which obstructs reuse.
- Strict certification - Certification is needed to ensure quality and safety of products. However, when products such as bricks are reused, they are often compared and evaluated based on the requirements for new products. This results that products are sometimes rejected to be reused, while they are still of good quality to be reused again. Products that often still have the potential to be repurposed or refurbished become unnecessary waste. This certification method where reused products are evaluated based on the standards of new products obstructs reuse.
- Handboek voor Openbare Ruimte - Design principles stated in the Handboek voor Openbare Ruimte should ensure a uniform appearance of the public space in the urban area. However, the design principles used 20-30 years ago might be different from those currently used. So, if changes are made for the design principles, the products harvested may not be reused anymore, which obstructs reuse.

The drivers identified in this research to reuse products from assets in the Dutch GWW sector are:

- Case studies - Reuse of products is not an established practice in the Dutch GWW sector, and pilot initiative give the opportunity for actors in the GWW sector to get more familiar with wokring with reused products. Case studies can moreover reduce the scepticism of actors regarding reused products.
- Setting high ambition by formal alderman - Since the client in the GWW sector are often public institutions it helps if people with impact formulate clear ambitions to stimulate reuse.
- Making a material inventory - Supply driven design requires a material to be made at the project location and products that could be reused surrounding the project location.
- Physical or digital market place - To do this material inventory, a physical or digital market place should be available.
- Involving the contractor early on in the design process - Involving the contractor early in the design process, instead of making the contractor only responsible for the realisation reduces the risk of design not being able to be implemented or products prescribed not being able to be reused.
- Involving the management department in the design phase - The same account for the management depart from the municipality in the design of public space.
- Use contracts that support collaboration between actors - This can be done legally supported by using UWVGC contracts or construction teams.
- Iterative nature between the feasibility and design phase - When reused components can not be delivered on time, it is important to be able to adopt your design easily according to the products available. Therefore, it is important to have an iterative nature between the feasibility and the realisation phase. When drawbacks occur, it is important to be able to adopt your design easily according to the products available.
- Material passports - Furthermore, when the project is finalised a final enabling factor to stimulate reuse is ensuring that all the products used in the design are registered in the material passport. This makes it easier when the project is demolished for the materials to be reused.
- Willingness of the project leader to take risk- project leader needs to be willing to take a risk, and deviate from the standard way of working. This will give an important push to the transition to reused products from assets in the Dutch GWW sector.
- Financial incentives - To stimulate reuse and overcome the current additional cost for reused components financial incentives could be given in the form of subsidies or envy discounts by the national government, provinces or municipalities.

8. PRACTICAL RECOMMENDATIONS

This research ends by providing practical recommendations to stimulate reuse for assets in the Dutch GWW sector. An important barrier is the additional costs for reuse, to overcome this barrier it is recommended that financial incentives and funding schemes are provided by the national government. Since the clients of assets in the GWW sector are often public institutions there is often a lack of resources to take the risk to reuse products. Providing funding will also ensure upscaling of the reuse market, which results in lower prices for reusable products. It is furthermore recommended that contractors and clients work together on how to facilitate the reuse market places. At this moment there a different public and private initiatives that facilitate these reuse market places. It is important that these actors collaborate and coordinate, so that a clear market place for assets in the GWW sector is realised. Lastly, it is recommended that clients, urban planners, project leaders, and contractors are informed about the environmental benefits of reusable products. These knowledge campaigns can be facilitated by governmental organisation or private parties.

During the interviews conducted in this research the interviewees often mistake reuse waste strategies with recycling. This shows that more knowledge is needed in the GWW sector about reuse waste strategies. This knowledge could be provided by engineering and consulting companies. Moreover, it would be beneficial to organize sessions where the identified barriers and drivers to reuse products from assets in the Dutch GWW sector are discussed with experts in the field. The results of this research can be validated by organizing these session with more experts. These sessions might lead to better understanding between actors and possibly act as the starting point for figuring out how to overcome barriers or stimulate driving factors. These sessions can be organized by consultancy and engineering firms. It is crucial that these sessions are not just attended by the interviewees from this research.

This research identified reuse barriers and drivers for assets in the Dutch GWW sector. It is recommended that clients, contractors, urban planners and municipalities determine which of these barriers are present in their own organisation. Moreover, it is recommended that actors evaluate which of the identified barriers and drivers are within their power to control. Some barriers might be overcome by communication and collaboration between actors. However, this research indicated that some barriers can only be overcome by a certain actor. This also regards the drivers identified in this research. The barriers and drivers categorization framework, which was used in this research may be applied in such studies to highlight previous identified barriers and drivers.

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APPENDICES

Appendix A - Interview protocol explorative interviews

Script prior to interview

I'd like to thank you once again for being willing to participate in this interview. As I have mentioned to you before, my study seeks to understand what are potential barriers for different stakeholders to reuse materials. This study also seeks to understand what are possible strategies to bridge these barriers. The aim of this research is to get a better understanding of barriers for materials reuse and bridging strategies in the Dutch context.

Our interview today will last approximately 45 minutes during which I will be asking questions about what materials can be reused, who are the actors involved in reusing materials, what the key barrier are to reuse materials, and possible strategies to overcome these barriers.

Consent to record interview

Are you okay with me recording our conversation today ?

If yes: Thank you! Please let me know if at any point you want me to turn off the recorder or keep something you said off the record.

If no: Thank you for letting me know. I will only take notes of our conversation

Before we begin the interview, do you have any questions? [Discuss questions] If any questions (or other questions) arise at any point in this study, you can feel free to ask them at any time. I would be more than happy to answer your questions.

To begin this interview, I would like to ask you some question about your work at WB.

Question 1:

What is your current position at WB?

Question 2:

What projects have you worked on for WB? and what was your role and responsibility?

a) Reuse potential

Thank you for your responses. I'd like to now ask you question regarding the reuse potential of products from CDW.

Question 3:

What construction products have you reused already in your projects? And why did you decide to reuse these products?

If no construction products have been reused in projects of interviewee move onto question 6

Question 4:

What is/was your source for reused construction products?

- Do you have knowledge of a digital marketplace for the reuse of construction products? If yes, please specify.
- Do you have knowledge of a digital database for product information (materials passports)? If yes, please specify.

Question 5:

Did you reuse the products for their intended purpose/function or for a different purpose? Please specify.

Question 6:

Based on your expertise which construction products are easiest/have the biggest potential for reuse, and which are most difficult to reuse? Why?

b) Actors involved

Thank you for sharing information about your experiences with reusable products. I'd like to now ask you a few questions about the main actors involved in projects you worked regarding material reuse.

Question 7:

Who are/were the main actors involved in the project related to the reuse of construction products? What were their roles and responsibilities?

If the interviewee did not work on projects related yet to material reuse, ask them to describe their current direct and indirect stakeholders. Moreover, ask them to describe how this dynamic might be different when working with reusable materials.

Question 8:

Who are/were your direct stakeholders in previous projects and what are their roles and responsibilities? Who are/were your indirect stakeholders and what are their roles and responsibilities?

Question 9:

What dynamic would change for your direct and indirect stakeholders if you would work with reusable products? What business processes would change?

c) Reuse barriers

I'd like to now ask a few questions specifically about barriers for reusing materials.

Question 10:

In your opinion, what are the main challenges with reuse of construction products today?

Question 11:

Who or what is creating this barrier? (Prompt: internal to the company, industry, along the supply chain or driven externally by policy or the wider economic environment in which they operate)?

d) Strategies to bridge barriers

My final question are about potential strategies and success factors for reusable construction products

Question 12:

In your opinion, what measures should be considered to increase utilization of reusable construction products?

Question 13:

In your opinion, what are success factors for increased utilization of reusable construction products?

Question 14:

Before we end this interview, do you have any other comments or suggestions related to reuse of construction products that we did not discuss?

	Background information	What are the materials that could be reused?	Who are the actors involved, and what are their business processes?	What are the key barriers for reusing materials from CDW?	How does the business process need to be adapted, so materials can be reused?
Question 1	X				
Questions 2	X				
Question 3		X			
Question 4		X			
Question 5		X			
Question 6		X			
Question 7			X		
Question 8			X		
Question 9			X		
Question 10				X	
Question 11			X	X	
Question 12					X
Question 13					X

Appendix B - Interview protocol case study

Script prior to interview

I'd like to thank you once again for being willing to participate in this interview. As I have mentioned to you before, my study seeks to understand what are potential barriers for different stakeholders to reuse materials in the Croeselaan project. This study also seeks to understand what are possible strategies to bridge these barriers. The aim of this research is to get a better understanding of barriers for materials reuse and bridging strategies in the Dutch context.

Our interview today will last approximately 45 minutes during which I will be asking questions about what materials can be reused, who are the actors involved in reusing materials, what the key barrier are to reuse materials, and possible strategies to overcome these barriers.

Consent to record interview

Are you okay with me recording our conversation today ?

If yes: Thank you! Please let me know if at any point you want me to turn off the recorder or keep something you said off the record.

If no: Thank you for letting me know. I will only take notes of our conversation

Before we begin the interview, do you have any questions? [Discuss questions] If any questions (or other questions) arise at any point in this study, you can feel free to ask them at any time. I would be more than happy to answer your questions.

A. Introduction

Question 1: What was your role and what were your responsibilities in the Croeselaan project?

Question 2: I am showing you a picture now. Could you indicate where you were involved in the process?

B. Reuse barriers

Question 3: In what way were these challenges reflected in the realisation of the Croeselaan in Utrecht in the initiative phase?

Question 4: On which challenges did you have influence?

Question 5: Besides these 4 challenges, are there any other challenges that you think relate to the initiative phase of an area development from the municipal perspective (client)?

Question 6: How have decisions in earlier phases influenced circular ambitions?

C. Bridging strategies and drivers

Question 7: How might you have handled things differently afterwards?

Question 8: What should someone have done differently in the first phase of the area development?

Question 9: How did you try to overcome these challenges during the realisation of the Croeselaan?

Question 10: Which steps had to be taken by which stakeholders in the realisation of the Croeselaan?

	Background information	What are the key barriers for reusing materials from CDW?	How does the business process need to be adapted, so materials can be reused?
Question 1	X		
Questions 2	X		
Question 3		X	
Question 4		X	
Question 5		X	
Question 6		X	
Question 7			X
Question 8			X
Question 9			X
Question 10			X

Appendix C - Code book

Theme	Code group	codes	N
Barriers			**119**
	Economic		**22**
		Additional cost reuse	11
		Lack of reuse market	6
		Difficult time planning	5
	Organisational		**17**
		Lack of collaboration and communication	6
		Lack of reuse market	5
		Time planning	4
		Lack of information	2
	Social		**16**
		Mindset	7
		Aesthetic	5
		Negative perception client	4
	Legal		**13**
		Handboek voor openbare ruimte	7
		Certification	4
		Strict contractual agreements	2
	Technical	Quality ensurance	**5**

Theme	Code group	codes	N
Enablers			40
	Economic		
		Envy korting	1
		CO2 taks	1
		Upscaling	1
		Reuse market place	2
		Financial benefit reuse	3
	Organisational		
		Construction team	1
		Circular procurement	3
		Reuse withing project	2
		Flexibile planning	2
		Involving contractor in design	3
		Involving management in design	4
		Knowledge, skills, expertise reuse	4
	Social		
		Awerness benefits reuse	2
		Case studies	4
		Willingness project leader	1
		Willingness contractor	2
	Legal		
		Adjusting certification reused products	2
		Adapt Handboek voor Openbare ruimte	2