

The Potential for Circular Building Reuse

How a Circular Building Reuse Framework Can Be Used to Implement Circular Ambitions in the Portfolio of the Netherlands Police.



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Foreword

One year before I began my studies in Delft, I visited Delft University of Technology with my mother during an open day for future students. I still remember the moment I realised that this was where I wanted to study. I walked through the doors of the main entrance of a beautiful old building, and walked right into a lively greenhouse-like part of the building filled with students working on models and design projects. I felt a pleasant energy in this building, something I could not fully explain it at this time. But I knew: this was the place I wanted to spend my time for the coming years.

The following year, I started the Bachelor's programme in Architecture and the Built Environment. What I did not know, is that I would soon realise I did not want to become an architect. I did, however, really like the processes around the construction of a building, the collaboration with the creatives who would design the built environment. This led me to continue my academic journey in the Master's programme in Management in the Built Environment. Starting this Master's felt like the beginning of a new chapter. It offered an opportunity to leave behind the challenging time I had experienced during my Bachelor's studies and to pursue a direction that aligned more closely with my interests. And now, seven years later, I am proud to present my Master's thesis.

This thesis presents the CBR framework: an integrated circular building reuse framework that supports the decision-making process in the pre-project phase on whether to reuse a building or not, and to assist in appointing the project-specific potentials for circular reuse. I have always had an interest in building reuse as a way to preserve heritage. Besides, I feel a responsibility to take care of the built environment and the world's natural resources that have been gifted to us. The principles of the circular economy provide a valuable approach to addressing these challenges, and their application within the field of building reuse aligns closely with both my professional interests and personal values.

Looking back, I realise that this aspiration – to contribute to the future of our living environment – is ultimately what brought me to Delft. Conducting research on how we can care for both the world we inhabit and the buildings we use every day, while applying the creative and critical thinking skills developed throughout my studies, is exactly what I had hoped to achieve when I first entered this faculty.

I would like to thank everyone who has supported me throughout this journey. First, I would like to thank my university supervisors, Monique, Brian, and Hedieh, for keeping my work on an academic level, whereas I was sometimes distracted by the practical application of the research. Your support and confidence in my work motivated me during moments when progress felt difficult.

I would also like to thank Casper and my colleagues at the Netherlands Police for making my time in the office both enjoyable and educational. Through our collaboration, I gained valuable insights into the practical application of research. Your genuine interest in my work and your enthusiasm for the development of the framework really motivated me.

And finally, I want to thank my family and friends for providing me so much emotional support these months, and actually the past seven years. You have always believed in me, even though sometimes I was not able to give everything I wanted to give. You have always been by my side, and comforted and motivated me to continue my search for what I wanted to achieve.

For a long time, I struggled to define what had fascinated me so much when I first entered the Faculty of Architecture. Today, I believe I finally understand. People often refer to the faculty as BK City, and that is exactly what it is. It is a place full of activity and creativity: students and staff, exhibitions and events, workshops, shops, and, of course, coffee bars – my personal favourite. It is a vibrant and inspiring environment that has shaped me both academically and personally. I am grateful for the opportunity to have studied here over the past seven years, and I look forward to carrying the lessons, experiences, and values I gained at BK City into the next stage of my professional life.

I hope you enjoy reading the thesis!

Leonoor
Delft, 2 June 2026

Abstract

Natural resources are being consumed too fast, and the built environment is a big contributor to this problem. The circular economy aims at extending a product's lifecycle using different strategies, for example reuse. Within the academic field of building reuse, there are several tools developed that define the building reuse potentials. Similarly, in the field of circularity, several design strategies discuss the implementation of circular building methods in the construction of buildings. Nevertheless, there is a research gap in the academic literature on the implementation of circular building methods for the building reuse process of existing buildings, especially for the early stages in this process. To fill this gap, this research will present an integrated circular building reuse framework. This study is conducted within the organization of the Netherlands Police, providing information on the experienced barriers of implementing circular ambitions within the organization. The aim of this research is to provide tools to formulate realistic and feasible objectives and ambitions. This, in turn, enhances the probability that circular ambitions are effectively integrated throughout the building process, thereby contributing to the long-term value of the built environment. The main research question to accomplish this aim is: "Which conditions are essential for effective circular building reuse, and how can these be integrated into a decision-making framework for the pre-project phase of building reuse?" . This research question will be answered using a combination of a literature review, expert interviews within the organization of the Netherlands Police, and desk research, and the framework is validated using a case study. The results section of this research addresses the retrieved data from the interviews with the experts from the Netherlands Police. This data, in combination with the previously gathered data from the literature review, will be combined to develop the CBR framework. The CBR framework supports the decision-making process in the pre-project phase on whether to reuse a building or not, and assists in appointing the project-specific potentials for circular reuse. Therefore, it bridges the research gap in academic literature on the implementation of circular building methods for the reuse of existing buildings.

Keywords: circularity, building reuse, decision-making, Netherlands Police

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List of abbreviations

ARP	Adaptive reuse potential
BCI	Building circularity index
CB	Circular building
CBR	Circular building reuse
CE	Circular economy
DfA	Design for Adaptability
DfD	Design for Deconstruction
ReSOLVE	Regenerate, Share, Optimize, Loop, Virtualize, Exchange
VRP	Value retention process

Introduction

01

1.1 Problem statement

Currently, natural resources are being consumed at a rate twice as fast as they can be regenerated (Akhimien et al., 2020). In the built environment, more than half of demolition materials coming from end-of-life buildings are being landfilled (Ellen MacArthur Foundation, 2015). The circular economy (CE) is about reusing and recycling these natural resources (Corona et al., 2019) that are likely to be demolished after their initially intended use. In Europe, the CE is becoming a more prominent topic of discussion (Ellen MacArthur Foundation, 2015). As mentioned in the report Ministry of Economic Affairs and Climate (2025), a circular economy would contribute to achieving climate neutrality and climate justice. The aim is to be fully circular by 2050, and several organizations have gathered in the National Program for Circular Economy (NPCE) and presented four ways to realise this: reduction of the use of raw materials, replacing raw materials, extending the lifecycle of products, and the reuse of raw materials. Value retention processes (VRPs) – like reduce, reuse, and recycle – are developed to implement circular economies and maintain the value of the materials for as long as possible (Eberhardt et al., 2021). Recent studies are mostly focused on recycling, and less on the reuse of materials (Rahla et al., 2021). The VRPs are described to help to include circularity, but still they are hard to implement in organizational processes due to a lack of awareness, unclear costs and additional time (Van Stijn, 2023). There are some well-developed strategic frameworks for circular design, like Design for Adaptability (DfA), which focuses on flexibility in use, and Design for Deconstruction (DfD), that designs for the long-term existence of the building (Rahla et al., 2021), that could support the realisation of the sustainability goals of the national government policies. However, most of these design strategies are applicable for the development of new buildings, rather than reusing existing structures.

Reuse of buildings is a way to preserve existing structures and extend the lifecycle of the building (Van Laar et al., 2025). As one of the VRPs (Eberhardt et al., 2021), reuse of buildings prevents the waste production of the demolition of buildings, and the reconstruction of a new building (Aigwi et al., 2023). The process of reusing an existing building is complex (Arfa, Lubelli, et al., 2022) due to unpredictability (Van Laar et al., 2025) and the involvement of many actors (Arfa, Lubelli, et al., 2022). Academic literature indicates several design methods or frameworks that assist in defining the building reuse potentials, like the transformation meter (Geraedts et al., 2025). Nevertheless, these frameworks focus solely on the building reuse process, and do not include other circular building methods or strategies.

There are some barriers on the implementation of circular building strategies. Akhimien et al. (2020) mention that there is too little focus on the actual implementation of circular building strategies or interventions in the process. The frameworks for circular design, like the ReSOLVE framework, and the general ambitions, like being fully circular by 2050, are well-established, but the actual road to realise these interventions is lacking. Another barrier of implementing circular solutions in the built environment is the difficulty of measuring the outcomes of circularity using standardized decision-making (Van Laar et al., 2025). Circularity metrics are tools to measure the impact of circular strategies, but they mainly focus on one aspect of circular economies (Corona et al., 2019), while ideally organizations both incorporate CE strategies in their business models (Geisdoerfer et al., 2020), as well as circular building methods that ensure the value of the materials for as long as possible (Eberhardt et al., 2021). According to Corona et al. (2019), circularity metrics can be divided into two groups: circularity measurement indices, the first group, provide a circularity degree to a system. Examples of circularity measurement indices are the Material Circularity Indicator (MCI), focusing on material recirculation; the New Product-level circularity metric, which measures the economic value recirculation; or the Circularity Index, scoring the circularity degree in a percentage. The second group is the circularity assessment tools, which analyses the effect of the implemented circular strategies. An example of this is the life cycle assessment (LCA), assessing the overall environmental impact throughout the whole lifecycle.

Both these barriers on the implementation on circularity strategies inquire integrated strategies within the building process that take into account multiple significant factors to the project. It is important that circular building strategies are included from the start of the project and to be specific on their practical implementation in the project.

Within the current academic literature on circularity, strategies are discussed to implement circular building methods in the construction of new buildings. Besides, several tools are developed to measure the circular performance of buildings after they are built, which are suitable for reused buildings as well. Consequently, there is a research gap in the academic literature on the implementation of circular building methods for the building reuse process of existing buildings, specifically for the early stages in this process.

1.2 Research goals and objectives

Through this research, more insights will be gathered on the topic of the implementation of circular buildings methods within the process of building reuse. The goal of this research is to refine the early stages of the decision-making process for building reuse, during which project goals and ambitions are defined, in order to better specify the extent to which circular ambitions can be achieved within a project. Ultimately, this study seeks to provide tools to formulate realistic and feasible objectives and ambitions. This, in turn, enhances the probability that circular ambitions are effectively integrated throughout the building process, thereby contributing to the long-term value of the built environment.

These research goals will be addressed by studying the academic literature within the fields of circular building methods and building reuse. Based on existing frameworks and tools, this research will present an integrative framework to assess the potential for circular building reuse. This framework is initially developed for the organization of the Netherlands Police, whose data will also be provided in a case study to concretize the framework.

1.3 Research questions

This leads to the following research question: “Which conditions are essential for effective circular building reuse, and how can these be integrated into a decision-making framework for the pre-project phase of building reuse?” . The relation between the research questions is illustrated in the conceptual model in figure 1.

This research question will be answered using the following sub-questions:

1. How is decision-making regarding building reuse currently organized?

This question aims at studying the current decision-making processes regarding building reuse. This study will include decision-making tools from academic literature on building reuse, to find theoretically proven and organizationally feasible ways of measuring potentials of building reuse.

2. Which conditions and barriers for effective circular building methods emerge from academic literature?

This question will look into the field of circular building and how this is performed successfully. The question aims at presenting conditions and barriers in the process and design of circular buildings that determine the success rate of the project. Besides, several tools will be discussed that measure the circular performance of buildings.

3. What barriers hinder the implementation of circular building ambitions within the Netherlands Police? In this question, the focus will be on finding out the current state of developing with circular building methods at the Netherlands Police. The aim of this research question is to find barriers, based on academic literature retrieved from sub-question two, in the process of developing circular buildings.

4. What does an integrative framework on circular building reuse require in order to assist in the early decision-making process of building reuse?

This question analyses the previously discussed themes or circularity and the decision-making process of building reuse, and establishes criteria for a future framework that will combine these two topics. This final stage of the research will compile all gathered data to return to the main research question and develop the final framework on circular building reuse.

1.4 Research output

At the end of this research, an integrated circular building reuse framework will be presented that can be implemented in the early stages of the decision-making process of building reuse. The thesis will provide a review of academic literature on building reuse, with a focus on how its potential is assessed in advance; an analysis of existing circularity assessment tools used to evaluate building circularity performance; and the development of an integrated circular building reuse framework, proposed for application within the context of the Netherlands Police.

In addition, the report will include an empirical study conducted in collaboration with the Netherlands Police. Document analysis of existing policies and ambitions will provide insight into the current state of circular objectives and the integration of building reuse strategies. Furthermore, expert interviews will explore practical challenges related to these topics and provide insights into the experiences of employees of the Netherlands Police involved in circular building reuse processes.

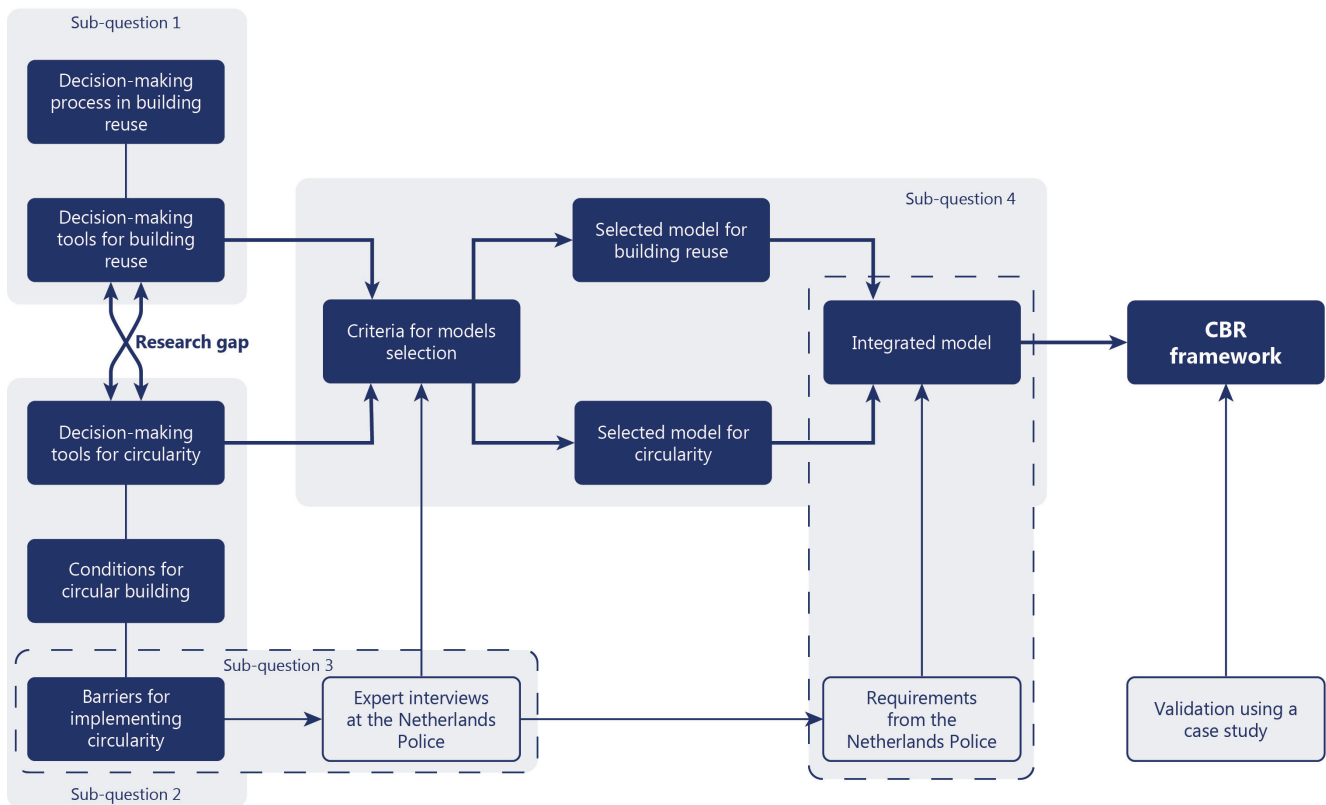


Figure 1. Conceptual model

1.5 Relevance

1.5.1 Societal relevance

Natural resources are being consumed too fast, especially within the construction industry. Consequently, strategies aimed at minimizing the use of virgin materials and extending the lifespan of existing resources have become increasingly important. Two closely related concepts addressing this issue are the circular economy and building reuse, which are both discussed in this thesis.

This study contributes to the practical application of circular strategies, by developing a framework that combines principles of circular building methods to an existing framework used in the decision-making process of building reuse. This could assist in the circular transformation of buildings, making sure the depletion of natural resources can be reduced.

This thesis is written in collaboration with the Netherlands Police, whose organizational strategy includes the reuse of existing buildings. A social relevant organization like the Netherlands Police, possessing a large real estate portfolio, can be of significant influence in the transformation from a linear to a circular economy. The findings of this thesis, and the proposed CBR framework, will help the Netherlands Police in implementing circular ambitions within the process of reusing existing buildings. In doing so, the Netherlands Police can serve as an example for other public organizations.

1.5.2 Scientific relevance

The benefits and challenges of circular building methods and building reuse are frequently studied in academic literature. Within the CE, there are several strategies for the implementation of circular building methods within the construction of new buildings. In addition, several assessment models exist to evaluate the circular performance of buildings once they have been constructed. Nevertheless, there are little frameworks that define the circular potential of building prior to their development, whether in the context of new construction or building transformation.

There are tools, applicable in the pre-project phase, that indicate the effectiveness of building reuse. However, the majority of these tools are quite complex and rely heavily on quantitative data.

Current academic literature lacks integrated tools capable of assessing both the reuse potential and the future circular potential of buildings undergoing reuse. This thesis addresses this gap by proposing a Circular Building Reuse framework that combines these two dimensions. While initially developed for the Netherlands Police, the framework contributes to the broader transition toward a circular economy by translating existing academic insights into an integrated and practical decision-making framework.

Research Methods

02

2.1 Type of study

This thesis addresses the following research question: “Which conditions are essential for effective circular building reuse, and how can these be integrated into a decision-making framework for the pre-project phase of building reuse?” To answer this question, the study is structured around four sub-questions:

1. How is decision-making regarding building reuse currently organized?
2. Which conditions and barriers for effective circular building methods emerge from academic literature?
3. What barriers hinder the implementation of circular building ambitions within the Netherlands Police?
4. What does an integrative framework on circular building reuse require in order to assist in the early decision-making process of building reuse?

The analysis of building reuse models and circularity assessment methods applicable to the early stages of the design process is grounded in academic literature. The selection and integration of these models are informed by interviews and insights provided by experts from the Netherlands Police, thereby giving the study an empirical dimension (Patten, 2017).

2.2 Methods and techniques

In order to answer the research question, the sub-questions should be studied first. These sub-questions all rely on different methods, which are summarized in table 1.

Table 1. Research questions and research methods

Research question	Method
1. How is decision-making regarding building reuse currently organized?	Semi-systematic literature review
2. Which conditions and barriers for effective circular building methods emerge from academic literature?	Semi-systematic literature review
3. What barriers hinder the implementation of circular building ambitions within the Netherlands Police?	Semi-systematic literature review Interviews
4. What does an integrative framework on circular building reuse require in order to assist in the early decision-making process of building reuse?	Desk research Integrative literature review Case study

2.3 Data collection

2.3.1 Semi-systematic literature review

In order to gain more knowledge on the topics of decision-making for building reuse and circular building, and to base the foundations of the interviews on academically proven facts, the first phase of the study will consist of a literature review. To get a broad understanding of the past research on these topics, and how they developed over time, a semi-systematic literature review will be done (Snyder, 2019). Like this, more possibly relevant methods of approaching challenges in building reuse or in circular building could be studied. The semi-systematic literature review of building reuse will consist of a general description of the decision-making process, specified to that of building reuse. This literature review will also contain different models to assess the success-rate of building reuse.

The semi-systematic literature review of circularity includes a more general description of the evolving importance of circularity over time, the building methods to include circularity, and different assessment methods to measure the effectiveness of circular building. Also, the literature will provide barriers of implementing circular building methods, which will be examined during the interviews.

In order to find sources for this literature review, different search strategies will be used. The majority of the literature on the topics of building reuse and circular building methods derive from articles and academic publications, which are found in search engines like Scopus and Google Scholar. These engines were provided keywords like “circularity ” AND “assessment tool ”, “circularity potential indicator ”, and “reuse ” AND “building ” AND “criteria ”. Attention was given to the publication date of the articles and to the application of the study: studies in the context of the built environment were preferred.

Some of the described tools for defining reuse potentials or for assessing circular performances are based on publications by non-academic authors, like governmental bodies or tools developed by organizations or foundations.

When relevant studies were found, additional relevant studies were identified through backward snowballing by reviewing the reference lists of the article.

2.3.2 Interviews

To gain insight into the current implementation of circular ambitions in the organization of the Netherlands Police, in-depth interviews will be conducted. Before conducting these interviews, some informal interviews are conducted, in order to establish some basic knowledge on the experiences on the topic of circularity (Dowling et al., 2015), which helped to formulate the interview questions for the in-depth interviews.

The interview will be semi-structured, making sure that certain topics are covered, but still leaving room for other relevant dimensions that could come up during the conversation (Karatsareas, 2022). The interviews aim at providing understanding on the current processes on building reuse and circular building, and more specifically on appointing barriers experienced in the implementation of circular building. These barriers will be compared to the barriers mentioned in literature. Triangulation, using multiple data sources – in this case the interview answers and literature – makes the study more credible and will provide a more complete picture on the topic (Jentoft & Olsen, 2017).

According to Kirchherr et al. (2018) and Grafström and Aasma (2021), there are four categories of barriers of implementing circularity in the built environment: technological barriers, market/economic barriers, institutional/regulatory barriers, and social/cultural barriers. These four categories are kept in mind when conducting the interviews, to secure a diversity of answers. The results of the interviews will be categorised in the same four categories of barriers.

After conducting and transcribing the interviews, they will be analysed using ATLAS.ti, to group the data in codes and to be able to compare them to each other. The codes will be partly pre-determined, like the codes on the barriers. However, due to the style of the interviews – semi-structured – not all codes can be defined before the analysis of the interviews. Therefore, some codes will arise during the analysis of the interviews, and will then be applied to all previously analysed interviews.

According to Kahlke et al. (2026), the decision about who to interview is dependent on reaching sufficient information power to answer the research question, which is dependent on the aim of the study and the way academic literature is used in the study. In this case, the aim of the interviews is to combine the barriers on implementing circularity from the literature and from the experiences by experts provided in the interviews. Therefore, the people interviewed in this study will be experts in the field of circularity, preferably people who are involved in the implementation of circular strategies within the organisation of the Netherlands Police. Table 2 presents the experts of the Netherlands Police that are interviewed for this thesis. Appendix 1 presents the interview questions that will be asked to guide the conservation.

Table 2. Job functions of the interviewees

Interviewee	Job function
INT1	Policy Department Coordinator
INT2	National Real Estate Portfolio Manager
INT3	Housing Coordinator
INT4	Sustainability Policy Advisor
INT5	Architect and Advisor

2.3.3 Integrated literature review

After the semi-systematic literature review has provided different approaches to measure the effectiveness of building reuse and of circular building, in depth interviews are conducted to find the barriers in implementing circular building within the organisation of the Netherlands Police. After this, specific models or methods on assessing the effectiveness of building reuse and circular building could be studied. An integrative literature review is used to review literature in an integrative way in order to be able to create a new framework (Toraco, 2005). Integrative literature uses the critically analysed literature to synthesize the existing ideas into a new formulation of the topic. In this case, existing literature, retrieved in the first three sub-questions, is used create combined framework that presents new knowledge of the topic.

2.3.4 Desk research

Using the secondary data from the organization of the Netherlands Police, information about the decision-making processes, building reuse, and circularity will be gathered. This will contribute to the final stage of the research, in which the combined model on building reuse and circularity will be developed. Besides, some of the developed cost indicators from the Netherlands Police will be used in the developed framework to indicate the financial feasibility and possible financial considerations. Desk research involves the analysis of institutional reports (Barbieri et al., 2025) written by the Netherlands Police. These reports will help to develop a feasible and useful decision-making framework for the Netherlands Police, that can contribute to their current policies and procedures.

2.3.5 Case study

For the final phase of the thesis, a case study is used to validate the CBR framework. Accordingly to the research of (Yunus et al., 2023), this case study serves two purposes. The first purpose is to confirm the interviews. Different interviews, and therefore different perspectives, are used to develop the final framework. The application of a case study to the framework ensures the validation within one integrated system, rather than in different interviews (Yunus et al., 2023). This case study is conducted within the organization of the Netherlands Police, to make sure the framework is applicable for the right audience. A building from the existing real estate portfolio of the Netherlands Police will be elected for this case study, ensuring the testing of the practical application of the framework, which is the second purpose of the case study. An expert from the Netherlands Police is asked to review the developed framework, where this expert was asked to give comments and suggestions for the improvement of the framework (Angkananon et al., 2013). By using a known case for the expert, the use of the framework is close to how the framework would be used in reality, and will therefore be of good use for the validation of the framework.

Literature Review

03

This chapter will introduce the general processes of decision-making. This process will then be specified to the field of building reuse, answering the first sub-question. The different stages of building reuse will be discussed, as well as the factors to take into account in the process of building reuse. Also, some tools will be demonstrated that indicate the effectiveness of building reuse projects. Finally, in order to answer the second sub-question, this chapter will define the aspects of the circular economy, and discuss the theory of the building layers. Similar to the part on building reuse, several frameworks will be presented in the field of CE that measure the circular performance of a building. This chapter will end in the description of the decision-making process of CE in building reuse, and address barriers of implementing circular building methods in practice. Consequently, the first two sub-questions will be answered in this chapter.

3.1 Decision-making

Decision-making is a term used for all processes and methods to find the right solution to a challenge. The complete process includes the generating of alternatives, choosing one of them and evaluating the outcome (Hallo et al., 2020). Delays in decision-making is one of the bigger issues in the current construction sector (Khahro et al., 2023), influencing the rest of the process. Decision-making takes place in all different stages of a construction process and a building’s lifecycle. However, Khahro et al. (2023) state that late decision-making process is an important factor in delays for the construction of projects, making it more important to speed up the process of decision-making and making it more efficient. In this paragraph, the decision-making process will be described, and it will be studied where in this process decisions and ambitions for building reuse and circularity are established.

3.1.1 The process of decision-making

Decision-making is about “generating alternatives and selecting one of those alternatives in order to prepare a suitable action” (Hallo et al., 2020, p. 3). Khahro et al. (2023) provides a general decision-making process that states seven steps of the process, shown in figure 2. This process illustrates the stated definition on proposing alternatives, selecting one of these and implementing and evaluating this alternative.

The process starts with the problem, for which alternatives will be proposed using the collected information. The information can be gathered by different actors of the project, like the client or the contractors. After the decision is taken, the chosen alternative should be implemented and monitored (Khahro et al., 2023). When another problem arises, this process starts all over again.

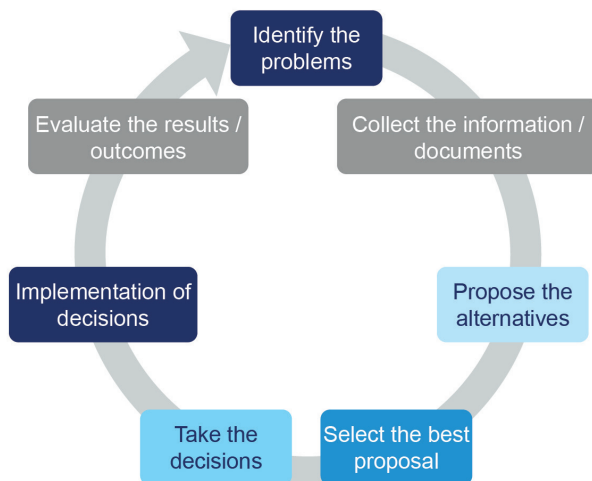


Figure 2. The general decision-making process (Khahro et al., 2023)

In a more simplified way, this process exists of four stages: information collection, decision modelling, decision making, and decision implementation (Zavadskas et al., 2008). In the first stage, after the problem is defined, the information is collected that could be useful to solve this problem, and the expected outcome of the process is established. For circular building reuse, this stage could include measuring the current condition of the building, and defining ambitions for the future (circular) condition of the building. In the second stage, decision modelling, the gathered data is analysed, after which possible alternatives can be developed to solve the problem. This could include certain design strategies, or the degree of reusing building components or materials. When the alternatives are proposed, the third stage of decision-making starts. In this stage, the best alternative will be chosen, based on the results from the previous stages. In the final stage, the decision implementation, this chosen alternative will be implemented and the results will be assessed. When this implementation appears to be unsuccessful, the process will start over at the information gathering stage.

Bakht and El-Diraby (2015) distinguishes three main components of the decision problem: decision makers, decision tools, and selection techniques. Throughout the process of decision-making, these components – with all their influential elements – should lead to a choice. The decision maker has to generate several alternatives using the information and the objectives of the project. The decision tools are the evaluation methods that measure the consequences of the proposed alternative. The selection techniques are the techniques and strategies used to come to a final best alternative when taking into account the consequences. This process is summarized in figure 3.

This topic of this research is mainly focusing on the objectives of the decision-making, referring to the aims of the decision. In the history of decision-making, the objectives have changed from technical criteria into more sustainability-influenced criteria (Bakht & El-Diraby, 2015). These aims can include ambitions on circularity or strategies based on building reuse. The objectives are the main take-aways that need to be achieved in order to select the right alternative to solve the problem, and is therefore an important factor for the decision maker to take into account.

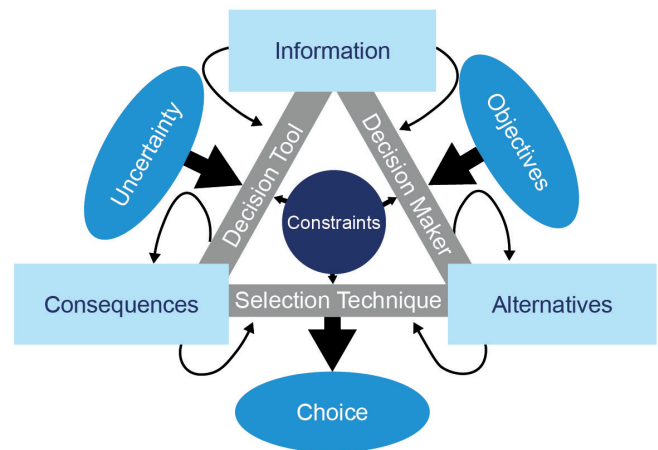


Figure 3. Components of the decision-making problem (Bakht & El-Diraby, 2015)

3.2 Building reuse

This research focuses on the reuse of existing buildings. The process of building reuse, just like any other process, includes decision-making processes, which follow the same cycle as described in the previous paragraph. This study aims at developing a framework for the early stages of decision-making in building reuse, which will therefore be the focus of this paragraph. This paragraph will provide a better understanding of the definition of building reuse and the process of building reuse. Finally, it will present some models used in the first two stages, as described by Zavadskas et al. (2008), of decision-making processes: information collection and decision modelling.

Building reuse is described as “the process of converting a building to a function which is significantly different from the original function” (Arfa, Lubelli, et al., 2022, p. 1). The conservation of existing buildings has been done for a long time in history; formerly it was done to save time, energy and money (Misırlısoy & Günçe, 2016), nowadays more benefits of building reuse are known. Building reuse not only makes sure that historic buildings are preserved (Van Laar et al., 2025) and increases the quality of neighbourhoods and their communities (Van Laar et al., 2025; Arfa, Lubelli, et al., 2022), it also has environmental benefits by extending the life of the building, which minimizes waste and emissions and preserves resources (Van Laar et al., 2025). However, building reuse is also complex due to its unpredictability (Van Laar et al., 2025) and due to the involvement of many actors and actions (Arfa, Lubello, et al., 2022).

3.2.1 The process of building reuse

According to Arfa, Zijlstra, et al. (2022), four main phases of the reuse process can be identified: the pre-project phase, the preparation phase, the implementation phase, and the post-completion phase. As mentioned in the research, decision-making is a more repetitive aspect in the first two phases, while the design is still developed. Especially in the first phase, the pre-project phase, decisions are made on the future existence of the building, and the goals and ambitions are set for the project.

In the pre-project phase – also known as the initiative phase – the main focus is on the question whether the building should be preserved, reused or demolished (Arfa, Zijlstra, et al., 2022). This is the first decision-making moment of the process of building reuse, in which there are several factors that will affect whether the reuse project will be successful, which will be described in more detail in the next paragraph. The pre-project phase is the main phase of this research, as in this phase the first design briefs are developed, that include the overall ambitions for the project, including the ambitions based on circular building reuse. Including a framework that can help establish these ambitions in a realistic manner will help to better define the project scope.

As the initiative of the project has been established, the second phase begins, which is the preparation phase. This phase is different from regular building processes, as with adaptive reuse a process starts with an existing building. This building and its surroundings should be properly analysed in order to start designing (Arfa, Lubelli, et al., 2022). Different categories of analyses have been studied, which all contain slightly different types of analysis. All studies include the architectural analysis of the building itself, as well as urban analysis of the environment of the building. Within these analyses, more detailed analyses can be performed, like technical analyses, historical analyses, and functional analyses (Arfa, Lubelli, et al., 2022). At the end of the preparation phase, the design strategy is defined and the third phase can start: the implementation phase. In this phase, the design strategy will be implemented. Generally, it can be stated that the longer and more detailed the

first two phases have been executed, the shorter and less complex the implementation phase will be (Arfa, Lubelli, et al., 2022). In this phase, the costs of the project, time management, and the expertise of the executive team are important factors to keep in mind. Finally, after completion of the project, the post-completion phase will begin, which is the last phase of the building reuse process. Maintenance of the building will ensure the long-term quality of the building and its services. Besides, a while after the completion of the project, as post-occupancy evaluation (POE) should be carried out, to evaluate the successes and failures of the project, and to identify improvements for future projects (Arfa, Lubelli, et al., 2022).

3.2.2 Early decision-making for building reuse

For this research, the phases in which the decisions are made for the ambitions on circular building reuse are studied. Research by Zulkanain et al. (2022) presents all factors that affect the decision-making process of building reuse. These factors can be used for all building typologies, and all have an impact on the process of building reuse. Based on the client of the project, and the characteristics of the project, these factors will all have a different importance.

1. Actors

The actors, everyone that will impact the decision for the future use of the building, should be properly defined, as they change in every project. They can be part of four categories of actors: users, producers, investors and regulators (Mısırlısoy & Günçe, 2016). The actors are the main factors impacting the decision-making process.

2. Adaptive reuse potential

The adaptive reuse potentials are essential in defining the sustainability goals of the building. This potential can be measured on multiple levels of the building. Different tools to measure the adaptive reuse potential are discussed later in this chapter.

3. Regulation and legislation

Regulations – standards and purposes used to influence the behaviour of the actors – and legislation – rules, regulations, and laws, developed by authorities – are there to make sure existing buildings will perform on a certain level.

4. Economic

Just like in any other project, the building reuse process is very dependent on the available money for the project. The price of new construction can be higher than the price to transform an existing building into a new function, but this is dependent on other factors within the project.

5. Location

The location and accessibility of a building is determining for the future use of the building. Depending on the function of the building, other aspects of the location will be important to keep in mind.

6. Architectural value

Reusing old buildings for new functions might need changes in the building's architectural characteristics. However, the historic values should be taken into account in this process, in order to preserve the complete context of the building.

7. Environment

Demolishing a building has negative influences on the environment, and for constructing new buildings, a lot of raw materials and energy is used. For building reuse, both these processes are not, or little, needed. However, still resources are used and waste is created. These environmental impacts should be taken into account in the process of building reuse.

8. Social and culture

The impact of the building reuse process on the society should be considered, since it is positive if it aligns with the wishes or requirements of the surrounding population. New functions can disrupt the population socially and culturally, which this is an important factor to take into account.

Using similar factors as described by Zulkanain et al. (2022), research by Mısırlısoy and Günçe (2016) presents a step-by-step consideration of factors for the decision-making process of building reuse of heritage buildings. This approach includes: defining the actors; analysing of existing fabric; deciding on the conservation actions; defining the adaptive reuse potentials; and deciding on the functional changes. Defining the actors, as described in the previous paragraph as well, is the first step. The second step is analysing the existing fabric, existing of different aspects that including identifying the original function of the building, the physical character, and the needs of the district. In the third step, the conservation actions should be decided, which is directly affected by the previous analysis of the existing fabric. After this, the adaptive reuse potentials of the building should be identified. These potentials – categorized by physical, economic, functional, environmental, political, social, and cultural potentials – will help to develop the strategies for the building process. In this

step, it will be decided which degree of building reuse is possible for this building. Lastly, the decision on the new function can be made. The decision will depend on the evaluation of all the previous steps (Misırlısoy & Günçe, 2016). For this research, especially the fourth step is interesting: defining the adaptive reuse potential, since this can provide a prediction on the effectiveness of (circular) building reuse.

Geraedts et al. (2025) developed a framework, the transformation meter, that introduces the use of ‘veto criteria’ as the first step in the decision-making process of building reuse. These criteria are developed to make a first quick assessment of the building and evaluate if building reuse is feasible for this building (Wilkinson et al., 2014). These ‘veto criteria’ exist of four categories: market, location, building, and organisation/actors. The criteria within these factors could be based on legal requirements, but also on client-specific requirements, meaning the client is free to add or leave out certain criteria. When these ‘veto criteria’ are not met, the process of reusing this building will probably not be possible, meaning the client does not have to proceed further research (Geraedts et al., 2025). The ‘veto criteria’ as used in the transformation meter are presented in table 3. The use of, a kind of, ‘veto criteria’ within any other framework or model for decision-making processes, could be advantageous for the efficiency of the process, leaving out unnecessary research when the building reuse is likely to be unfeasible.

Table 3. Veto criteria as used by Geraedts et al. (2025)

Category	Veto criteria
Market	<ul style="list-style-type: none"> • Demand of housing for local target groups
Location	<ul style="list-style-type: none"> • Zoning plan change permit • No health risks from odour, noise, pollution
Building	<ul style="list-style-type: none"> • Free ceiling height > 2,60 m
Organization / actor	<ul style="list-style-type: none"> • Presence of enthusiastic initiator with influence • Meets the requirements regarding location and accessibility • Meets the requirements regarding the size and character of the building • Willingness to sell the building • Positive attitude towards conversation

3.2.3 Decision-making tools for building reuse

There are several tools or models that can be used in the decision-making process for building reuse, that can indicate the effectiveness of building reuse projects. For this research, some of the methods that are applicable to the pre-project phase of the decision-making process are identified and studied in more detail. In the results section of this research, one of these models will be elected, based on the challenges and needs of the Netherlands Police. Some models are summarized in table 4 and will be further discussed in this paragraph.

Table 4. Decision-making tools for building reuse

Model	Pros	Cons	Source
ARP model	<ul style="list-style-type: none"> • Can be used at any point of time • Can be used for any building typology • Little quantified data is needed • Includes a broad variety of categories scored • Is able to rank buildings based on the useful life 	<ul style="list-style-type: none"> • Very broad model • Complex calculations 	(Conejos et al., 2013); (Langston et al., 2008); (Pourebrahimi et al., 2023)

Table 4 (continued). Decision-making tools for building reuse

Model	Pros	Cons	Source
adaptSTAR model	<ul style="list-style-type: none"> • Suitable for pre-project phase • Includes a broad variety of design criteria • Can be used in two ways: one more general and one more detailed • User-friendly model • Can be used for any building typology 	<ul style="list-style-type: none"> • The categories are weighted scores • Focus is mainly on adaptability of buildings 	(Conejos et al., 2013); (Conejos et al., 2014); (Sharifi & Farahinia, 2020)
iconCUR	<ul style="list-style-type: none"> • Can be used at any point of time • Simplifies a lot of factors into three categories (condition, utilization, reward) • Can be used for any building typology • Is able to score and rank buildings 	<ul style="list-style-type: none"> • Needs quantified data, and is therefore a time-consuming model 	(Langston & Smith, 2011)
Transformation meter	<ul style="list-style-type: none"> • Covers the whole process of building reuse • Includes a broad variety of criteria (including veto criteria) • Mostly based on qualitative data • User-friendly model 	<ul style="list-style-type: none"> • Time-consuming when used as a whole • Initially developed for the transformation office-housing 	(Geraedts et al., 2025); (Wilkinson et al., 2014)

The Adaptive Reuse Potential model

A method for assessing the potential of building reuse is the Adaptive Reuse Potential (ARP) model. The method is based on the fact that, according to Wilkinson et al. (2014), buildings deteriorate and will eventually become obsolete. The framework considers the current and expected life of the building in years (Langston et al., 2008), as well as an estimation of the physical, economic, functional, technological, social, legal, and political obsolescence (Wilkinson et al., 2014). Building obsolescence is the decrease of the functioning of a building due to varying factors (Pourebrahimi et al., 2023). All these seven obsolescence factors are used to calculate the useful life of the building, resulting in an index of reuse potential as a percentage (Langston et al., 2008). The seven obsolescence types, as described by Pourebrahimi et al. (2023), are summarized in table 3. Using the ARP method, existing buildings within an organization's portfolio can be ranked based on the adaptive reuse potential. The model also provides a timeframe in which the intervention should take place, based on the current building age and the expected useful life (Wilkinson et al., 2014).

Table 5. Building obsolescence types (Pourebahimi et al., 2023)

Obsolescence	Description
Physical	The loss of quality of a building, resulting in loss of utility.
Economic	There is a mismatch in incomes and costs, meaning the owner cannot get enough rate of return from operation anymore.
Functional	The building is no longer useful or effective.
Technological	The building (components) are no longer technologically favourable.
Social	The building is no longer useful due to changes in social needs.
Legal	The building no longer meets the legal requirements.
Political	Political interference on the building increases/decreases the useful life.

The adaptSTAR model

Just like the ARP model, the adaptSTAR model measures the adaptive reuse potential of a building (Sharifi & Farahinia, 2020). The adaptSTAR model is a weighted checklist, based on the seven obsolescence types of the ARP model (Conejos et al., 2014). Within the seven main criteria, 26 sub-criteria are established, each being assigned a percentage as well, adding up to a total score of 100%. The model can either be used by only using the seven general design criteria, or in a more detailed way by using the 26 sub-criteria (Sharifi & Farahinia, 2020). After the assessed project is scored, the scores will result in a building rating. The ARP model could be seen as the foundation of the adaptSTAR model, which is focused on optimizing design strategies (Conejos et al., 2013). Therefore, it is best to use the adaptSTAR model only after completing the steps of the ARP model.

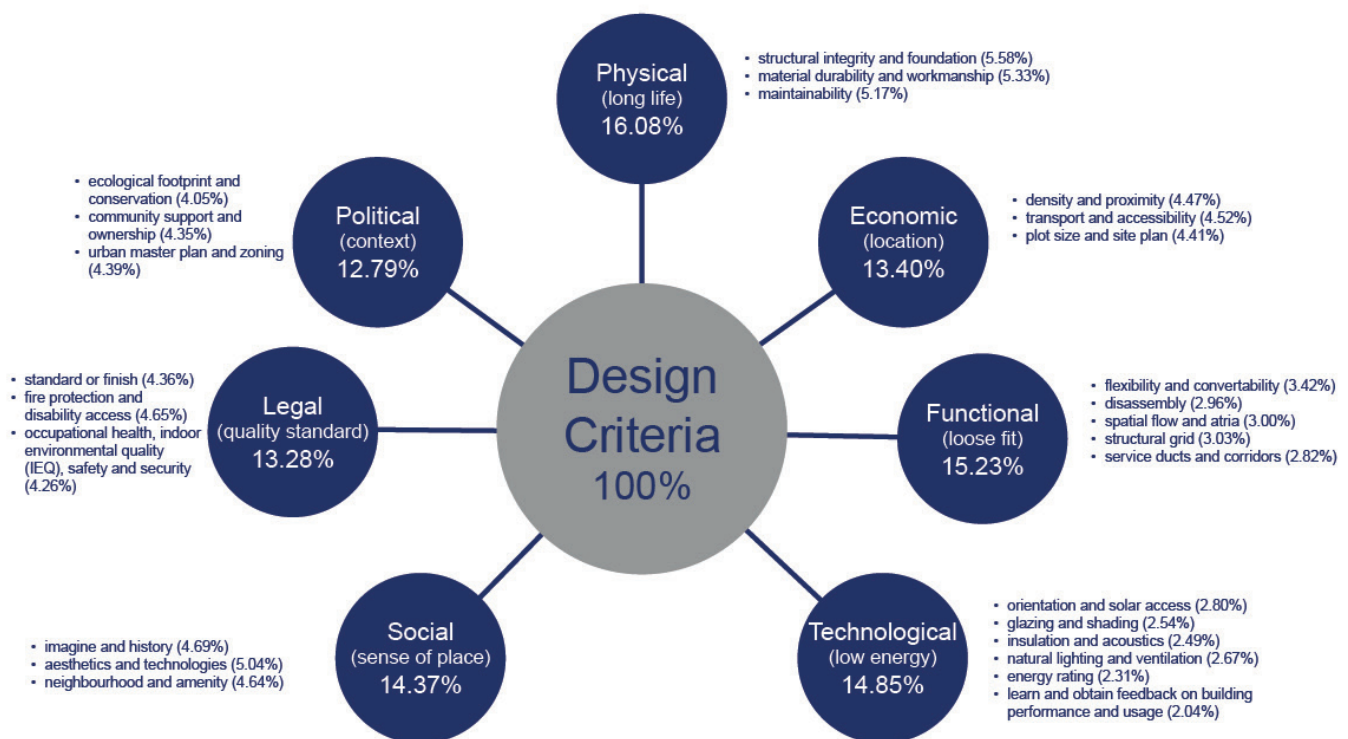


Figure 4. The adaptSTAR model (Conejos et al., 2014)

iconCUR

The iconCUR is a decision-making tool to define the condition of a building. The tool uses the criteria of condition, utilization, and reward, which are quantified in a worksheet and are provided a score. The criteria condition and utilization are measured on a scale from 0 (low) to 5 (high), whereas the criteria reward measures the feasibility of the intervention. After filling in the model, a type of action will be recommended, for example reuse/adapt or renovate/preserve (Langston, 2013). The placement on this matrix is determined by quantitative data on the building.

Transformation meter

The transformation meter, developed by Geraedts et al. (2025), is a tool that measures the potential for transforming office buildings into housing (Wilkinson et al., 2014). This model is based on the factors that influence the success of this transformation: the duration of the vacancy, the cause of vacancy, and the municipal policy. The transformation meter exists of five steps (Geraedts et al., 2025):

0. Inventory of vacant offices

1. Quick scan: evaluation of adaptive reuse potential based on veto criteria

This scan is based on nine veto criteria within four categories – market, location, building, and organisation/actors. When one of these criteria is not met, the transformation is almost impossible.

2. Quick scan: exploration of financial feasibility

This step evaluates the financial feasibility of the project, as a project is not likely to succeed when the project is hardly profitable.

3. Evaluation of location and building based on gradual criteria

In this step, a more detailed scan will provide possible opportunities and challenges for the further process. The criteria are divided into two categories: the building location and the characteristics of the building itself. Criteria for the building location includes, for example, the accessibility, the physical characteristics of the environment, and the technical aspects of the environment, like sun exposure and the air quality. Criteria for the building itself include the current technical aspects of the building, like the dimensions, the quality of the structure, and the installations, as well as reuse opportunities of the building, like the opportunity of expanding the building.

4. Determination of transformation class

Based on these criteria, the transformation class can be determined. This is based on the scores, and indicates how well the building is able to be transformed.

5. Risk inventory checklist

Finally, the potential risks and solutions will be defined. This is done within the categories of market and location, and of the building itself.

The transformation meter is a step-by-step approach to find the potential of an office building to be transformed into housing, requiring mainly qualitative data. It takes into account a lot of aspects of the process, making it both a complete model and a time-consuming model. The model is initially developed for the transformation of offices to housing, but the format could be adapted to the transformation of other functions.

To conclude, there are several models or tools that indicate the effectiveness of building reuse. The models described in this chapter are all applicable to the early stages of decision-making, but all have their own focus or emphasis on a particular part of the decision-making process. This chapter described the process of building reuse, and how certain tools can be used to identify reuse potentials. This study, however, aims at including a focus of circular building in the reuse of existing buildings. The next paragraph will explain more about the CE and its application in the built environment. Compared to the paragraph on building reuse, this paragraph on circularity will also provide some relevant tools or models on the assessment of circular building strategies.

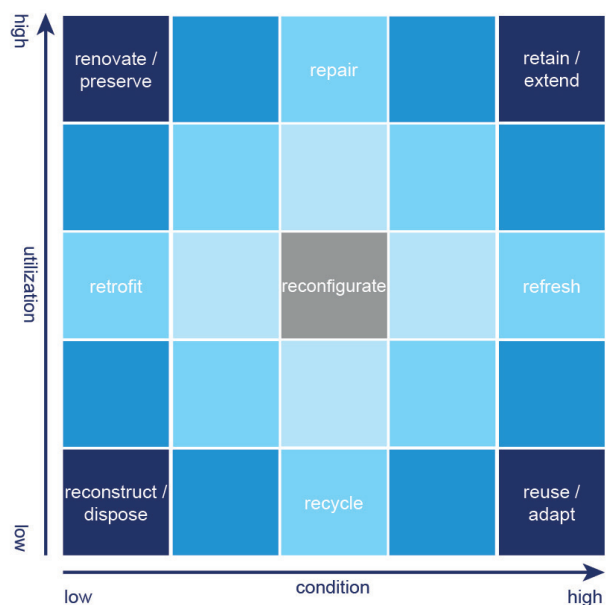


Figure 5. 2D matrix of the iconCUR model (Langston, 2013)

3.3 Circularity

Akhimien et al. (2020, p. 4) defines circular economy (CE) in buildings as “a strategic programming of a building to easily change its configuration for longevity and potentially be susceptible to the loop of reduce, reuse and recycle for resource efficiency” . Reduce, reuse, and recycle are part of the value retentions processes (VRPs), which are developed to implement circular economies and maintain the value of the materials for as long as possible (Eberhardt et al., 2021). Reduce is about minimizing the use of materials, reuse is about using materials multiple times in its original function, and recycle is about processing end-of-life materials in new products (Van Stijn, 2023).

According to Motiei et al. (2024), effective circular building (CB) development should include three dimensions: resource management, design management and collaboration management. Resource management is about the building materials, the energy and the water, and how these resources are being used throughout the building process. The collaboration among the stakeholders, sharing of knowledge and educating others on CB development is part of collaboration management. Finally, design management focuses on the decision-making actions in the design process, based on three main factors: CB loop, tools and digitalization. As described by Van Stijn (2023), slowing, closing and narrowing loops are ways to reach the goals of CE. Slowing loops is about extending the life of materials, so less resources are needed. Closing loops is about recycling materials when they reach end-of-life. Narrowing loops is about minimizing the use of materials. CB development incorporate these loops in the design, wherein multiple loops can be used within one process (Motiei et al., 2024). The different loops are related to the VRPs mentioned before, their connections are described in table 6.

Table 6. The correlation between VRPs and CB-loops

VRP	Description	Loop
Reduce	To minimize the use of materials.	Narrowing loop
Reuse	Extending the life of a material, by reusing the material for its original function.	Slowing loop
Recycle	Processing end-of-life materials.	Closing loop

3.3.1 Shearing layers

Reusing a building is done throughout the different layers of a building. In the book ‘How Buildings Learn: What Happens When They’re Built’, Brand (1995) explains the concept of the shearing layers. He states that buildings exist of six different layers (the six S’s), that all have a different rate of changing. Each of these layers – site, structure, skin, services, space plan, and stuff – have their own lifespan, and can operate independently (Friedman, 2025). The lifespan of the layer is also influenced by the use and context of the building (Urquhart et al., 2019). For example, the stuff in a highly occupied office will be changed more often than the stuff in a home. This does not only give insight into how the building works, but also has the intention to present that layers with a shorter lifespan does not have to limit the layers with longer lifespans (Davis et al., 2024), since they all operate apart from each other. According to Friedman (2025), the layers can be divided into long-lasting layers (site, structure, and skin) and short-lasting layers (services, space plan, and stuff). The short-lasting layers change more often and have little impact on the long-lasting layers. The other way around, interventions to the long-lasting layers do have an impact on the short-lasting layers.

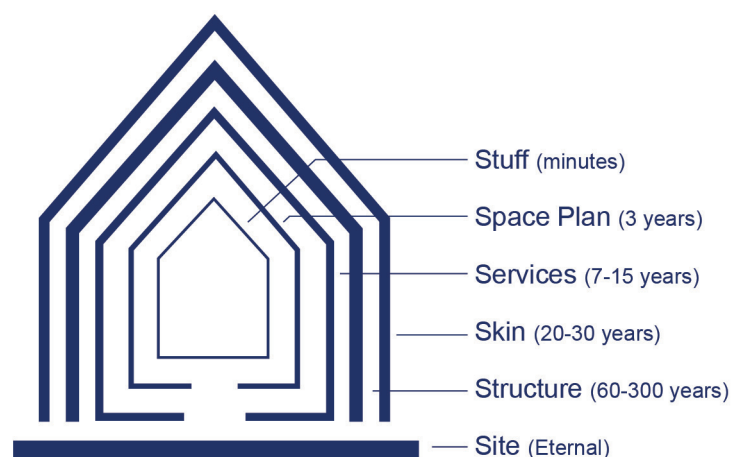


Figure 6. The shearing layers of Brand (adapted from Urquhart et al., 2019)

3.3.2 Decision-making tools for circularity

In the field of CE, there is an increasing number of assessment tools to measure the circular performance of a building (Corona et al., 2019). However, most of them are evaluation tools which can be used after the completion of the building. This study focuses on the early stages of decision-making processes, in which the building is not designed yet and therefore circular performances of the building are not yet possible to measure. In this paragraph, several models will be discussed that identify the circular potential of buildings. Corresponding to the previous paragraph on building reuse, one of these models will be chosen to continue working with in this research.

Table 7. Decision-making tools for circularity

Model	Pros	Cons	Source
Circular Flow	<ul style="list-style-type: none"> Identifies potential CE-related opportunities Broad model: can be used for strategic decision in different sectors 	<ul style="list-style-type: none"> Process-based: little implemented on single projects Focus on organizational flows and ambitions Time-consuming and requires a lot of quantitative data 	(Barros et al., 2023)
Building Circularity Index (BCI)	<ul style="list-style-type: none"> Includes different layers: products, elements, and the building itself Defines the circular potentials of buildings in an early design stage 	<ul style="list-style-type: none"> Calculated using a lot of different formulas and quantitative data 	(BCI Gebouw & Alba Concepts, 2022)
Design for Disassembly (DfD)	<ul style="list-style-type: none"> Qualitative assessment method Focus on reuse of elements or products of the building Creates more independence for buildings 	<ul style="list-style-type: none"> More easy applicable to new constructions Related to the EoL stage 	(Motiei et al., 2024); (Tsoka & Tsikaloudaki, 2025)
Design for Adaptability (DfA)	<ul style="list-style-type: none"> Qualitative assessment method Main aim is flexibility: in use and in space Commonly used in building reuse Considerable strategy in pre-design phase Can be applied to all building layers 	<ul style="list-style-type: none"> Little focus on material flows More a strategy than an assessment method 	(Motiei et al., 2024); (Tsoka & Tsikaloudaki, 2025)
ReSOLVE framework	<ul style="list-style-type: none"> Can be implemented in different sectors and scales Considers all building layers No quantitative data needed 	<ul style="list-style-type: none"> No scoring included in the framework 	(Lucas & Löscke, 2024); (Ellen MacArthur Foundation, 2015)

Circular Flow

The Circular Flow tool (Barros et al., 2023) is developed to identify opportunities in integrating circular economies in companies processes. The tool aims at closing the loops of external flows, and therefore becoming more independent. Circular Flow calculates the CE in an organization in percentages, using an equation that takes into account the inflow and outflow of internal and external processes. It can be used to calculate any process in the organization, which makes it possible to find specific processes that need improvement to in-

crease the circularity performance. The tool is developed to internalize flows within an organization, but can be applied in any sector, including real estate.

Building Circularity Index

The Building Circularity Index (BCI) is a method developed by BCI Gebouw and Alba Concepts (BCI Gebouw & Alba Concepts, 2022). The calculation method is developed in order to distinguish circular ambitions of buildings in an early stage of the design process. The BCI is a combination of the existing CE assessment methods on material use and detachability, leading to five separate scores. All these scores are gathered in the BCI calculation to present one final score on the overall building circularity. Due to the diversity of the BCI, nearly all layers of a building – as described by Brand (Brand, 1995) – are taken into account in this score, except the ‘site’ and ‘stuff’.

Design for Disassembly

Design for Disassembly (DfD), as described by Motiei et al. (2024), is a design strategy for circular building processes, with the aim of building demountable buildings. This design strategy is closely related to the end-of-life stage of the building, where the reuse or recycling of building elements or products will happen. This design strategy makes the building less dependent on new materials, as the loops are closed by recycling end-of-life materials. DfD can be applied at different levels: material reuse/recycling, component reuse, and building relocation (Tsoka & Tsikaloudaki, 2025), making the strategy widely applicable.

Design for Adaptability

Adaptability in the built environment is about buildings responding to certain changes (Tsoka & Tsikaloudaki, 2025), providing flexibility in the building layout, which can expand the useful life of a building (Motiei et al., 2024). Common reasons for changing the building are obsolescence of the building, a new function of the building, and other social or environment changes (Tsoka & Tsikaloudaki, 2025). A design-based strategy for implementing DfA is designing according to the shearing layers models of Steward Brand (Tsoka & Tsikaloudaki, 2025), implicating that all the layers of a building operate apart from each other (Friedman, 2025), making adaptability more easy.

ReSOLVE framework








The ReSOLVE framework is a CE framework developed by the Ellen MacArthur Foundation (EMF) in 2015, and is designed for businesses to implement circular principles into their organization (Lucas & Lösckke, 2024). It includes six actions to take into account for implementing circular ambitions: Regenerate, Share, Optimize, Loop, Virtualize, and Exchange. Ellen MacArthur Foundation (2015) describes the “six actions to transform the built environment” as presented in table 8. This framework does not provide a calculation or scorecard to measure exact numbers on circularity, but it does provide a broad vision on applying circularity in the built environment.

Table 8. Actions from the ReSOLVE framework (Ellen MacArthur Foundation, 2015)

ReSOLVE	Action
Regenerate	Regenerate and restore natural capital
Share	Maximise product utilisation
Optimize	Optimise system performance
Loop	Keep components and materials in closed loops and prioritise inner loops
Virtualise	Deliver utility virtuality
Exchange	Select resource input wisely

Adapting the ReSOLVE framework to a context that is more building-related, Arup (2016) combined the building layers, as described before, with the actions provided by the ReSOLVE framework. Additionally to the six layers of the building delivered by Brand (1995), (Arup, 2016) adds one more layer: system. This layer includes the broader environment of the building; the context of the city. In table 9, the design actions, specified to the built environment, per building layer are presented, following the six factors of the ReSOLVE framework.

Table 9. ReSOLVE actions within the building layers (Arup, 2016)

	Regenerate	Share	Optimize	Loop	Virtualise	Exchange
System 	Extracting and reuse of biological resources via anaerobic digestion to create and supply energy onto the grid	Sale of energy back to the grid	Optimisation of transport links between built assets. Integration of low carbon systems. Designing out waste strategies	Renewable and circular resource flows. Adapt use over time	Virtual/digital storage via cloud systems. Smart systems to improve systems integration	Integrated circular city design approach
Site 	Detoxify and regenerate brownfield land to revive the biosphere	Online platforms to facilitate space sharing. Open source data platforms for sharing designs	Use of localised renewable energy sources and distributed networks	Retrofit and reuse existing buildings and assets for different uses	Open source design via openly accessible online platforms	Construction using alternative sustainable and low impact materials
Structure 	Nature-based design solutions. Low impact materials, design and construction	Reuse of structural elements of buildings	Design for longevity and adaptability	Design for disassembly. Regeneration of buildings for mixed use	Internet of Things / ICT / BIM to monitor performance and facilitate maintenance and repair	Use sustainable materials and approaches
Skin 	Integration of green walls and surfaces. Extraction of green walls for composting and reuse	Pool or share assets, equipment and personnel. Design for disassembly	Leasing of facade in performance based contracts	Modular design and off-site prefabrication	BIM to monitor performance and facilitate repair	Integration of bio-facades
Services 	AD recycling biological nutrients and biogas	Reuse of building components	Leasing of lighting and energy. Sensor-based lighting	Open design and operating standards. Rainwater harvesting, grey water recycling, battery storage on-site	Smart sensors. Monitor and deliver maintenance services remotely	Shift to services over ownership. Internet of Things. LED light replacement
Space 	Use biodegradable and compostable materials	Maximising space utilisation	Design for flexible use. Maximise use of daylight and natural ventilation	Remanufacturing of products and components	Video and virtual conferencing	Natural lighting and ventilation solutions
Stuff 	Use biodegradable and compostable materials	Maximising space utilisation	Design for flexible use. Maximise use of daylight and natural ventilation	Remanufacturing of products and components	Video and virtual conferencing	Natural lighting and ventilation solutions

In conclusion, these models all include tools that can be used in the early stages of the decision-making process to implement circularity in the building. All models are applicable to building reuse as well. Building reuse on its own is a way to implement CE strategies in the built environment. However, this study aims at developing a more detailed framework for the circular potential of buildings on all building layers. The discussed models provides these deeper insights, and when combined with a model from building reuse, it can result in a combined decision-making tool for circular building reuse.

3.3.3 Circularity in building reuse

Reuse of buildings is one of the value retention processes (Eberhardt et al., 2021). Reuse helps in reducing the inputs of resources, reduces waste, and creates less emissions (Van Laar et al., 2025). There are several benefits of the reuse of existing buildings, among which economic factors, social factors, cultural and historical factors, environmental factors, and organizational factors. Aigwi et al. (2023) and Rakhshan et al. (2020) both found that reuse stimulates economic benefits, mainly due to the reduction of costs due to the reuse of components. Also, the construction time of the building will be shorter than in the case of demolition and construction of a new building (Aigwi et al., 2023). Social factors of building reuse include improvement of the quality of life (Aigwi et al., 2023) and the understanding of the citizen’s concerns on sustainability (Rakhshan et al., 2020). Aigwi et al. (2023) mentions the factor of culture and history, which is about preserving the identity of an area by reusing existing buildings. Environmental factors of reuse are about energy efficiency, waste reduction and lower embodied energy (Aigwi et al., 2023 & Rakhshan et al., 2020). These benefits will improve the building performances (Aigwi et al., 2023). Finally, Rakhshan et al. (2020) also mentions organizational benefits of reuse. Mainly, organizations will improve competitiveness to showcase their circular building methods in reuse.

3.3.4 Barriers of implementing circularity

Besides all the well-developed frameworks and tools for circularity, there are also challenges when it comes to building circular buildings. According to Kirchherr et al. (2018) and Grafström and Aasma (2021), there are four categories of barriers of implementing circularity in the built environment: technological barriers, market/economic barriers, institutional/regulatory barriers, and social/cultural barriers. These barriers are summarized in table 10. These barriers describe a broad variety of factors, that can be included in any stage of the building process.

Table 10. Barriers of implementing circularity (Kirchherr et al., 2018 & Grafström and Aasma, 2021)

Category of barrier	Example of barrier
Technological barriers	<ul style="list-style-type: none"> Limited circular design Too few large-scale demonstration projects Lack of data, e.g. on impacts Ability to deliver high quality remanufactured products
Market / economic barriers	<ul style="list-style-type: none"> Low virgin material prices High upfront investment costs Limited funding for circular business models Limited standardization
Institutional / regulatory barriers	<ul style="list-style-type: none"> Obstructing laws and regulations Lack of global consensus Limited circular procurement
Social / cultural barriers	<ul style="list-style-type: none"> Lacking consumer interest and awareness Hesitant company culture Operating in a linear system Limited willingness to collaborate in the value chain

The Netherlands Police

04

This thesis is written in collaboration with the Netherlands Police. The developed framework is based on the experienced barriers of implementing circular ambitions within the organization. Consequently, the framework is adjusted to these specific organizational characteristics. Therefore, this chapter introduces the background information on the organization of the Netherlands Police, required to understand the context of the thesis and the CBR framework, and to answer the third sub-question.

4.1 The Netherlands Police

Since 2013, the Netherlands Police has merged into one organization, developing and maintaining one real estate portfolio (Nationale Politie, 2023b). The real estate portfolio of the Netherlands Police currently exists of around 1.890.000 m², divided into four segments: offices, police stations, special-use buildings, like prison cell complexes and emergency communication centres, and the remaining built environment. The division of the building stock by segments is presented in table 11, with the aim to reduce this portfolio size to 1.520.000 m².

Table 11. Portfolio size of the Netherlands Police per segment (Nationale Politie, 2023d)

Segment	Current portfolio size (in m ²)	Target portfolio size (in m ²)
Offices	692.000	403.000 - 535.000
Police stations	393.000	222.000 - 512.000
Specials	545.000	304.000 - 542.000
Remaining	262.000	262.000
Total	1.890.000	1.210.000 - 1.851.000

In the report by Nationale Politie (2023b), it is mentioned that there should be a good balance between the “long-term ambitions” and the “short-term feasibility”, in order to realise the strategic aims of the organisation and to gain control over the portfolio. The accommodation vision (huisvestingsvisie) describes the long-term visions and ambitions of the real estate portfolio (Nationale Politie, 2023b). The document on the target portfolio (streefportefeuille) defines the future of the portfolio based on the size, the locations, the quality, et cetera. Finally, the real estate strategy (vastgoedstrategie) describes the process towards this future portfolio (Nationale Politie, 2023d).

4.1.1 Long-term vision

The aim of the real estate portfolio of the Netherlands Police is that it will be qualitative, affordable, and feasible, while always supporting the services and working processes of the police (Nationale Politie, 2023b). However, the current size of the portfolio is too big, and the organisation aims at disposing around 370.000 m² of the built environment (Nationale Politie, 2023d). Due to rising costs for the portfolio (Nationale Politie, 2025b) and a changing need for working environments (Nationale Politie, 2023b), this leads to a shift in the goals of the portfolio. In the report by Nationale Politie (2023c), the goals of the portfolio are described:

1. Efficient use of accommodation (efficiënter huisvesten)
2. Sustainability in line with national government policy (verduurzamen in lijn met rijksbeleid)
3. Realistic and feasible pace of renewal (reëel en maakbaar vernieuwingstempo)
4. Manageable operation costs (beheersbare exploitatiekosten)
5. Appropriate quality (passende kwaliteit)

These goals include the decrease in the size of the portfolio to 1.520.000 m², focus on the (re)use of the existing portfolio (Nationale Politie, 2023d): including the improvement of the quality of the accommodations, and the sustainability of the buildings (Nationale Politie, 2023c).

To realise these goals, different strategies are developed based on the different segments of the portfolio (Nationale Politie, 2023d), these are shown in figure 7.

The first strategy, developed for the police stations, is called **optimizing when opportunities arise** (optimaliseren op natuurlijke momenten). It focuses on the decrease of space and maintenance interventions happening at times at which regular maintenance was planned. These interventions are aimed at improving quality, technical aspects and sustainability in the buildings. Standardizing the interventions and the products could help to reduce the effort it takes.

Densification and standardization (verdichten en standaardiseren), the second strategy used for the offices, has the main aim at highly reducing the amount of space used for this segment. By building new office buildings in a flexible and standardized way, the development can be marked-based and this part of the portfolio can be optimized.

The third and fourth strategy are both developed for the portfolio segment of the special-use buildings. The third strategy, **asset-based quality improvement** (objectgerichte kwaliteitsimpuls), is written for the part of this segment that has a strong local orientation, like prison cell complexes. In this segment, the portfolio stock will remain the same, and the focus will be put on future-proofing the buildings, mainly using renovation. To renovate within a short timeframe, standardization can be used.

The fourth strategy, **quality improvement through national-level optimization** (kwaliteitsimpuls door landelijke optimalisatie), is developed for the special-use buildings without a strong local orientation, like police emergency communication centres. Within this segment, the primary process of the services is the main priority. Standardization can be used to make sure the interventions run smoothly and timely. For offices within this segment, the same strategy – densification and standardization – as for the other offices can be used.

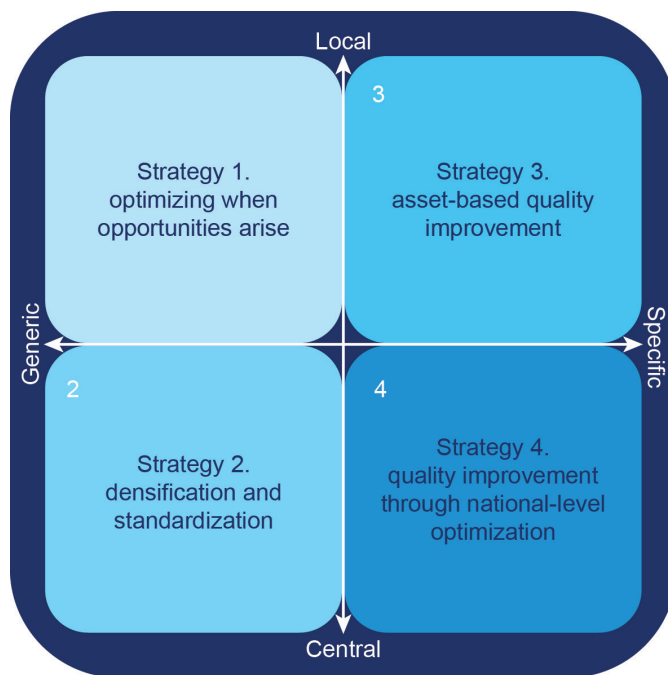


Figure 7. Four strategies of the Netherlands Police, based on the portfolio segments (own work, based on (Nationale Politie, 2023d))

In the document by Nationale Politie (2023d), a graph, shown in figure 8, is presented with the prioritization of strategies based on the impact and the effort. The strategy for the police stations – optimizing when opportunities arise – seems to have low priority due to its low impact. The strategies of the special-use buildings – asset-based quality improvement and quality improvement through national-level optimization – have a large impact and take a bigger effort. Therefore these are categorised as ‘large projects’, due to the difference in functionalities of the buildings and the short timeframe given for interventions.



Figure 8. Prioritising the strategies based on their impact and effort (Nationale Politie, 2023d)

4.1.2 Building reuse

It is part of the strategy of the Netherlands Police to reuse more existing buildings (Nationale Politie, 2023d). This could either be buildings that are already in their portfolio, or they can buy or rent the property to reuse the building. In the strategies of the Netherlands Police per portfolio segment, the strategies for police stations and the special-use buildings include the improvement of existing buildings to make them more future-proof (Nationale Politie, 2023d).

Toolbox adaptability of Police buildings

The Netherlands Police developed a toolbox: the Toolbox for Adaptability police buildings (Toolbox adaptief vermogen politiegebouwen) (Nationale Politie, 2021), which presents the relevance of adaptive buildings and tools for making adaptive buildings. It mentions the importance of adaptive buildings so that buildings can be reused more easy. In this document, they say a building is adaptive when it responds well to changing and unforeseen needs.

Comparable to the Shearing Layers of Brand (Brand, 1995), this toolbox distinguishes six layers of a building, that all have their own lifespan (Nationale Politie, 2021). These layers differ slightly from the layers of Brand, but the aim of the layers theory is comparable: the layers operate on their own, so the total lifespan of the building is not dependent on one single layer.

The **environment** of the building includes availability of transportation possibilities, facilities and parking. Also non-physical characteristics like social security and noise pollution affect the adaptability of the building. The land the property is built on, the **plot**, highly influences the adaptability of the building. Compact buildings can create space for expansion of the building, and by clustering functions in the building, the flexibility in expansion/downscaling is increased. The **structure** of the building includes the construction, floors, cores of the building and riser shafts. Open-space structures, like columns, increase the flexibility of the building. The **skin** has different requirements per function of the building, for example on isolation and ventilation. The skin should be adaptable for changing functions. **Services** can add to the adaptability of the building by being accessible. Service shafts and other rooms for services should be spacious enough to foresee future changes. Finally, the **interior elements** of the building include both the interior walls, furniture and sanitary facilities. These elements should be detachable to ensure the adaptability of the building.

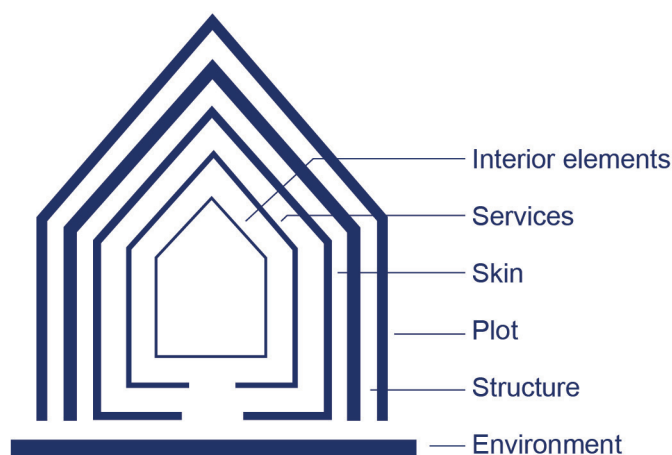


Figure 9. Building layers according to Nationale Politie (2021)

4.1.3 Circularity

Currently at the Netherlands Police, the inclusion of circular building is mentioned as an ambition rather than as a requirement. The preference of reusing existing buildings (Nationale Politie, 2023d), as mentioned before, is a circular ambition that provides a firm foundation for further circular developments. However, most aims for circularity are developed at portfolio-level (Nationale Politie, 2023a).

Nationale Politie (2023a) describes the ambitions of the Netherlands Police on sustainable development of their real estate portfolio. In the near future, they have two formal checkpoints: one in 2030 and one in 2050. In 2030, the aim is to have a 60% CO2 reduction compared to 1990, and 60% of circular material use. For 2050, the Netherlands Police aims at a 100% for both these topics.

For the topic of circularity, this document presents four ambitions:

1. In 2030, 60% of the material use is circular.
2. Preferably, existing buildings are reused, rather than new construction.
3. Preferably, materials are reused or biobased, rather than raw materials.
4. The complete portfolio is designed reusable and adaptive.

To develop an integrative strategy to realise the ambitions from the Nationale Politie (2023a), the strategy aligns with the three principles of the trias energetica and with the existing vastgoedvisie. The strategy exists of three main principles:

1. **Reduce:** Minimize the use of materials and energy. This begins with the first goal of the portfolio, efficiënter huisvesten (Nationale Politie, 2023c). Part of this principle is the reuse of existing buildings within the portfolio of the Netherlands Police.
2. **Sustain:** As mentioned in the goals of the portfolio, sustainability goals are in line with the ones for the national government (Nationale Politie, 2023c), and interventions for sustainable or circular developments will take place when the opportunities arise (op natuurlijke momenten) (Nationale Politie, 2023a).
3. **Accelerate:** speeding up the realisations can make the organisation benefit from economies of scale. This can be done by clustering interventions or by initiating programs.

More recent studies by the Netherlands Police, reported by Nationale Politie (2025a), elaborate on the previously mentioned ambitions for circularity. This report states that this challenge should be addressed on two

levels: portfolio level and project level.

On portfolio level, it is important to implement ambitions when opportunities arise (op natuurlijke momenten), and to monitor the existing real estate portfolio. Specifically on circularity, the main principle for the portfolio level is to prioritize renovation or building reuse over new construction.

On project level, it is important to distinguish a quality standard to determine the degree of sustainability and circularity. As described by Nationale Politie (2023c), there are three quality levels (kwaliteitsniveaus). Quality level A is the highest level, and includes the complete future-proofing of the building at the intervention. This can be achieved in new constructions, but also in the reuse of buildings. For building reuse, circularity in quality level A means that:

- The indicator for detachability is as high as possible.
- The percentage of reusable, reused, or biobased materials is as high as possible.
- The material flows are mapped out.

Quality level B describes the current requirements of the Netherlands Police. Besides, this level includes the expected requirements for the coming ten years. For circularity, quality level B includes:

- If a building is demolished, the building will be demolished according to a certified demolition process (verificatieregeling circulair slooproject), in order to harvest reusable materials.
- In public/visible locations, extra attention will be given to circular interventions.

Quality level C is only applicable for buildings that are not part of the future real estate of the Netherlands Police, and have no requirements or ambitions on circularity.

As stated in the introduction of this chapter, there should be a good balance between the long-term ambitions and the short-term feasibility of the strategies of the Netherlands Police (Nationale Politie, 2023b). To align with the aims of the portfolio – quality, affordability, and feasibility, while still supporting the services and working processes of the police (Nationale Politie, 2023b) – the strategies developed by the Netherlands Police per portfolio segment require efficient interventions that will leave the building's functionality in tact as long as possible. These interventions need to include different aspects based on the functionality of the segment. To make choices for a suitable action within the strategy, it is important to have a well-developed decision-making process (Hallo et al., 2020). Decisions made early in the process, have a larger impact on the rest of the project (Wilkinson et al., 2014). So when the Netherlands Police has certain goals for the portfolio, like reusing existing buildings or circularity ambitions, these should be part of the decision-making process from the start to realise their integration within the project.

Results

05

This chapter discusses the results gathered from the interviews with the experts from the Netherlands Police, and relates these results to the academic literature presented in the previous chapter. This answers the third research question. Afterwards, the development of the CBR framework will be described, reaching from the criteria for electing the applicable frameworks from the literature; to the structure and elements of the CBR framework; to the validation of the framework based on a case study. This chapter will answer the fourth research question on the requirements of the integrated framework.

5.1 Barriers of implementing circularity at the Netherlands Police

As described in the previous chapter, there are four categories of barriers when it comes to implementing circularity in the built environment: technological barriers, economic barriers, institutional barriers, and cultural barriers. During the interviews with experts of the Netherlands Police, these barriers were discussed. During the interviews, all four categories were discussed with all experts interviewed (fig. 12). After asking the questions which of these barriers are applicable to the organization of the Netherlands Police, INT1 said “I think that everything stated here applies to our organization” . Two more of the experts agreed with this and mentioned they intercorrelation (INT2, INT3). The outcomes of these interviews will be discussed in this paragraph.

Table 12. Co-occurrence table of the barriers mentioned by the interviewees

	INT1	INT2	INT3	INT4	INT5	Total
Economic	4	5	5	2	5	21
Institutional	8	9	6	8	5	36
Cultural	6	8	12	4	5	35
Technological	6	3	6	5	4	24
Total	24	25	29	19	19	116

5.1.1 Economic barriers

The first category is that of the economic barriers, being a comprehensible barrier for the Netherlands Police, since they are currently experiencing serious budget cuts (INT2). The strategy of the Netherlands Police of reusing more existing buildings instead of new constructions, has also been for financial reasons (INT1, INT3, INT4, INT5).

Some of the experts mention that circular building is overall more expensive than traditional building methods (INT1, INT2), while others say that circular building is not necessarily more expensive (INT3, INT4), mentioning this is the main reason for most internal actors to not include circular ambitions. “It does not necessarily have to be more expensive if we simply approach the tendering process more intelligently” , as mentioned by INT3. There are architects that design circular buildings based on their own visions and ambitions. INT4 agrees with this point, and elaborates further on it that “there are two ways to approach the commercial sector” . The first way is to provide the architect with a strict list of requirements which have to be met, resulting in higher costs to realise exactly these demands. The second approach is to stimulate the architect to come up with smart and innovative solutions for circular building, by which they can win the tender and maybe save some money for themselves, making the project less expensive. Therefore, the way of approaching an architect has an impact on the expenses on circular building methods.

Besides the discussion on whether circular building methods are more expensive than traditional building methods, there is an overarching uncertainty concerning the budgeting of circular ambitions. Multiple experts mention it is hard to calculate the estimated amount of money needed for circular reuse of buildings (INT1, INT5), due to unforeseen challenges in the process. This is closely related to the technical barriers, but also to the previously related factor of externalizing circular building methods to architects and other external partners, who are expertized in this field. As also mentioned by INT5, this outsourcing can take away some of the uncertainties with the project managers or other actors in the circular building reuse process at the Netherlands Police by “allowing those professionals to demonstrate their high level of professionalism and expertise” .

A final economic barrier within the organization of the Netherlands Police is closely related to the institutional barrier, and states that when there is no policy for circularity, no budgets will be withheld for circularity (INT1, INT2). Because of the budget cuts within the organization, ambitions like circularity are under a lot of pressure

(INT5). According to INT2, the main focus of the Netherlands Police now is to save costs, leaving less priority for (circular) ambitions that are not included in the policy of the organization. “If such requirements are not established, these are the most easily dismissed ambitions, which tend to disappear once the first contractor’s cost estimate is received” , mentioned by INT1, summarizes this barrier well.

5.1.2 Institutional barriers

The lack of policy on circularity (INT1, INT5) causes that the organization of the Netherlands Police experiences difficulties in implementing circular ambitions for their real estate portfolio, because no money is budgeted for it (INT2). Writing down policies on a topic includes developing requirements, which can be translated into measurable KPIs. According to different experts, these requirements can help to implement circularity in the organization (INT2, INT4, INT5), budget costs for circular building (INT1), and to make sure it is a manageable and controllable factor (INT3) , especially in larger organizations like that of the Netherlands Police (INT2, INT5). Top-down approaches like this will make sure that “that [strict policies] can be used to enforce measures” , for example to be included in the Programme of Requirement (PoR) (INT3). When circularity is a part of the PoR, tenders will automatically include circular building requirements (INT4). Even without strict policies on circularity, tenders could be set out in a way that architects and contractors are more stimulated to include circular building methods (INT3, INT4), as described in the previous paragraph. Besides this, part of the lack of policy is that currently there are a lot of ambition documents and toolboxes for the implementation of circular building methods, like the Toolbox for Adaptability police buildings (Toolbox adaptief vermogen politiegebouwen) (Nationale Politie, 2021), but “they just end up in some folder, or you forget about them for a bit” (INT5). Project managers receive a lot of documents, of which some are policy and some are ambitions. As discussed before, the documents that are not policy are the ones that are neglected first (INT1, INT5).

Another institutional barrier at the Netherlands Police is that currently most of the projects are developed by one department (INT5, INT1). According to multiple experts (INT2, INT4), in the current organization it is mainly depending on one or few people in the process whether a project is developed using circular building methods. This can either be a sustainability advisor or a project manager (INT4), or even an architect or contractor (INT3) that follows its own vision of circular building. Whereas, according to INT1 “it is about integrated teams, where you already look at the early stage of a project, i.e. the pre-project phase, to explore how different disciplines can be brought together” . When collaborating in these integrated teams “you will also know which decisions need to be made, and you will not have discussions at every phase of the project” (INT1).

5.1.3 Cultural barriers

To focus more on circular building reuse in the acquisition of transformation of a building is a different mindset than the Netherlands Police currently has; focussing on technical aspects of the building (INT2). Besides this, it also requires a different focus from the Netherlands Police to ask critical questions to external parties when it comes to circularity (INT1), which requires a certain amount of technical knowledge on circularity. Additionally, there should be an organizational culture of acceptance that the quality of reuse is not always as high as that of new constructed buildings. As mentioned by INT3: “In essence, the shift is that we should embrace the idea that scratches on interior walls are acceptable – even something to appreciate” . Instead of focusing on this lower aesthetic quality, the organization should show off their pride on the performance on circularity (INT1, INT2, INT3, INT4).

In the paragraph about institutional barriers, the lack of top-down policy-making is discussed. However, from the perspective of cultural barriers, bottom-up approaches would have a larger impact on the implementation of circular building methods. Sometimes, according to INT3, it is very effective if there are some people in the project team who are aware of the circular ambitions and possibilities, and can spread this knowledge to others. However, this same person also mentions that “if we really want to scale this up, we simply need formal, strict requirements” (INT3). INT5 agrees with this, emphasising the importance of sharing an ambition within a project team. According to INT2, this can best be reached using a step-by-step approach. “Just try shifting a few things, or adjusting some focus points. I think that works best” (INT3). Eventually, this can motivate other people to also include likewise actions, which will eventually grow bigger (INT3).

The final cultural barrier is about the awareness of what circularity is and what circular building includes. Within the organization of the Netherlands Police, a lot of people still see circularity as a complex topic that requires a lot of technical knowledge and costs a lot of money (INT3). In the first place, people mostly think,

circular building is expensive. However, this argument is based on a lack of knowledge or experience on the topic (INT3), which prevents people to realistically think about circular developments (INT2). INT5 mentions that this consciousness is growing among people, but mainly among external parties like architects, restarting the discussion about the outsourcing of knowledge to external parties. If the organization would be more aware of the innovativeness and expertise of architects and contractors, they could play a bigger role in this (INT4), especially since the Netherlands Police does not develop the building themselves (INT5).

5.1.4 Technological barriers

The final category of barriers is the technological barriers. The first technical barrier is that there is no data within the organization of the Netherlands Police on their current performance on circularity (INT2, INT4), making it hard to define specific goals for future targets. For example, the Netherlands Police aims at using 60% of circular materials by 2030 (Nationale Politie, 2023a). However, there is no data on the current performance on this topic (INT2). There are tools within the organization of the Netherlands Police to measure buildings, than can be useful in the process of buying or selling a building (INT5). However, there is not one tool used for every project. In each project, another tool can be the pivotal tool used to base a decision on, or a combination of tools (INT5). When using multiple tools, all the gathered data slightly differs from each other as well, making it hard to create one general database.

A second technological barrier is that, “in the pre-project phase, you should carefully assess whether the intended function for the building is actually suitable for that building” (INT1), requiring thorough investigations. In this quality-check of the building, it is important to also take into account the circular potential of the building, including which materials or elements of the building could be reused (INT2). And when there are elements of the building that could be reused, there should be enough knowledge, inhouse or external, on how to store these elements (INT5). Although every expert interviewed agrees with the storage of reused materials, some of them explain why an external storage, managed by experts, is more likely to succeed. As mentioned by INT3, “I think that as the police, we are better off working with existing marketplaces than trying to set up our own” , which other experts agree with (INT4, INT5). If the Netherlands Police is willing to be more supply-driven, unleashing the culture that every wish or aim for the real estate is achievable (INT2), they could use more circular elements, based on the stock of the supplier (INT4).

Currently, “much of our policy is based on new-build construction” (INT2), which will have a different quality than reused buildings. This makes it important that at the pre-project phase, the technical knowledge of circular building reuse should be sufficient enough to assess the future potential of developing this building in a circular way (INT2). This knowledge can be used to write out a proper tender including circular ambitions (INT1, INT4).

Finally, a technological barrier is the lack of prove on the results of circular building methods (INT1). Especially on economic aspects, the effects of building circular buildings can help to develop better (financial) business cases (INT1, INT2). Gaining more knowledge on the process of circular building can be done by visiting factories, to understand “what you can do with it when it reaches end of life” (INT5), looking into inspiring examples (INT4), or by appointing circular “ambassadors” within the organization of the Netherlands Police (INT2). It takes some time to make the extra effort of getting familiar on the topic of circular building (INT5), but in the end it will “inspire and motive” (INT4) the people at the organization, making circular building more likely to be included in the building processes at the Netherlands Police.

Table 13. Barriers of implementing circularity within the Netherlands Police

Category of barrier	Example of barrier
Economic barriers	<ul style="list-style-type: none"> • Budget cuts • Uncertainty about the costs of circular building • No budgeting for circular ambitions
Institutional barriers	<ul style="list-style-type: none"> • The lack of policy, and therefore the lack of KPIs • Tenders do not include circular ambitions • Too many ambition documents / toolboxes result in them not being used • Lack of shared knowledge and responsibility
Cultural barriers	<ul style="list-style-type: none"> • Mindset is still on traditional building techniques • Lack of bottom-up motivation • Lack of awareness on the topic of circularity
Technological barriers	<ul style="list-style-type: none"> • No data on the current performance • Lack of knowledge on how to assess projects for building reuse • Lack of prove on the results of circular building methods

5.2 Development of the framework

5.2.1 Criteria for electing the models

Using the data from the interviews and the literature, the aim of the to-be developed framework can be defined. The interviewees were asked to tell about the process of building reuse and if there are certain requirements to a building that needs to be met for the building to be suitable for reuse. Besides, during the interviews the four categories of barriers of implementing circularity were discussed, the results of this are described in the previous paragraph. On the one hand, multiple experts discussed the importance of the current and fixed characteristics of the environment and the building in the decision-making in the pre-project phase (INT1, INT2); where is decided whether the building will be reused or not. INT1 mentioned that the pre-project phase is about the location of the building and whether it suits the function of the to-be developed building, because this provides the most circular, and futureproof solution. On the other hand, it is necessary to investigate the future circular potentials of the building when it will be reused (INT1, INT2). When assessing a building for its future use, it should not only be looking at in a technical way, also there should be looked at the possibilities for circular building methods in the building and what parts of the building could be reused (INT2).

These findings are gathered and will all be part of the final CBR framework. The aim of the framework is to support the decision-making process in the pre-project phase on whether to reuse a building or not, and to assist in appointing the project-specific potentials for circular reuse. The framework will focus on both the current characteristics of the environment and the building, and the future potentials for circular reuse.

In order to pick the right frameworks from the literature to combine for the final CBR framework, some criteria are established that need to be met. The criteria derive from the interviews and the discussed literature and are applicable for this research and for this specific case for the Netherlands Police.

1. Suitable for the phase. The first criteria is about the phase of the decision-making process that is focused on in this study: the pre-project phase. In this phase, the expectations of the client are set (Arfa, Zijlstra, et al., 2022), which can be managed by predicting them on beforehand. This phase includes the acquisition of the building, which therefore requires technical knowledge on the current state of the building and the potentials for reusing this building (INT1, INT2).

2. Can assess the current characteristics. The purpose of the framework is twofold, of which the first aim is to assess the current characteristics of the environment and the building. As described by Mısırlısoy and Günçe (2016), the analysis of the existing fabric, and its corresponding conservation actions, is a step that needs to be taken before identifying the circular reuse potentials of the building. The assessment of the current characteristics will determine the feasibility of the building reuse.

3. Can establish potentials for circular reuse. The other part of the aim of the developed framework is to establish the potentials of circular building reuse. As Corona et al. (2019) describes, there are two types of circularity metrics. Circularity assessment tools, that measure the effects of circularity, and circularity indices, measuring the circularity degree. This framework focuses on models that identify the circular potential of

buildings, which can be used to write out tenders for architects and contractors (INT1, INT4).

4. User-friendly. The final criteria reflects to the utility of the model, mentioned as a requirement to evaluate a framework (Corona et al., 2019). A few factors determine the user-friendliness of the framework:

- The framework should be qualitative, due to the lack of data on the current performance on circular building at the Netherlands Police (INT2, INT4).
- The framework should be flexible, so it can be used on a wide range of projects, as the case of the Netherlands Police includes a broad real estate portfolio (INT1).
- The framework should be straightforward, so it requires little time and effort to implement it in complex organizations like the Netherlands Police (INT3).

In tables 14 and 15, these criteria are examined against the different frameworks introduced in the previous chapter. One table is dedicated to the frameworks on building reuse, and one on the frameworks on circularity, since the second criteria slightly differs for them. The examination of the frameworks will lead to the election of two suitable frameworks that will be combined to develop the final framework.

Table 14. Assessment of the building reuse models against the criteria

	Suitable for the phase	Can assess the current characteristics	Can establish potentials for circularity	User-friendly			Total
				Qualitative	Flexible	Straightforward	
ARP model	x	x	x	-	x	-	~
adaptSTAR	x	x	x	-	x	-	~
iconCUR	x	x	~	-	x	-	-
transformation meter	x	x	x	x	x	~	x

Table 15. Assessment of the circularity models against the criteria

	Suitable for the phase	Can assess the current characteristics	Can establish potentials for circularity	User-friendly			Total
				Qualitative	Flexible	Straightforward	
Circular Flow	x	~	x	-	~	-	-
Building Circularity Index	x	x	x	-	x	-	~
Design for Disassembly	-	-	-	x	-	-	-
Design for Adaptability	x	-	-	x	x	-	-
ReSOLVE framework	x	x	x	x	x	~	x

Based on these examinations of the frameworks on the three given criteria, there are two frameworks suitable for the aim of the framework: to support the decision-making process in the pre-project phase on whether to acquire a building or not, and to assist in appointing the project-specific potentials for circular reuse. These frameworks are the transformation meter, developed by Geraedts et al. (2025), and the ReSOLVE framework developed by the Ellen MacArthur Foundation (2015).

The transformation meter

The transformation meter, developed by Geraedts et al. (2025), aligns well with the aims of the framework. Due to the different steps of the framework, both the current characteristics as the future potentials for circular reuse are assessed. The first two steps – the veto criteria and the financial feasibility study – prevents the organization from undergoing time-consuming and possibly complex studies on projects that are not guaranteed to be successful, making the framework well applicable for complex organizations like the Netherlands Police (INT3). The second part of the framework can be used to define the potentials for circular ambitions. However, this part does not force the organization to implement certain strategies or requirements – it mainly provides the project team with more knowledge on the circular building methods.

The transformation meter is initially developed for the transformation of offices to residential buildings (Wilkinson et al., 2014), which means it is not directly suitable for this case. Nevertheless, the structure of the framework can be used to translate this into the CBR framework.

The ReSOLVE framework

The ReSOLVE framework, developed by the Ellen MacArthur Foundation (2015), is a widely applied tool to implement CE strategies, also for the field of building reuse. The actions described in the framework, especially the ones related to the building layers by Arup (2016), can be implemented in frameworks that measure the potentials for circular building reuse. Using the actions from this framework, the specific ambitions for circular building can be defined, which will lead to more targeted tendering processes (INT1, INT4).

Toolbox adaptability of Police buildings

To make sure the framework is applicable to the case of the Netherlands Police, the CBR framework will be aligned with an existing tool of the organization: the Toolbox for Adaptability police buildings (Toolbox adaptief vermogen politiegebouwen) (Nationale Politie, 2021). The building layers described in the toolbox will be part of the structure of the CBR framework. This will highlight the fact that a building exists of different layers that all operate independently (Friedman, 2025), and will create awareness on the different levels of circular design possibilities in a building (INT2).

5.2.2 Developing the framework

The CBR framework is based on the structure of the transformation meter, includes the principles of the ReSOLVE framework, and aligns with the building layers of the Toolbox for Adaptability Police Buildings. After the development of the criteria described in the framework, the framework has been tested by conducting a case study together with an expert of the Netherlands Police.

Step 1. Quick scan based on veto criteria

The first step of the framework focuses on the first part of the aim of the framework: to support the decision-making process in the pre-project phase on whether to reuse a building or not. This step includes the veto criteria, which have to be met in order to continue the building reuse process. These criteria either derive from the literature or from the interviews with the experts. Interviewees were asked the question which factors determine the suitability of a building to be reused, of which some factors can be seen as veto criteria, since they cannot be changed. This includes, for example, the location of the building, which should be both reachable for the employees (INT1, INT2, INT3, INT4, INT5) as well as it should be accessible for the public (INT4, INT5). The fact that every interviewee mentions this criteria, concludes that this factors could be seen as a veto criteria, that has a large impact on the feasibility of a project. All the veto criteria of step 1 are described in table 16.

Step 2. Exploration of the financial feasibility

Another frequently mentioned criteria is the financial feasibility of the project (INT1, INT2, INT3), due to the budget cuts. This is not part of the veto criteria in step 1, since the financial feasibility is addressed in the second step of the CBR framework.

As described by Zulkanain et al. (2022), the economic feasibility is an important factor that affects the decision-making process of building reuse. To assure the future success of the project, the financial feasibility of the project should be determined. To determine the building's life cycle costs, the building operating costs is a required data source, including the energy and water consumption (Dwaikat & Ali, 2018). However, the costs of consuming energy and water can be minimized after the circular renovation of the building. Therefore, the

Table 16. Definitions of the veto criteria of the CBR framework

Veto criteria	Definition of the criteria	Source
Is the owner willing to sell (or rent out) the building?	Does the current owner of the building want to sell or rent out the building to the Netherlands Police?	(Geraedts et al., 2025)
Can permits be granted for a zoning plan change?	Does the new function of the building align with the current zoning plan? And could it be changed if needed?	(Geraedts et al., 2025)
Are there no health risks from odour, noise, or pollution?	Are there any health risks in the environment that could withhold the project?	(Geraedts et al., 2025); (Nationale Politie, 2021)
Are there no environmental risks like flood risk or land subsidence?	Are there any environmental risks at the location that could withhold the project?	Validation session
Is the location reachable for employees?	Is the location reachable by car and public transport? And in case of a police station, can police cars leave the location quick enough?	Interviews (INT1, INT2, INT3, INT4, INT5); (Nationale Politie, 2021)
Can the (outside and inside of the) building be properly secured?	Can the building be secured on the level that is demanded by the function of the building?	Interviews (INT1, INT2)
Does the building have access to energy sources by being connected to the power grid?	Is the building connected to the local power grid? And does it provide enough power for the function of the building?	Interviews (INT2, INT3)
Is the building visible and accessible for the public?	Is the building currently, or in the near future, at a visible and accessible location for the public?	Interviews (INT4, INT5)

operating costs of the future building are hard to establish.

The Netherlands Police has defined the cost indicators for circular transformations of different building typologies (Nationale Politie, 2026), based on different topics: insulation, installations, and solar panels. These cost indicators can be used to determine the costs of transforming a building into a specific function. These costs indicators are updated regularly, which means the CBR framework has to be updated according to these costs indicators as well.

Step 3. Detailed evaluation based on gradual criteria

When the first two steps are completed, and they are both positively assessed, the building can be evaluated in more detail. This step is focused on the second part of the aim of the framework, which is to assist in appointing the project-specific potentials for circular reuse. The criteria in this step are divided into the six layers - environment, plot, structure, skin, services, and interior elements - of a building as used in the Toolbox for Adaptability police buildings (Nationale Politie, 2021). The criteria are, just like in the first step, based on the literature and on the results from the interviews. Besides, in this step all criteria are aligned with the actions derived from the ReSOLVE framework, making sure the framework assess the building on circularity. In this step, the criteria are assessed gradually, meaning that each criterion is provided a score: low performance (0 points), medium performance (5 points), or high performance (10 points). In table 17, all the criteria in this step are presented and defined.

Table 17. Definitions of the criteria of the CBR framework

Criteria - environment	Definition of the criteria	Source	ReSOLVE
What is the distance to the closest public transport station?	This includes public transport stations that enable regular traveling to other transportation hubs.	(Nationale Politie, 2021); Interviews (INT3, INT5)	Share Optimize
Are there physical barriers blocking daylight to the facades?	Any fixed barriers, like buildings.	(Nationale Politie, 2021)	Optimize Exchange
Is the location of the building suitable for other functions?	When the building is obsolete, can the location host other functions than the current one?	(Arup, 2016); Interviews (INT2, INT5)	Optimize Loop
Does the location use localised renewable energy sources?	Like solar energy, wind power, or geothermal energy.	(Arup, 2016)	Optimize Loop
Criteria - plot			
Are there possibilities for expanding facilities outside the plot?	For example, are there empty terrains surrounding the building that can be added to the plot?	(Nationale Politie, 2021)	Optimize Loop
Are there possibilities for expanding facilities inside the plot?	Is there space on the plot to expand the facilities?	(Nationale Politie, 2021)	Optimize Loop
Can (part of) the plot be disposed?	Are there redundant parts of the plot that could be disposed?	(Nationale Politie, 2021)	Optimize Loop Share
Criteria - Structure			
What is the positioning (of barriers) of the load-bearing structure?	Does the positioning enable flexible use of the space?	(Nationale Politie, 2021)	Optimize Loop
How is the building circulation organized?	Are all stairs and elevators placed at one place, or are they spread throughout the building?	(Nationale Politie, 2021)	Optimize Loop
Are there possibilities for moving the building circulation?	Can the stairs and elevators be moved to another place?	(Nationale Politie, 2021)	Optimize Loop
What is the horizontal grid size?	What is the horizontal grid size?	(Nationale Politie, 2021) Interviews (INT5)	Optimize Loop
What is the floor height?	The clear floor-to-ceiling height.	(Nationale Politie, 2021) Interviews (INT5)	Optimize Loop
To what extent can components of the structure be reused?	Like reusing steel beams.	(Arup, 2016); (Nationale Politie, 2021)	Share Loop
Are low-impact materials used in the construction?	For example timber or biobased materials like hempcrete.	(Arup, 2016)	Regenerate

Table 17 (continued). Definitions of the criteria of the CBR framework

Criteria - skin	Definition of the criteria	Source	ReSOLVE
How are windows placed in order to provide natural daylight to the building?	What is the shape and size of the windows, and are they placed regularly?	(Nationale Politie, 2021)	Optimize Exchange
Can windows be opened?	By the users themselves, to ensure natural ventilation.	(Nationale Politie, 2021)	Optimize Exchange
How is the operation of sun shading organized?	Can people operate the sun shading themselves?	(Nationale Politie, 2021)	Optimize Exchange
To what extent can elements of the skin be reused?	Assuming all building layers operate independently.	(Arup, 2016); (Nationale Politie, 2021)	Share Loop
Criteria - services			
What is the location of building services?	And are they operated by the users, or regionally?	(Nationale Politie, 2021)	Share Optimize
To what extent can the installation components be uncoupled?	In case the installations needs to be changed, does this influence other building layers?	(Nationale Politie, 2021)	Share Optimize Loop
Are there possibilities for rainwater harvesting and recycling?	On the building plot or nearby.	(Arup, 2016)	Loop
To what extent can the installations be reused?	Assuming all building layers operate independently.	(Arup, 2016); (Nationale Politie, 2021)	Share Loop
Criteria - interior elements			
Is the building layout suitable for multiple functions?	When the building is obsolete, does the layout of the building enable the use of the building for other functions?	(Nationale Politie, 2021); Interviews (INT2, INT5)	Loop
Can interior walls be moved?	Possibly by taking it down and reassembling it.	(Arup, 2016); (Nationale Politie, 2021)	Share Optimize Loop
Can building components be reused or exchanged?	Assuming all building layers operate independently.	(Nationale Politie, 2021)	Share Optimize Loop
Are biodegradable or compostable materials used?	Like bamboo or timber.	(Arup, 2016)	Regenerate Loop
Are there possibilities for video and virtual conferencing?	To encourage hybrid working.	(Arup, 2016)	Virtualize

Step 4. Determination of the circular building reuse potential

The fourth step of the CBR framework defines the circular building reuse potential of the building. The score is expressed in percentages, and scoring is done per building level and for the entire building. Since the intention is that all building layers operate independently (Friedman, 2025), the scoring of one building layer does not have to influence the scoring of other layers.

Step 5. Risk inventory

Based on the answers provided in the third step, the risks of this project can be determined. All the scores from the third step are summarized in this step, so there is an overview of the criteria that could form a risk for the project. Some of the low performance scores – and therefore risks – are inevitable, for example when a building is located in an urban environment and the plot is densely built, the criteria in the building layer ‘plot’ will possibly be low. This risk inventory does not require further actions to be taken, it provides the user of the framework with awareness on the risks of the project.

5.3 Validation by a case study

In order to validate the CBR framework, the framework has been completed together with an expert from the Netherlands Police. This chapter will present the completed framework on the case of the Marten Meesweg. This office building has a large surface area, is located on a well-accessible and visible location, and is – as it is currently used – connected to the power grid. This makes this building a proper candidate for the CBR framework, to discover the circular building reuse potential of this real estate. Besides the presentation of the completed CBR framework, this chapter will also appoint the improvement of the framework, after feedback was provided during the validation.

Step 1. Quick scan based on veto criteria

In the first step of the framework, the veto criteria are examined. The first version of the framework contained the same veto criteria as seen in figure 10, except the one examining the environmental risks. Also, the accessibility of the location for the employees and the public were combined, whereas separate criteria are assigned to each of these groups of people. Therefore, these criteria are separated into two criteria. Apart from these two adjustments, and the rephrasing of some of the criteria, little comments were given on this step in the validation session.

All the veto criteria were answered with the answer ‘yes’, meaning the next step could be started.

Veto criteria	Definition	Source	Assessment (yes/no)
Is the owner willing to sell (or rent out) the building?	Does the current owner of the building want to sell or rent out the building to the Netherlands Police?	Owner	Yes
Can permits be granted for a zoning plan change?	Does the new function of the building align with the current zoning plan? And could it be changed if needed?	Municipality	Yes
Are there <u>no</u> health risks from odor, noise, or pollution?	Are there any health risks in the environmental that could withhold the project?	On-site observations / real estate agent	Yes
Are there <u>no</u> environmental risks like flood risk or land subsidence?	Are there any environmental risks at the location that could withhold the project?	On-site observations / real estate agent	Yes
Is the location reachable for employees?	Is the location reachable by car and public transport? And in case of police stations, can police cars leave the location quick enough?	On-site observations	Yes
Can the (outside and inside of the) building be properly secured ?	Can the building be secured on the level that is demanded by the function of the building?	On-site observations	Yes
Does the building have access to energy sources by being connected to the power grid?	Is the building connected to the local power grid? And does it provide enough power for the function of the building?	Municipality	Yes
Is the building visible and accessible for the public?	Is the building currently, or in the near future, at a visible and accessible location for the public?	On-site observations	Yes

Figure 10. Case study results of the first step of the CBR framework

Step 2. Exploration of the financial feasibility

The second step includes the determination on the financial feasibility of the project. This step is performed by an expert in this field, meaning this step could not be carried out during the validation session.

Part of this step is to determine the transformation costs of the building, which can be used to assess the financial feasibility of the project. For this step, the new function of the building should be known, as well as the total surface area of the building and what part of the building will be reused for a new function. This number could be set to 100%, if the entire building is reused for the new function. However, in case of a reuse for multiple functions, this number can be adjusted and multiple calculations can be carried out.

For this case study, a fictional new function of the building has been applied, in order to test the calculation tool.

Building characteristics		Transformation costs	
Address	Marten Meesweg 35, Rotterdam	Total surface area (in m ²)	18.889
Construction date	1989	New function	Forensic investigation
Surface area (in m ²)	18.889	Transformed surface area (in %)	50%
Current function	Office	Transformation costs (€/m ²)	€ 1.957
Future function	Forensic investigation	Transformation costs	€ 18.482.887

Figure 11. Case study results of the second step of the CBR framework

Step 3. Detailed evaluation based on gradual criteria

In the third step, the more detailed criteria are assessed to define the circular potential of the building. Although the framework was experienced as straight-forward and not time-consuming to complete, in this step the definition of the criteria was lacking. The addition of clear definitions of all criteria contributed to the user-friendliness of the framework, and makes it more consistent in use.

For nearly all the building layers, the experience suggests that it was easy to complete. Only the criteria within the layer of 'services' was encountered to be more complex, due to the technical factors included in the criteria that are invisible for the user of the building. Nevertheless, some of the information could be found in the floor plans of the building.

Environment

Criteria	Definition	Low performance (0 pt)	Medium performance (5 pt)	High performance (10 pt)	Assessment	ReSOLVE
What is the distance to the closest public transport station?	This includes public transport stations that enable regular traveling to other transportation hubs.	>1000 m	500-1000 m	<500 m	10	Share, Optimize
Are there physical barriers blocking daylight to the facades?	Any fixed barriers, like buildings	Yes	Partly	No	10	Optimize, Exchange
Is the location of the building suitable for other functions?	When the building is obsolete, can the location host other functions than the current one?	No	For a few other functions	Yes, to all functions	5	Optimize, Loop
Does the location use localised renewable energy sources?	Like solar energy, wind power, or geothermal energy.	No	Some	Yes	5	Optimize, Loop
Score:					75%	

Plot

Criteria	Definition	Low performance (0 pt)	Medium performance (5 pt)	High performance (10 pt)	Assessment	ReSOLVE
Are there possibilities for expanding facilities <u>outside</u> the plot (parking, greenery, building, etc.)?	For example, are there empty terrains surrounding the building that can be added to the plot?	No	Expansion up to 50% is possible	>50% expansion is possible	0	Optimize, Loop
Are there possibilities for expanding facilities <u>inside</u> the plot (parking, greenery, building, etc.)?	Is there any space on the plot to expand the facilities?	No	Expansion up to 50% is possible	>50% expansion is possible	0	Optimize, Loop
Can (part of) the plot be disposed?	Are there redundant parts of the plot that could be disposed?	No	Disposal up to 50% is possible	>50% disposal is possible	0	Optimize, Loop, Share
Score:					0%	

Structure

Criteria	Definition	Low performance (0 pt)	Medium performance (5 pt)	High performance (10 pt)	Assessment	ReSOLVE
What is the positioning (of barriers) of the loadbearing structure (columns or loadbearing walls)?	Does the positioning enable flexible use of the space?	The possibility for adapting the layout of the building is severely hindered by loadbearing structures	The possibility for adapting the layout of the building is slightly hindered by loadbearing structures	The possibility for adapting the layout of the building is not hindered by loadbearing structures	10	Optimize, Loop
How is the building circulation organised (stairs, elevators)?	Are all stairs and elevators placed at one place, or are they spread throughout the building?	Building has one decentralized staircase and/or elevator core	Building has one centralized staircase and/or elevator core	Building has one centralized staircase and/or elevator core, and each building wing has its own staircase and/or elevator core	10	Optimize, Loop
Are there possibilities for moving the building circulation (stairs, elevators)?	Can the stairs and elevators be moved to another place?	No	Moving the building circulation is possible in only one direction	Moving the building circulation is possible in both directions	10	Optimize, Loop
What is the horizontal grid size?	The size between the structural elements.	0,30 m	0,90 m or 1,80 m	>3,60 m	10	Optimize, Loop
What is the floor height?	The clear floor-to-ceiling height.	<2,60 m	2,60-3,40 m	>3,40 m	5	Optimize, Loop
To what extent can components of the structure be reused?	Like reusing steel beams.	Components of the structure are not reusable	Components of the structure are partly reusable	Components of the structure are easily reusable	5	Share, Loop
Are low-impact materials used in the construction?	For example timber or bio-based materials like hempcrete.	No	Partly	Yes	0	Regenerate
Score:					71%	

Figure 12. Case study results of the third step of the CBR framework

Skin						
Criteria	Definition	Low performance (0 pt)	Medium performance (5 pt)	High performance (10 pt)	Assessment	ReSOLVE
How are windows placed in order to provide natural daylight to the building?	What is the shape and size of windows, and are they placed regularly?	There are no to little windows	There are plenty of windows, but they have different sizes and are placed on different heights	There are plenty of big, uninterrupted windows	10	Optimize, Exchange
Can windows be opened?	By the users themselves, to ensure natural ventilation.	<10% of the windows can be opened	10-80% of the windows can be opened	>80% of the windows can be opened	5	Optimize, Exchange
How is the operation of sun shading organised?	Can people operate the sun shading themselves?	Centralized for the entire building	Per building department, wing, floor, unit, etc.	On the level of the smallest skin grid	10	Optimize, Exchange
To what extent can elements of the skin be reused?	Assuming all building layers operate independently*.	Elements of the skin are not reusable (due to heritage protection status)	Elements of the skin are partly reusable	Elements of the skin are easily reusable	10	Share, Loop
Score:					88%	

Services						
Criteria	Definition	Low performance (0 pt)	Medium performance (5 pt)	High performance (10 pt)	Assessment	ReSOLVE
What is the location of building services (cooling, heating)?	And are they operated by the users, or regionally?	One centralized location for the entire building	On multiple locations throughout the building	Building services are operated on regional level (e.g. district heating)	10	Share, Optimize
To what extent can the installation components be uncoupled?	In case the installations needs to be changed, does this influence other building layers?	The installation components can not be uncoupled	The installation components can partly be uncoupled	The installation components can easily be uncoupled	0	Share, Optimize, Loop
Are there possibilities for rainwater harvesting and recycling?	On the building plot or nearby.	No	Yes, but it has a lot of disadvantages	Yes	0	Loop
To what extent can the installations be reused?	Assuming all building layers operate independently*.	The installations are not reusable	The installations are partly reusable	The installations are easily reusable	5	Share, Loop
Score:					38%	

Interior elements						
Criteria	Definition	Low performance (0 pt)	Medium performance (5 pt)	High performance (10 pt)	Assessment	ReSOLVE
Is the building layout suitable for multiple functions?	When the building is obsolete, does the layout of the building enable the use of the building for other functions?	The building layout is suitable for only one function	The building layout is suitable for 2-4 functions	The building layout is suitable for 4+ functions	10	Loop
Can interior walls be moved?	Possibly by taking it down and reassembling it.	No, this is too expensive or structural challenging	Interior walls can be demolished and rebuilt	Interior walls can be easily moved (e.g. demountable partition walls)	10	Share, Optimize, Loop
Can building components (interior walls, floors, ceilings) be reused or exchanged?	Assuming all building layers operate independently*.	No	50-80% is reusable or exchangeable	All building components are easily reusable or exchangeable	10	Share, Optimize, Loop
Are biodegradable or compostable materials used?	Like bamboo or timber.	No	Partly	Yes	0	Regenerate, Loop
Are there possibilities for video and virtual conferencing?	To encourage hybrid working.	No	In some parts of the building	Yes	10	Virtualise
Score:					80%	

Figure 12 (continued). Case study results of the third step of the CBR framework

Step 4. Determination of the circular building reuse potential

The fourth step examines the results from the previous step, and provides a circular reuse potential to the building. Based on this step, the final step of the CBR framework can be completed.

It could be concluded that this building scores quite well on most of the building layers. However, the building layers 'plot' and 'services' both score quite low. For the plot of the building, this has to do with the built environment of the building. The plot is located in an urban environment, surrounded by other buildings and plots. This means that outside the building plot, there is no flexibility for expanding the plot. Besides, the plot itself is almost completely filled by the building on it, except for some space for parking. This makes it hard to expand facilities inside the plot, or to dispose part of the plot.

For the building layer of 'services', the completion of the framework was experienced challenging, as described in the previous paragraph. This results in an insecure score for the circular building reuse potential of this building layer.

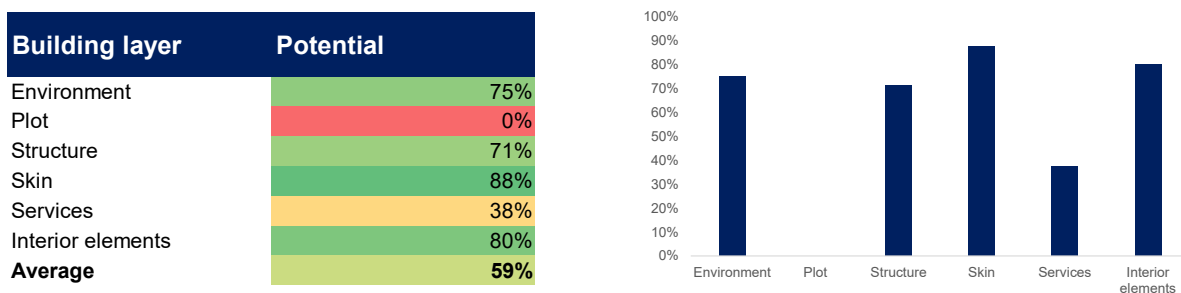


Figure 13. Case study results of the fourth step of the CBR framework

Step 5. Risk inventory

In the final step of the CBR framework, the possible risks of this project are discussed. This step summarizes all criteria evaluated in step 3, and provides an opportunity for the user to note down the cause of a low score, and the possible risk for this criterion.

As discussed in the previous paragraph, the building layer 'plot' scores a low potential for circular building reuse, due to its embedding in the built environment. A risk of this is that the building location is only suitable for functions that do not require a lot of outdoor space.

Another risk, applicable to multiple building layers, is the lack of use of low-impact or biodegradable materi-

als. This means that when these materials are no longer required, waste would be created since these materials are hard to recycle. This requires to think critically about the future use of these materials, which can mean, for example, that structures could not be replaced or moved, which influences the flexibility of the space and therefore the suitability for multiple functions. All assigned risks for this case study are shown in figure 14.

Environment

Criteria	Assessment	Cause	Potential risk
What is the distance to the closest public transport station?	10		
Are there physical barriers blocking daylight to the facades?	10		
Is the location of the building suitable for other functions?	5	Little outdoor space.	The location is suitable for a specific type of building functions.
Does the location use localised renewable energy sources?	5	There are solar panels on the roof.	The building is dependent on external energy sources.

Plot

Criteria	Assessment	Cause	Potential risk
Are there possibilities for expanding facilities <u>outside</u> the plot?	0	The plot is entirely surrounded by other building plots.	Facilities can not be added outside the building plot, therefore the location is suitable for a specific type of functions.
Are there possibilities for expanding facilities <u>inside</u> the plot?	0	The majority of the building plot is occupied by the building.	Facilities can not be added inside the building plot, therefore the location is suitable for a specific type of functions.
Can (part of) the plot be disposed?	0	The majority of the building plot is occupied by one building.	The size of the plot is hardly adjustable, therefore the location is suitable for a specific type of functions.

Structure

Criteria	Assessment	Cause	Potential risk
What is the positioning (of barriers) of the loadbearing structure?	10		
How is the building circulation organised?	10		
Are there possibilities for moving the building circulation?	10		
What is the horizontal grid size?	10		
What is the floor height?	5	The floor height is around 3 meters.	Some building functions might require higher floor heights.
To what extent can components of the structure be reused?	5	Some components of the structure are made of reusable materials, like steel, some of materials that are harder to reuse, like concrete.	The demolition of (part of) the building would lead to the creation of waste.
Are low-impact materials used in the construction?	0	There are no, as far as known, low-impact materials used in the construction.	At the EoL stage of the building, materials are harder to recycle.

Skin

Criteria	Assessment	Cause	Potential risk
How are windows placed in order to provide natural daylight to the building?	10		
Can windows be opened?	5	Around 20% of the windows can be opened.	Natural ventilation is limited.
How is the operation of sun shading organised?	10		
To what extent can elements of the skin be reused?	10		

Services

Criteria	Assessment	Cause	Potential risk
What is the location of building services?	10		
To what extent can the installation components be uncoupled?	0	The installation components, as far as known, can not be uncoupled.	Possibly, other building layers will be influenced due to the changing of installations.
Are there possibilities for rainwater harvesting and recycling?	0	There are no possibilities, as far as known, for rainwater harvesting and recycling.	All water consumption of the building is dependent on potable water resources.
To what extent can the installations be reused?	5	Some of the installations, as far as known, could be reused.	The demolition of (part of) the building would lead to the creation of waste.

Interior elements

Criteria	Assessment	Cause	Potential risk
Is the building layout suitable for multiple functions?	10		
Can interior walls be moved?	10		
Can building components be reused or exchanged?	10		
Are biodegradable or compostable materials used?	0	There are no, as far as known, biodegradable or compostable materials used.	At the EoL stage of the building, materials are harder to recycle.
Are there possibilities for video and virtual conferencing?	10		

Figure 14. Case study results of the fifth step of the CBR framework

Concluding, this chapter has presented the developed CBR framework, filling the research gap of a lacking framework that integrates a decision-making tool that combines both building reuse potentials as well as circular building potentials. The framework is validated using a case study from the Netherlands Police. The findings and implications of the results will be discussed in the next chapter.

Discussion

06

The aim of the thesis is to present an integrated circular building reuse framework that can be implemented in the early stages of the decision-making process of building reuse. The CBR framework accomplishes this aim, by including both the assessment of the current characteristics of the location and the building, to assist in the decision-making process of building reuse, as well as the inclusion of criteria that define the circular potentials for the building. This chapter will reflect back on the presenter literature, and will discuss the correlation between this literature and the results of the thesis. Besides, some limitations to the research will be discussed, as well as proposals for future research. Also, some recommendations will be done to the Netherlands Police on how to realise their ambitions for circularity, including the implementation of the CBR framework.

6.1 Comparison to the literature

The aim of the study was to present a combined framework to indicate potentials for circular building reuse. To develop this framework, multiple existing models from literature are described and critically analysed using data from interviews with experts. In this chapter, the four categories of barriers for implementing circularity are discussed to analyse the comparison of these barriers based on the literature, and the experiences of these barriers as described by the interviewees. Besides, the expected relevance of the elected models is discussed in comparison to the relevance of these models based on the results from the interviews. Also, the added value of the CBR framework compared to the existing frameworks will be discussed.

6.1.1 Barriers of implementing circularity

In the literature review, the four categories of barriers for implementing circularity are introduced (Kirchherr et al., 2018; Grafström and Aasma, 2021). These barriers are used as a structure for the interviews to analyse the experience of these barriers within the organization of the Netherlands Police.

Economic barriers

In the literature, most of the economic barriers derive from the lack of financial support to the circular building (Kirchherr et al., 2018). This is an economic barrier experienced by the Netherlands Police as well, especially in combination with the lack of policy on circularity (INT1, INT2). Nevertheless, study also shows that building reuse has financial benefits, because few new elements or materials have to be purchased (Aigwi et al., 2023; Rakhshan et al., 2020), and the construction time is shorter than with the construction of a new building (Aigwi et al., 2023). However, the process of building reuse is quite unpredictable, which can lead to unforeseen expenses and delays (Van Laar et al., 2025), making it hard to predict the financial needs on forehand.

Institutional barriers

Lacking policies and the procurement strategy are the main institutional barriers mentioned in the literature (Kirchherr et al., 2018), which aligns well with the mentioned institutional barriers from the Netherlands Police. The lack of policy on circularity within the organization of the Netherlands Police (INT1, INT5) results in project managers not using the developed toolboxes and documents that can support the implementation of circular strategies (INT5). However, study by Arfa, Lubelli, et al. (2022) states the importance of the pre-project and the preparation phase by mentioning that the implementation phase will be less complex and shorter if these two phases are well thought out. Therefore, it would be useful to have some policies on these first phases of the decision-making process, since they will influence the writing of the tender, and therefore the entire process that is followed.

Cultural barriers

Based on the literature, the lack of awareness and the lack of willingness to cooperate in the CE are the main cultural barriers (Kirchherr et al., 2018). The shift in mindset, especially when it comes to the aesthetic quality of the building, is an identifiable cultural barrier within the organization of the Netherlands Police (INT1, INT2, INT4). However, different studies mention positive cultural effects of circular reuse: Rakhshan et al. (2020) points out that building reuse can create understanding of people's concerns about environmental sustainability. Besides, building reuse preserves the environment's identity (Aigwi et al., 2023). Although the shift to reuse of building may require a shift in the mindset of the users, this shift also includes positive influences on the environment and the users, which possibly are predominating.

The lack of willingness to cooperate in the CE (Kirchherr et al., 2018) is another mentioned cultural barrier from the literature. However, in the interviews it is mentioned that within the organization of the Netherlands Police, there is a growing awareness on circularity (INT5). Besides, the Netherlands Police is aware of its position towards commercial parties, like architects and contractors, that can be motivated to develop circular buildings (INT4). The interview results do therefore not align with this cultural barrier, as described in the literature.

Technological barriers

Technological barriers are about the lack of technologies to implement circular building strategies (Kirchherr et al., 2018). For the Netherlands Police, this barrier is applicable to three levels: there is no data on the current performance on circularity (INT2, INT4), there is too little knowledge on assessing existing buildings for circular reuse potential (INT1, INT2, INT5), and finally there is too little prove on the effects of circular building methods (INT1). In the literature, the importance of defining the adaptive reuse potential is oftentimes mentioned (Zulkanain et al., 2022; Mısırlısoy & Günçe, 2016). This potential can be measured on different levels of the building (Zulkanain et al., 2022) and will help to develop the right design strategy Mısırlısoy & Günçe, 2016).

Overall, it can be stated that the barriers of implementing circularity experienced by the Netherlands Police aligns well with the barriers described in the literature. Yet, after analysing the interviews, the interconnection between the barriers have become more clear. The CBR framework provides a starting point for approaching these barriers. By using this step-by-step framework, the awareness will grow on the different aspects of circular building reuse. The first and third step – assessing the criteria – create awareness on the specific environmental- and building-related aspects that need to be considered when taking into account circularity in the building reuse process. The second step ensures the incorporation of economic aspects of the building reuse. The overall framework – specifically the final two steps – indicate the technological knowledge that is required for an organization like the Netherlands Police. After completing the framework, enough knowledge is gathered to write out a tender for architects or contractors, who are then responsible for the implementation of circular building methods in the transformation of the building. Thereby, the CBR framework can contribute to approaching the experienced barriers in implementing circular ambitions.

6.1.2 Discussed models for building reuse

Within the field of building reuse, four models were discussed that all had the possibility of appointing potentials for building reuse: the ARP model, the adaptSTAR model, the iconCUR model, and the transformation meter. Table 4 summarizes the advantages and disadvantages of these models, based on academic literature and on the aim of the study. One overarching feature of all the discussed models is the different categories of potentials mentioned. As presented in the research by Mısırlısoy and Günçe (2016) as well, the following factors should be taking into account when developing a strategy for building reuse: physical, economic, functional, environmental, political, social, and cultural. Reviewing the discussed models from the literature review, this aspect is what made most models suitable for the CBR framework; the ARP and the adaptSTAR model are both based on the seven obsolescence types (Wilkinson et al., 2014; Sharifi & Farahinia, 2020), the iconCUR tool distinguishes criteria within the categories of condition, utilization, and reward (Langston, 2013), and the transformation meter addresses all the categories throughout the different steps in the framework (Geraedts et al., 2025).

However, when conducting the interviews, the lack of (technical) knowledge on circularity and the limited time and money available for non-policy ambitions like circularity, clarified the intended qualities of the framework. The aim of the CBR framework – to support the decision-making process in the pre-project phase on whether to reuse a building or not, and to assist in appointing the project-specific potentials for circular reuse – resulted in the exclusion of several models. The ARP model, the adaptSTAR model, and the iconCUR model are all based on quantitative data, and are therefore too time-consuming and complex for the current organization and means of the Netherlands Police.

The transformation meter meets most of the criteria based on the literature and the results of the interviews, and is therefore most suitable for the CBR framework. The framework is suitable for the pre-project phase, and can assess both the current characteristics as well as the future potentials for circularity. Besides, the framework requires little quantitative data. The use of the first two steps – the veto criteria and the financial feasibility – will prevent the user of completing the entire framework without the project being feasible. The later steps will provide a more detailed analysis of the circular building reuse potential of the building, contributing to two of the portfolio goals from the Netherlands Police: realistic and feasible pace of renewal (reëel en maakbaar vernieuwingstempo), and appropriate quality (passende kwaliteit). The inclusion of multiple steps within one framework can, however, lead to time-consuming processes. Especially when the framework is required to be completed by several different actors. The transformation meter can serve as a proper structure for the CBR framework, and offers flexibility to include CE-strategies to developed an integrated circular

building reuse framework.

6.1.3 Discussed models for circularity

Within the field of CE, a substantial amount of tools have been developed to assess the circular performance of buildings (Corona et al., 2019), which could be used in the pre-project phase to identify design strategies. Nevertheless, this would not align with the models discussed for building reuse, presenting models that define the potentials for building reuse based on different factors. Therefore, to create a combined framework using both fields of building reuse and circularity, models were discussed that could be implemented in the pre-project phase to present the circular potentials of the buildings, summarized in table 7. All the discussed models – the Circular Flow tool, the BCI, DfD, DfA, and the ReSOLVE framework – are widely applicable within decision-making processes and building typologies, and analyse the circular potential on different building levels. This makes the models suitable for combining it with other models from the field of building reuse to deliver one integrated framework.

The CBR framework should create consciousness on the aspects of circular building methods (INT3), and generate a base level of knowledge on the circular potential of a building (INT2), without using a lot of quantitative data. This knowledge can be used to write out proper tenders to architects and contractors, who eventually develop the buildings. Therefore, a suitable model for the CBR framework can assess the current and future potentials for circular building on different levels of the building. The Circular Flow tool and DfA are more focused on the strategic level of the decision-making process, and less on the project-level of establishing circularity potentials (Barros et al., 2023; Motiei et al., 2024). DfD and DfA are both assessment methods that are commonly used in the construction of buildings, focusing on the circular potentials at the EoL stage of the building (Motiei et al., 2024), making these tools harder to implement in building reuse. The Circular Flow tool and the BCI both calculate potentials for different building layers or processes, but the models require quantitative data (Barros et al., 2023; BCI Gebouw & Alba Concepts, 2022), making them time-consuming and complex.

The ReSOLVE framework is a widely used framework, providing awareness to the user on the CE possibilities within the built environment (Ellen MacArthur Foundation, 2015). The framework itself does not provide a scoring or the defining of a potential. However, the framework presents adequate actions that can be applied to other frameworks to distinguish circular potentials. Combining the transformation meter – which provides the structure of the framework – with the ReSOLVE framework – providing the actions to distinguish circular potential – the CBR framework will meet its aim to support the decision-making process in the pre-project phase on whether to reuse a building or not, and to assist in appointing the project-specific potentials for circular reuse. Nevertheless, this framework needs to be well applied within the context of the transformation meter, to assure the practical application of the ReSOLVE actions.

6.1.4 The Circular Building Reuse framework

The CBR framework, aside from the previously discussed frameworks, presents a tool that includes both the assessment of the current characteristics of the location and the building, to assist in the decision-making process of building reuse, as well as the inclusion of criteria that define the circular potentials for the building. The structure of the CBR framework, based on that of the transformation meter, fits well with the requirements from the Netherlands Police: the framework is straightforward, requires little quantitative data, and is flexible in use throughout their real estate portfolio.

Academically, the CBR framework presents a tool that indicates the circular potential of buildings in the pre-project phase, which is uncommon in existing literature. Majority of the existing tools for circular building are either based on the explanation of circular design strategies, or assess the circular performance of buildings after their construction. In addition, the CBR framework combines this circular potential framework with the process of building reuse, which is another underexposed topic in academic literature.

6.2 Limitations

This study has several limitations that should be considered when interpreting the findings. While the research provides a combined framework that both values the feasibility of building reuse, and defines the circular potential of the building, certain methodological and theoretical constraints may have influenced the results.

First of all, the research has been conducted within the organization of the Netherlands Police. For the development of the CBR framework, experts within the organization have been interviewed to gather information on the process of building reuse and on the current barriers for implementing circular ambitions in their decision-making processes. Within the organization, five experts have been interviewed. These experts all have a different function in the organization, all having to deal with the topic of sustainability. Nevertheless, interviewing more experts from a broader field of expertise would have strengthened the validity of the research. Different experts from within the organization of the Netherlands Police that could have been interviewed are for example expert from the field of acquisition or experts from the finance department. Besides, it would be interesting to see how other – external – parties would experience the barriers of implementing circularity, like architects, contractors, or suppliers.

Another limitation on the final CBR framework is the scope of the framework. The framework has been developed for the entire real estate portfolio of the Netherlands Police, including all building segments they operate in: offices, police stations, and specials. The CBR framework is developed for the entire portfolio, meaning the criteria in the framework are not specified for one building typology. Although most of the criteria are not dependent on the function of the building, some criteria, like the ability to secure the building in different ways, should be slightly adapted for specific functions. Still, using the CBR framework as a base for the criteria, the specific definition of the criteria can easily be specified per function.

A final limitation of this research is regarding the validation of the CBR framework. As a validation, the developed framework has been filled in using a case study of an existing building within the real estate portfolio of the Netherlands Police. This case study has been done together with an expert from the Netherlands Police, whose function is sustainability coordinator for housing. One of the recommendations of this validation session was to involve multiple disciplines in the completion of the framework, to make sure every aspect of the model can be filled in with the right certainty on the topic. For example, the criteria on ‘services’ require some technical knowledge on the current installations in the building. This knowledge might not be known by anyone who fills in the CBR framework. However, due to a limited timeframe, this has not been done within this research.

In general, this study has found the necessary academic literature and expert input to develop the final CBR framework, which was the aim of the study. In the development of this framework, some limitations might have influenced the results, especially due to the organization-specific features of the results.

6.3 Recommendations for the Netherlands Police

6.3.1 Academic recommendations on the CBR framework

Specify the CBR framework

The CBR framework is currently developed for the transformation to any building typology. Therefore, the criteria described in the model are to be interpreted per function. When the framework is to be used for a specific function, the criteria in the first and thirds step and the cost indicators in the second step can be adapted in more detail. This will ensure the efficient use of the framework and more detailed results in the fourth and fifth step.

Work in a multidisciplinary team

To assure the results of the CBR framework are integrally obtained, it is recommended to complete the framework in a multidisciplinary team. To cover all the topics in the framework, it is recommended to collaborate with the current owner of the building, who can provide the legal, environmental, and some building-specific information; a sustainability expert, who has knowledge within the field of CE; a financial advisor, who can advise the team on the financial feasibility of the project; and the property manager of the building, who can provide specific information about the building, for example on the installations. This collaboration will ensure efficient and thorough usage of the framework.

6.3.2 Organizational recommendations

Create awareness

Within the current organization of the Netherlands Police, there is little awareness on the impact of circularity and on the implementation of circular ambitions. As a bottom-up approach to achieve a culture-shift to a

more circular economy, raising awareness at the employees of the Netherlands Police is an important first step. Commercial parties play a significant role in the implementation of the circular ambitions. Nevertheless, the client is the responsible party to provide the commercial parties with these ambitions. The awareness on this division of responsibilities is essential in implementing circular ambitions in the real estate portfolio of the Netherlands Police.

Generate knowledge

To facilitate a well-developed process for the circular reuse of buildings, the Netherlands Police should possess a certain amount of knowledge on this topic. Generating knowledge on the process of circular building can, for instance, be done by visiting factories or suppliers that operate based on CE principles, by for example using biobased materials or second-hand building components. Also, knowledge can be gained by studying examples of buildings that are built according to circular principles. These insights will extend the internal knowledge base of the Netherlands Police, and can contribute to the definition of measurable ambitions on circular building reuse.

Introduce policy

The final, and most effective, recommendation is the introduction of policy on the circular ambitions of the Netherlands Police would enable the organization to develop requirements to realise these ambitions, which would make circularity a manageable factor in the organization. This policy would not necessarily have to include building requirements, only requiring employees to use toolboxes or frameworks, like the CBR framework, would increase the awareness and knowledge within the fields of circular building reuse.

6.4 Follow-up research

Validation of the framework

Further research could be useful to validate the CBR framework in more detail. As described, it would be recommended to complete the framework within a multidisciplinary team, to cover all the topics in the framework. Completing the framework within such a team to validate the tool, would provide valuable insights into the interpreting of the framework. This would ensure the criteria in the framework could be updated to more precise and critical criteria.

Carry out more case studies

In order to validate the framework more, and test the feasibility of the framework, more case studies could be carried out in future researches. The framework would be tested on a broad range of different building types, to make sure the tool is widely applicable within the real estate market. The first case studies could be carried out within the organization of the Netherlands Police, for which the framework is initially developed. Later on in the process, the framework could be applied to the real estate portfolio of other organizations, to test the flexibility of the framework to be used for other parties.

Institutional feasibility

Further research would be required to explore the practical implementation of circularity within the organization of the Netherlands Police. As discussed throughout the thesis, there are multiple categories of barriers of implementing circularity. In the interviews, the barriers experienced within the organization of the Netherlands Police are discussed. A framework, like the CBR framework, could support the organization in implementing circular ambitions. However, for large organizations like this, this would not be sufficient. Future research could find out a strategy to implement circular ambitions within organizations that have no policy on it, experience budget cuts, and do not contain much knowledge on the topic.

Conclusion

07

In the process of developing the CBR framework, the following main question guided the research: “Which conditions are essential for effective circular building reuse, and how can these be integrated into a decision-making framework for the pre-project phase of building reuse?” . The aim of the research is to refine the early stages of the decision-making process for building reuse, in order to increase the likelihood of formulating realistic and feasible ambitions for circular building reuse.

The CBR framework presents a decision-making framework that is applicable in the pre-project phase of building reuse. This framework assists in defining the feasibility of the overall reuse process, and evaluating the circular potential of the building. The structure of the framework is based on the five steps of the transformation meter (Geraedts et al., 2025) and contains the actions of the ReSOLVE framework (Ellen MacArthur Foundation, 2015) to implement circular principles in the tool. The first step of the CBR framework supports the decision-making process in the pre-project phase on whether to reuse a building or not, by assessing the building and its environment on eight veto criteria. These criteria are based on political, environmental, and functional requirements of the building reuse, and all need to be met in order to proceed to the next step of the framework. The second step of the CBR framework explores the financial feasibility of the building reuse process. After the first two steps are successfully completed, the future circular potential of the building is evaluated. Based on the actions from the ReSOLVE framework – regenerate, share, optimize, loop, virtualise, and exchange – the building is examined on all its different layers (Brand, 1995; Nationale Politie, 2021). This evaluation provides a score on the circular reuse potential of the building, presented in step 4, and are discussed in the risk inventory in the final step of the framework. The integrated framework supports the decision-making process in the pre-project phase on whether to reuse a building or not, and assists in appointing the project-specific potentials for circular reuse. Therefore, it bridges the research gap in academic literature on the implementation of circular building methods for the reuse of existing buildings.

Although the CBR framework answers the main research question – to develop an integrated circular building reuse framework for the pre-project phase of building reuse – there are some limitations to this research. First of all, the sample size of the interviewees could be larger, which could lead to more diverse and better supported data for the development of the framework. Besides, the framework is developed for the entire real estate portfolio of the Netherlands Police, making it quite abstract. Concretizing the framework for a specific segment of the portfolio would enable the definition of more detailed criteria, which would make the framework results more detailed for this segment. Finally, the CBR framework is validated with one expert from the Netherlands Police, providing comments and feedback on the improvement of the framework. The validation of the framework within a multi-disciplinary team would ensure more in-depth feedback on all aspects of the framework, throughout all the building layers.

Therefore, future research would be recommended to validate the framework in more detail, collaborating in a multi-disciplinary team of experts. This validation can be carried out using multiple case studies, to test the feasibility and practical application of the framework within different segments of the real estate portfolio of the Netherlands Police. This framework provides a tool for the definition of circular reuse potentials of buildings, however this does not ensure the implementation of circular building methods, which is dependent on a variety of other factors. Further research would be required to explore the practical implementation of circularity within the organization of the Netherlands Police.

Reflection

Personal reflection

Starting this Master's programme, I started thinking about what topics would be interesting for my thesis. A thesis always felt as something so big, something you really had to enjoy every part of. During the previous years, I started developing more and more interest in the field of real estate with a public function. So when the opportunity arose to do a graduation for the organization of the Netherlands Police, I knew that that really interested me. As mentioned in the foreword, the topic of 'circular transformations' is something that matches my personal interest and values as well.

Conducting this research within the Netherlands Police provided a unique opportunity to gain insight into a large public organization and to become familiar with its working environment and decision-making processes. During my studies, I learned a lot of hard skills which I could use during my graduation. But in addition to this, I wanted to further develop my soft skills during this internship. Working in a team; communicating with others; discussing topics; presenting findings; and most of all speaking up whenever I want to share something or need something from someone else are soft skills I wanted to develop. A skill that is specifically useful for this thesis, is the skill of interviewing. This is something that, before my thesis, I never did but was necessary for this research. I will tell more about the interviews in the paragraph on academic reflection.

At the beginning of the internship, I felt a bit hesitant in my role of intern. I had trouble in asking around for help, and was shy in contacting people to chat with me about the topic of my research. However, with some good help from my colleagues at the Netherlands Police, I did manage to do this, which showed me the interest that other people had in my research. This made it much easier to contact other people, and besides helped me a lot in framing the scope of my research.

Another challenge throughout the thesis process was the level of independence required. During the previous seven years of education, I had always worked within relatively structured assignments and clearly defined objectives. I was the only one responsible for the path of this research, which could make me feel quite insecure. However, I experienced that by talking to a lot of different people: mentors from the university; colleagues from the Netherlands Police; but also friends and family who are unfamiliar with the topic, helped me a lot in finding the right path for this research. By explaining to others what I was doing in this research, I was able to find the essence of the research, and by regular sessions with my mentors, I could manage to write this down for the final thesis.

Looking back on the thesis process, I can confidently say that I learned as much about myself as I did about conducting research. I experienced what it is like to enter a new professional environment and discovered that colleagues are often willing to offer support, share knowledge, and take a genuine interest in both your work and personal development. I also learned to better identify the type of support I needed and to recognise who was best positioned to provide it. Throughout the project, I was fortunate to be supported by an extensive and highly engaged team of supervisors and mentors. Initially, this felt somewhat overwhelming. As the process progressed, however, I came to understand each person's expertise, perspective, and working style. This helped me to seek guidance more effectively and to ask the right questions to the right people. I am grateful for all these learning opportunities, and can reflect back on a period where I not only wrote an entire research, but also developed a lot of personal skills that I can use in the rest of my life.

Academic reflection

During my past seven years of studying, I learned a lot of academic hard skills. Still, I felt there was a lot more to learn during my graduation. First of all, I wanted to learn how to do a research that is both based on literature and aligns with the organization's ambitions and objectives. Having an internship at the Netherlands Police was a great opportunity, but could challenge me in the focus on the academic research. Given the practical relevance of the topic, there was a risk of focusing primarily on developing a tool for the organization rather than conducting an academic study. With the right help from my mentors at the university, and changing my own perspective on the thesis, I think I managed to make this research based on academic findings and an academic research gap, which I could apply to the organization's objectives in the development of the actual framework.

One aspect of the research methodology that was entirely new to me was conducting interviews. When I first thought of this as a main research method of this thesis, I doubted my own skills in doing this. However, after

discussing these doubts with my mentors, and developing well thought-off research questions based on the literature, that would guide me through these interviews, I got more confident in this process. Especially after talking to experts from the Netherlands Police, who I was planning to conduct the interviews with as well, I quickly realised that all these people were very enthusiastic to talk about their work, the organization they work for, and how certain challenges could be addressed. Throughout the interviews, I realised I got more familiar with the topic and the perspectives of the Netherlands Police on this topic, which made me go through the interviews more easy. At some interviews, I even got some compliments on the questions I asked or on the insights I had gained so far, which really boosted my confidence. Afterwards, I saw the benefits of planning out the interviews so well on forehand, which I was grateful for my mentors for who really supported me in this. I can reflect back on an experience in which I developed a new academic skill that will help me within my entire future career.

Another academic challenge within this research was the breadth of topics involved. The study brought together multiple fields of knowledge, including building reuse, circularity, and the management of organisational ambitions. The combination of all these different perspectives could feel quite overwhelming. During certain phases of the research, I found myself exploring several themes simultaneously without fully understanding how they would eventually come together within a single framework. As a result, I occasionally lost sight of the overarching narrative of the research, which led to uncertainty about the direction and value of my work. The past six months have involved collecting, analysing, and connecting a wide range of ideas and perspectives. Although not every article, report, or concept I studied is explicitly referenced in the final document, each contributed to my understanding of the topic and informed the decisions made throughout the research process. I learned that within academic research, it is really important to develop a broad understanding of the topic, in order to narrow down the research scope to a specific field of expertise that is relevant to the topic. In that sense, every source I explored contributed to the final outcome, whether visibly or behind the scenes.

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Appendix 1. Interview questions (in Dutch)

Introductie

Fijn dat u er kunt zijn vandaag. We nemen vandaag een interview af voor mijn afstudeeronderzoek aan de TU Delft, wat gaat over het circulair hergebruik van bestaande gebouwen. We hebben elkaar al eerder gesproken, dus u bent al bekend met het onderzoek wat ik doe. Dit interview heeft het doel om bestaande processen rondom het hergebruik van gebouwen en circulariteit binnen de organisatie van de politie beter te gaan begrijpen.

Kunt u mij in een zin vertellen wat u doet en op welk schaalniveau (portfolio vs project)?

Hergebruik van gebouwen

In de vastgoedstrategie van de politie staat dat er met voorkeur wordt gewerkt met het hergebruik van bestaand politievastgoed. Hergebruik wordt hier gezien als het transformeren van een gebouw naar een nieuwe functie, dit gebouw kan al in het vastgoedportfolio van de politie zitten of van daarbuiten worden aangekocht.

Kunt u me meenemen in het proces van het hergebruik van vastgoed?

Doorvraagmogelijkheden:

- Zijn er bepaalde voorwaarden voor een gebouw om geschikt te zijn voor hergebruik?
- Wie neemt uiteindelijk de beslissing of een gebouw hergebruikt wordt?
- Wat is het voornaamste doel van hergebruik volgens u?

Circulariteit

De circulaire economie gaat erover dat er zo min mogelijk nieuwe materialen worden gebruikt, en die in plaats daarvan er langer gebruik wordt gemaakt van bestaande materialen. Dit werkt op verschillende niveaus: het hergebruik van een gebouw zelf is al circulair, maar er zijn daarna nog veel verschillende manieren om een gebouw zo circulair mogelijk te ontwikkelen. De politie is bezig met het opstellen van richtlijnen en ka-ders omtrent circulariteit.

Kunt u me vertellen hoe circulariteit al wordt meegenomen in de huidige organisatie van de politie? Welke obstakels ervaart u bij het circulair bouwen binnen de politie?

Doorvraagmogelijkheden:

- Ervaart u technologische obstakels?
 - Bijvoorbeeld een gebrek aan (technische) kennis of het gebrek aan bewijs over het resultaat.
 - Ervaart u markt of economische obstakels?
 - Bijvoorbeeld hoge investeringskosten, en/of een lange terugverdiertijden.
 - Ervaart u institutionele obstakels?
 - Bijvoorbeeld een complexe regelgeving of een gebrek aan beleid rondom circulariteit.
 - Ervaart u sociale of culturele obstakels?
 - Bijvoorbeeld een gebrek aan bewustwording of kennis rondom circulariteit of een conservatieve cultuur.
 - Er worden op portefeuilleniveau wel eisen gesteld aan circulariteit: bijvoorbeeld dat 60% van het vastgoed in 2030 CO2-neutraal moet zijn. Hoe zorg je ervoor dat individuele projecten hiermee aan de slag gaan?
- Het blijkt dat ambities die vroeg in het ontwerpproces al worden vastgesteld een grotere kans van slagen hebben. Ook voor circulariteit is het dus van belang dat er vroeg over wordt nagedacht en op projectniveau doelen worden gesteld aan een gebouw.

Wat zou u adviseren, nog voor het ontwerp van het gebouw, om circulaire ambities beter te kunnen implementeren binnen de politie?

Denk aan:

- Gebouwlagen van Brand (ook beschreven in de toolbox adaptief vermogen)
- Design strategies (Df Optimization, Df Adaptability, Df Disassembly)

Afsluitend

We zijn aan het einde gekomen van dit interview. Aan de hand van deze informatie ga ik twee modellen kiezen, een voor gebouw hergebruik en een voor circulariteit, die uiteindelijk gecombineerd gaan worden tot één model voor circulair hergebruik. Dit model wil ik testen op bestaande gebouwen uit de portefeuille van de politie.

Kent u bestaande objecten binnen de vastgoedportefeuille van de politie die gepland staan om afgestoten te worden, die interessant zouden kunnen zijn als case study?

Om dit model te testen kan het anderzijds ook interessant zijn om reeds gerealiseerde gebouwen te testen aan de hand van dit model.

Kent u projecten waarin circulariteit aan de voorkant al is meegenomen (bijvoorbeeld door een toolbox te gebruiken) als concrete ambitie?

Wie zouden verder nog interessant zijn om te spreken voor dit onderzoek?

Appendix 2. Informed consent form (empty)

Due to covert information, the completed informed consent forms by the participants are protected and in a separate document.

Delft University of Technology
HUMAN RESEARCH ETHICS
INFORMED CONSENT FORM

U wordt uitgenodigd om deel te nemen aan een onderzoek genaamd “The potential for circular building reuse”. Dit onderzoek wordt uitgevoerd door Leonoor Eikelboom van de TU Delft, tijdens een afstudeerstage op de afdeling LPM bij de Nederlandse Politie.

Het doel van dit onderzoek is om een geïntegreerd framework voor circulair hergebruik van gebouwen te ontwikkelen, wat gebruikt kan worden om in de pre-project fase haalbare ambities omtrent circulair hergebruik vast te kunnen stellen. Het interview zal ongeveer 60-90 minuten in beslag nemen. De data zal gebruikt worden voor een master thesis, dat zal worden gepubliceerd op de TU Delft Repository. U wordt gevraagd om deel te nemen in een interview waarmee kennis wordt opgedaan over de huidige processen van hergebruik van gebouwen en circulariteit binnen de Nederlandse Politie.

Zoals bij elke (online) activiteit is het risico van een databreuk aanwezig. Wij doen ons best om uw antwoorden vertrouwelijk te houden. We minimaliseren de risico's door enkel gebruik te maken van beveiligde diensten. Daarnaast zullen de interviews geanonimiseerd worden wanneer delen hieruit gebruikt worden in het onderzoek.

Uw deelname aan dit onderzoek is volledig vrijwillig, en **u kunt zich elk moment terugtrekken zonder reden op te geven**. U bent vrij om vragen niet te beantwoorden. Na afronding van dit onderzoek zal de data van de interviews verwijderd worden.

Contactgegevens uitvoerend onderzoeker:

Leonoor Eikelboom
L.J.Eikelboom@student.tudelft.nl

Contactgegevens verantwoordelijke onderzoeker:

Monique Arkesteijn
M.H.Arkesteijn@tudelft.nl

	Ja	Nee
A: ALGEMEEN – ONDERZOEKSDOELEN, VERWACHTINGEN DEELNEMER, VRIJWILLIGE DEELNAME		
1. Ik heb de informatie over het onderzoek gedateerd 12-05-2026 gelezen en begrepen, of deze is aan mij voorgelezen. Ik heb de mogelijkheid gehad om vragen te stellen over het onderzoek en mijn vragen zijn naar tevredenheid beantwoord.	<input type="checkbox"/>	<input type="checkbox"/>
2. Ik doe vrijwillig mee aan dit onderzoek, en ik begrijp dat ik kan weigeren vragen te beantwoorden en mij op elk moment kan terugtrekken uit de studie, zonder een reden op te hoeven geven.	<input type="checkbox"/>	<input type="checkbox"/>
3. Ik begrijp dat mijn deelname aan het onderzoek de volgende punten betekent: <ul style="list-style-type: none"> • De audio van de interviews worden opgenomen met MS Teams. • De opnames zullen worden getranscribeerd om informatie uit de data te genereren. 	<input type="checkbox"/>	<input type="checkbox"/>
4. Ik begrijp dat de studie binnen 4 maanden of eerdere afronding van het onderzoek eindigt.	<input type="checkbox"/>	<input type="checkbox"/>
B: POTENTIELE RISICO'S DEELNAME		
5. Ik begrijp dat mijn deelname de volgende risico's met zich meebrengt: mogelijk fysiek of mentaal ongemak, zoals lichte stress. Ik begrijp dat deze risico's worden geminimaliseerd door de mogelijkheid om deelname op elk moment stop te zetten.	<input type="checkbox"/>	<input type="checkbox"/>
6. Ik begrijp dat mijn deelname betekent dat er persoonlijke identificeerbare informatie en onderzoeksdata worden verzameld, met het risico dat ik hieruit geïdentificeerd kan worden en reputatieschade kan oplopen op professioneel gebied.	<input type="checkbox"/>	<input type="checkbox"/>
7. Ik begrijp dat de volgende stappen worden ondernomen om het risico van een databreuk te minimaliseren, en dat mijn identiteit op de volgende manieren wordt beschermd in het geval van een databreuk: <ul style="list-style-type: none"> • De opnames van de interviews worden opgeslagen op persoonlijke servers. • Audiobestanden worden na het transcriberen verwijderd. • De getranscribeerde interviews zullen zijn geanonimiseerd. • Data is alleen toegankelijk voor het onderzoeksteam. 	<input type="checkbox"/>	<input type="checkbox"/>
8. Ik begrijp dat de persoonlijke informatie die over mij verzameld wordt en mij kan identificeren, zoals naam en contactgegevens, niet gedeeld worden buiten het studieteam.	<input type="checkbox"/>	<input type="checkbox"/>
9. Ik begrijp dat de persoonlijke data die over mij verzameld wordt, vernietigd zal worden na afloop van dit onderzoek.	<input type="checkbox"/>	<input type="checkbox"/>
C: ONDERZOEKSPUBLICATIE, VERSPREIDING EN TOEPASSING		
10. Ik begrijp dat na het onderzoek de geanonimiseerde informatie gebruikt zal worden voor het beter begrijpen van de huidige besluitvormingsprocessen bij de Nederlandse Politie en de	<input type="checkbox"/>	<input type="checkbox"/>

	Ja	Nee
toepassing hierop binnen het hergebruik van bestaande gebouwen en circulair bouwen. Deze data zal uiteindelijk deel zijn van het afstudeerrapport.		
11. Ik geef toestemming om mijn antwoorden, ideeën of andere bijdrages anoniem te quoten in resulterende producten.	<input type="checkbox"/>	<input type="checkbox"/>
D: (LANGE TERMIJN) DATA OPSLAG, TOEGANKELIJKHEID EN HERGEBRUIK		
12. Ik geef toestemming om de geanonimiseerde data die over mij verzameld worden gearhiveerd worden in de TU Delft Repository opdat deze gebruikt kunnen worden voor toekomstig onderzoek en onderwijs.	<input type="checkbox"/>	<input type="checkbox"/>
13. Ik begrijp dat de toegang tot de TU Delft Repository open is tot 10 jaar na publicatie.	<input type="checkbox"/>	<input type="checkbox"/>

Handtekeningen

Naam deelnemer

Handtekening

Datum

Ik, **de onderzoeker**, verklaar dat ik de informatie en het instemmingsformulier correct aan de potentiële deelnemer heb voorgelezen en, naar het beste van mijn vermogen, heb verzekerd dat de deelnemer begrijpt waar hij/zij vrijwillig mee instemt.

Leonoor Eikelboom

Naam onderzoeker



Handtekening

20-04-2026

Datum

Contactgegevens van de onderzoeker voor verdere informatie:

Leonoor Eikelboom

L.J.Eikelboom@student.tudelft.nl

06-26659427

Appendix 3. Interview transcripts

Due to covert information, the interview transcripts are protected and in a separate document.

Appendix 4. CBR framework step 1-5

Step 1. Quick scan based on veto criteria

The first step of the framework focuses on the first part of the aim of the framework: *to support the decision-making process in the pre-project phase on whether to reuse a building or not*. This step includes the veto criteria, which have to be met in order to continue the building reuse process. Answer all of the questions below with 'yes' or 'no'. If needed, consult a colleague or expert to fill in the right answer. Only if all questions are answered with the answer 'yes', you can proceed to the next step.

Veto criteria		Definition	Source	Assessment (yes/no)
Is the owner willing to sell (or rent out) the building?		Does the current owner of the building want to sell or rent out the building to the Netherlands Police?	Owner	Select answer
Can permits be granted for a zoning plan change?		Does the new function of the building align with the current zoning plan? And could it be changed if needed?	Municipality	Select answer
Are there <u>no</u> health risks from odor, noise, or pollution?		Are there any health risks in the environmental that could withhold the project?	On-site observations / real estate agent	Select answer
Are there <u>no</u> environmental risks like flood risk or land subsidence?		Are there any environmental risks at the location that could withhold the project?	On-site observations / real estate agent	Select answer
Is the location reachable for employees?		Is the location reachable by car and public transport? And in case of police stations, can police cars leave the location quick enough?	On-site observations	Select answer
Can the (outside and inside of the) building be properly secured ?		Can the building be secured on the level that is demanded by the function of the building?	On-site observations	Select answer
Does the building have access to energy sources by being connected to the power grid?		Is the building connected to the local power grid? And does it provide enough power for the function of the building?	Municipality	Select answer
Is the building visible and accessible for the public?		Is the building currently, or in the near future, at a visible and accessible location for the public?	On-site observations	Select answer

Step 2

Due to covert information, the financial data of the second step of the framework are protected and in a separate document.

Building characteristics

Adress	
Construction date	
Surface area (in m2)	
Current function	Select answer
Future function	Select answer

Transformation costs

Total surface area (in m2)	0
New function	Select answer
Transformed surface area (in %)	
Transformation costs (€/m2)	
Transformation costs	€ 0

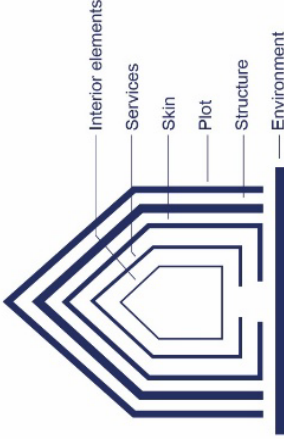
Step 3.

Step 3. Detailed evaluation based on gradual criteria

This step is focused on the second part of the aim of the framework, which is to assist in appointing the project-specific potentials for circular reuse. The criteria in this step are divided into the six layers of a building as used in the 'Toolbox for Adaptability police buildings'. The aim of these building layers theory is that the layers operate on their own, so the total lifespan of the building is not dependent on one single layer.

The **environment** of the building includes availability of transportation possibilities, facilities and parking. Also non-physical characteristics like social security and noise pollution affect the adaptability of the building. The land the property is built on, the **plot**, highly influences the adaptability of the building. Compact buildings can create space for expansion of the building, and by clustering functions in the building, the flexibility in expansion/downscaling is increased. The **structure** of the building includes the construction, floors, cores of the building and riser shafts. Open-space structures, like columns, increase the flexibility of the building. The **skin** has different requirements per function of the building, for example on isolation and ventilation. The skin should be adaptable for changing functions. **Services** can add to the adaptability of the building by being accessible. Service shafts and other rooms for services should be spacious enough to foresee future changes. Finally, the **interior elements** of the building include both the interior walls, furniture and sanitary facilities. These elements should be detachable to ensure the adaptability of the building.

In this step, the criteria are assessed gradually, meaning that each criteria is provided a score: low performance (0 points), medium performance (5 points), or high performance (10 points). Provide a score to each criteria, based on the performance indicators described in the table, whereafter a total score per building layer will be given.



Environment

Criteria	Definition	Low performance (0 pt)	Medium performance (6 pt)	High performance (10 pt)	Assessment	ReSOLVE
What is the distance to the closest public transport station?	This includes public transport stations that enable regular traveling to other transportation hubs	>1000 m	500-1000 m	<500 m	Select answer	Share, Optimize
Are there physical barriers blocking daylight to the facades?	Any fixed barriers, like buildings	Yes	Partly	No	Select answer	Optimize, Exchange
Is the location of the building suitable for other functions?	When the building is obsolete, can the location host other functions than the current one?	No	For a few other functions	Yes, to all functions	Select answer	Optimize, Loop
Does the location use localised renewable energy sources?	Like solar energy, wind power, or geothermal energy.	No	Some	Yes	Select answer	Optimize, Loop
Score:						0%

Plot

Criteria	Definition	Low performance (0 pt)	Medium performance (6 pt)	High performance (10 pt)	Assessment	ReSOLVE
Are there possibilities for expanding facilities outside the plot (parking, greenery, building, etc.)?	For example, are there empty terrains surrounding the building that can be added to the plot?	No	Expansion up to 50% is possible	>50% expansion is possible	Select answer	Optimize, Loop
Are there possibilities for expanding facilities inside the plot (parking, greenery, building, etc.)?	Is there any space on the plot to expand the facilities?	No	Expansion up to 50% is possible	>50% expansion is possible	Select answer	Optimize, Loop
Can (part of) the plot be disposed?	Are there redundant parts of the plot that could be disposed?	No	Disposal up to 50% is possible	>50% disposal is possible	Select answer	Optimize, Loop, Share
Score:						0%

Structure

Criteria	Definition	Low performance (0 pt)	Medium performance (6 pt)	High performance (10 pt)	Assessment	ReSOLVE
What is the positioning (of barriers) of the loadbearing structure (columns or loadbearing walls)?	Does the positioning enable flexible use of the space?	The possibility for adapting the layout of the building is severely hindered by loadbearing structures	The possibility for adapting the layout of the building is slightly hindered by loadbearing structures	The possibility for adapting the layout of the building is not hindered by loadbearing structures	Select answer	Optimize, Loop
How is the building circulation organised (stairs, elevators)?	Are all stairs and elevators placed at one place, or are they spread throughout the building?	Building has one decentralized staircase and/or elevator core	Building has one centralized staircase and/or elevator core	Building has one centralized staircase and/or elevator core, and each building wing has its own staircase and/or elevator	Select answer	Optimize, Loop
Are there possibilities for moving the building circulation (stairs, elevators)?	Can the stairs and elevators be moved to another place?	No	Moving the building circulation is possible in only one direction	Moving the building circulation is possible in both directions	Select answer	Optimize, Loop

Step 3. continued

What is the horizontal grid size?	The size between the structural elements.	>3.60 m	1.80 m or 0.90 m	0,30 m	Select answer	Optimize, Loop
What is the floor height?	The clear floor-to-ceiling height.	<2.60 m	2.60-3.40 m	>3.40 m	Select answer	Optimize, Loop
To what extent can components of the structure be reused?	Like reusing steel beams.	Components of the structure are not reusable	Components of the structure are partly reusable	Components of the structure are easily reusable	Select answer	Share, Loop
Are low-impact materials used in the construction?	For example timber or biobased materials like hempcrete.	No	Partly	Yes	Select answer	Regenerate
Score:						0%

Skin

Criteria	Definition	Low performance (0 pt)	Medium performance (5 pt)	High performance (10 pt)	Assessment	ReSOLVE
How are windows placed in order to provide natural daylight to the building?	What is the shape and size of windows, and are they placed regularly?	There are no to little windows	There are plenty of windows, but they have different sizes and are placed on different heights	There are plenty of big, uninterrupted windows	Select answer	Optimize, Exchange
Can windows be opened?	By the users themselves, to ensure natural ventilation.	<10% of the windows can be opened	10-80% of the windows can be opened	>80% of the windows can be opened	Select answer	Optimize, Exchange
How is the operation of sun shading organised?	Can people operate the sun shading themselves?	Centralized for the entire building	Per building department, wing, floor, unit, etc.	On the level of the smallest skin grid	Select answer	Optimize, Exchange
To what extent can elements of the skin be reused?	Assuming all building layers operate independently.	Elements of the skin are not reusable (due to heritage protection status)	Elements of the skin are partly reusable	Elements of the skin are easily reusable	Select answer	Share, Loop
Score:						0%

Services

Criteria	Definition	Low performance (0 pt)	Medium performance (5 pt)	High performance (10 pt)	Assessment	ReSOLVE
What is the location of building services (cooling, heating)?	And are they operated by the users, or regionally?	One centralized location for the entire building	On multiple locations throughout the building	Building services are operated on regional level (e.g. district heating)	Select answer	Share, Optimize
To what extent can the installation components be uncoupled?	In case the installations needs to be changed, does this influence other building layers?	The installation components can not be uncoupled	The installation components can partly be uncoupled	The installation components can easily be uncoupled	Select answer	Share, Optimize, Loop
Are there possibilities for rainwater harvesting and recycling?	On the building plot or nearby.	No	Yes, but it has a lot of disadvantages	Yes	Select answer	Loop
To what extent can the installations be reused?	Assuming all building layers operate independently.	The installations are not reusable	The installations are partly reusable	The installations are easily reusable	Select answer	Share, Loop
Score:						0%

Interior elements

Criteria	Definition	Low performance (0 pt)	Medium performance (5 pt)	High performance (10 pt)	Assessment	ReSOLVE
Is the building layout suitable for multiple functions?	When the building is obsolete, does the layout of the building enable the use of the building for other functions?	The building layout is suitable for only one function	The building layout is suitable for 2-4 functions	The building layout is suitable for 4+ functions	Select answer	Loop
Can interior walls be moved?	Possibly by taking it down and reassembling it.	No, this is too expensive or structural challenging	Interior walls can be demolished and rebuilt	Interior walls can be easily moved (e.g. demountable partition walls)	Select answer	Share, Optimize, Loop
Can building components (interior walls, floors, ceilings) be reused or exchanged?	Assuming all building layers operate independently.	No	50-80% is reusable or exchangeable	All building components are easily reusable or exchangeable	Select answer	Share, Optimize, Loop
Are biodegradable or compostable materials used?	Like bamboo or timber.	No	Partly	Yes	Select answer	Regenerate, Loop
Are there possibilities for video and virtual conferencing?	To encourage hybrid working.	No	In some parts of the	Yes	Select answer	Virtualise
Score:						0%

Step 4. Determination of the circular building reuse potential

The fourth step defines the circular building reuse potential of the building. The score is expressed in percentages, and scoring is done per building level and for the entire building. Since the intention is that all building layers operate independently, the scoring of one building layer does not have to influence the scoring of other layers.

Building layer	Potential
Environment	0%
Plot	0%
Structure	0%
Skin	0%
Services	0%
Interior elements	0%
Average	0%

Step 5. Risk inventory

Based on the answers provided in the third step, the risks of this project can be determined. All the scores from the third step are summarized in this step, so there is an overview of the criteria that could form a risk for the project. Some of the low performance scores – and therefore risks – are inevitable. This risk inventory does not require further actions to be taken, it provides the user of the framework with awareness on the risks of the project.

Environment

Criteria	Assessment	Cause	Potential risk
What is the distance to the closest public transport station?	Select answer		
Are there physical barriers blocking daylight to the facades?	Select answer		
Is the location of the building suitable for other functions?	Select answer		
Does the location use localised renewable energy sources?	Select answer		

Plot

Criteria	Assessment	Cause	Potential risk
Are there possibilities for expanding facilities <u>outside</u> the plot?	Select answer		
Are there possibilities for expanding facilities <u>inside</u> the plot?	Select answer		
Can (part of) the plot be disposed?	Select answer		

Structure

Criteria	Assessment	Cause	Potential risk
What is the positioning (of barriers) of the loadbearing structure?	Select answer		
How is the building circulation organised?	Select answer		
Are there possibilities for moving the building circulation?	Select answer		
What is the horizontal grid size?	Select answer		
What is the floor height?	Select answer		
To what extent can components of the structure be reused?	Select answer		
Are low-impact materials used in the construction?	Select answer		

Skin

Criteria	Assessment	Cause	Potential risk
How are windows placed in order to provide natural daylight to the building?	Select answer		
Can windows be opened?	Select answer		
How is the operation of sun shading organised?	Select answer		
To what extent can elements of the skin be reused?	Select answer		

Services

Criteria	Assessment	Cause	Potential risk
What is the location of building services?	Select answer		
To what extent can the installation components be uncoupled?	Select answer		
Are there possibilities for rainwater harvesting and recycling?	Select answer		
To what extent can the installations be reused?	Select answer		

Interior elements

Criteria	Assessment	Cause	Potential risk
Is the building layout suitable for multiple functions?	Select answer		
Can interior walls be moved?	Select answer		
Can building components be reused or exchanged?	Select answer		
Are biodegradable or compostable materials used?	Select answer		
Are there possibilities for video and virtual conferencing?	Select answer		

Appendix 5. Case study CBR framework step 1-5

Step 1. Quick scan based on veto criteria

The first step of the framework focuses on the first part of the aim of the framework: *to support the decision-making process in the pre-project phase on whether to reuse a building or not*. This step includes the veto criteria, which have to be met in order to continue the building reuse process. Answer all of the questions below with 'yes' or 'no'. If needed, consult a colleague or expert to fill in the right answer. Only if all questions are answered with the answer 'yes', you can proceed to the next step.

Veto criteria		Definition	Source	Assessment (yes/no)
Is the owner willing to sell (or rent out) the building?		Does the current owner of the building want to sell or rent out the building to the Netherlands Police?	Owner	Yes
Can permits be granted for a zoning plan change?		Does the new function of the building align with the current zoning plan? And could it be changed if needed?	Municipality	Yes
Are there <u>no</u> health risks from odor, noise, or pollution?		Are there any health risks in the environmental that could withhold the project?	On-site observations / real estate agent	Yes
Are there <u>no</u> environmental risks like flood risk or land subsidence?		Are there any environmental risks at the location that could withhold the project?	On-site observations / real estate agent	Yes
Is the location reachable for employees?		Is the location reachable by car and public transport? And in case of police stations, can police cars leave the location quick enough?	On-site observations	Yes
Can the (outside and inside of the) building be properly secured ?		Can the building be secured on the level that is demanded by the function of the building?	On-site observations	Yes
Does the building have access to energy sources by being connected to the power grid?		Is the building connected to the local power grid? And does it provide enough power for the function of the building?	Municipality	Yes
Is the building visible and accessible for the public?		Is the building currently, or in the near future, at a visible and accessible location for the public?	On-site observations	Yes

Step 2.

Due to covert information, the financial data of the second step of the framework are protected and in a separate document.

Building characteristics

Adress	Marten Meesweg 35, Rotterdam
Construction date	1989
Surface area (in m2)	18.889
Current function	Office
Future function	Forensic investigation

Transformation costs

Total surface area (in m2)	18.889
New function	Forensic investigation
Transformed surface area (in %)	50%
Transformation costs (€/m2)	€ 1.957
Transformation costs	€ 18.482.887

Step 3.

Step 3. Detailed evaluation based on gradual criteria

This step is focused on the second part of the aim of the framework, which is to assist in appointing the project-specific potentials for circular reuse. The criteria in this step are divided into the six layers of a building as used in the Toolbox for Adaptability police buildings. The aim of these building layers theory is that the layers operate on their own, so the total lifespan of the building is not dependent on one single layer.

The **environment** of the building includes availability of transportation possibilities, facilities and parking. Also non-physical characteristics like social security and noise pollution affect the adaptability of the building. The land the property is built on, the **plot**, highly influences the adaptability of the building. Compact buildings can create space for expansion of the building, and by clustering functions in the building, the flexibility in expansion/downscaling is increased. The **structure** of the building includes the construction, floors, cores of the building and riser shafts. Open-space structures, like columns, increase the flexibility of the building. The **skin** has different requirements per function of the building, for example on isolation and ventilation. The skin should be adaptable for changing functions. **Services** can add to the adaptability of the building by being accessible. Service shafts and other rooms for services should be spacious enough to foresee future changes. Finally, the **interior elements** of the building include both the interior walls, furniture and sanitary facilities. These elements should be detachable to ensure the adaptability of the building.

In this step, the criteria are assessed gradually, meaning that each criteria is provided a score: low performance (0 points), medium performance (5 points), or high performance (10 points). Provide a score to each criteria, based on the performance indicators described in the table, whereafter a total score per building layer will be given.

Environment

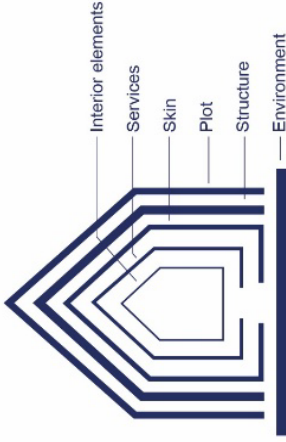
Criteria	Definition	Low performance (0 pt)	Medium performance (5 pt)	High performance (10 pt)	Assessment	ReSOLVE
What is the distance to the closest public transport station?	This includes public transport stations that enable regular traveling to other transportation hubs.	>1000 m	500-1000 m	<500 m	10	Share, Optimize
Are there physical barriers blocking daylight to the facades?	Any fixed barriers, like buildings	Yes	Partly	No	10	Optimize, Exchange
Is the location of the building suitable for other functions?	When the building is obsolete, can the location host other functions than the current one?	No	For a few other functions	Yes, to all functions	5	Optimize, Loop
Does the location use localised renewable energy sources?	Like solar energy, wind power, or geothermal energy.	No	Some	Yes	5	Optimize, Loop
Score:					75%	

Plot

Criteria	Definition	Low performance (0 pt)	Medium performance (5 pt)	High performance (10 pt)	Assessment	ReSOLVE
Are there possibilities for expanding facilities outside the plot (parking, greenery, building, etc.)?	For example, are there empty terrains surrounding the building that can be added to the plot?	No	Expansion up to 50% is possible	>50% expansion is possible	0	Optimize, Loop
Are there possibilities for expanding facilities inside the plot (parking, greenery, building, etc.)?	Is there any space on the plot to expand the facilities?	No	Expansion up to 50% is possible	>50% expansion is possible	0	Optimize, Loop
Can (part of) the plot be disposed?	Are there redundant parts of the plot that could be disposed?	No	Disposal up to 50% is possible	>50% disposal is possible	0	Optimize, Loop, Share
Score:					0%	

Structure

Criteria	Definition	Low performance (0 pt)	Medium performance (5 pt)	High performance (10 pt)	Assessment	ReSOLVE
What is the positioning (of barriers) of the loadbearing structure (columns or loadbearing walls)?	Does the positioning enable flexible use of the space?	The possibility for adapting the layout of the building is severely hindered by loadbearing structures	The possibility for adapting the layout of the building is slightly hindered by loadbearing structures	The possibility for adapting the layout of the building is not hindered by loadbearing structures	10	Optimize, Loop
How is the building circulation organised (stairs, elevators)?	Are all stairs and elevators placed at one place, or are they spread throughout the building?	Building has one decentralized staircase and/or elevator core	Building has one centralized staircase and/or elevator core	Building has one centralized staircase and/or elevator core, and each building wing has its own staircase and/or elevator core	10	Optimize, Loop
Are there possibilities for moving the building circulation (stairs, elevators)?	Can the stairs and elevators be moved to another place?	No	Moving the building circulation is possible in only one direction	Moving the building circulation is possible in both directions	10	Optimize, Loop



Step 3. continued

What is the floor height?	The clear floor-to-ceiling height.	<2.60 m	2.60-3.40 m	>3.40 m	5	Optimize, Loop
To what extent can components of the structure be reused?	Like reusing steel beams.	Components of the structure are not reusable	Components of the structure are partly reusable	Components of the structure are easily reusable	5	Share, Loop
Are low-impact materials used in the construction?	For example timber or biobased materials like hempcrete.	No	Partly	Yes	0	Regenerate
Score:					71%	

Skin

Criteria	Definition	Low performance (0 pt)	Medium performance (5 pt)	High performance (10 pt)	Assessment	ReSOLVE
How are windows placed in order to provide natural daylight to the building?	What is the shape and size of windows, and are they placed regularly?	There are no to little windows	There are plenty of windows, but they have different sizes and are placed on different heights	There are plenty of big, uninterrupted windows	10	Optimize, Exchange
Can windows be opened?	By the users themselves, to ensure natural ventilation.	<10% of the windows can be opened	10-80% of the windows can be opened	>80% of the windows can be opened	5	Optimize, Exchange
How is the operation of sun shading organised?	Can people operate the sun shading themselves?	Centralized for the entire building	Per building department, wing, floor, unit, etc.	On the level of the smallest skin grid	10	Optimize, Exchange
To what extent can elements of the skin be reused?	Assuming all building layers operate independently*.	Elements of the skin are not reusable (due to heritage protection status)	Elements of the skin are partly reusable	Elements of the skin are easily reusable	10	Share, Loop
Score:					88%	

Services

Criteria	Definition	Low performance (0 pt)	Medium performance (5 pt)	High performance (10 pt)	Assessment	ReSOLVE
What is the location of building services (cooling, heating)?	And are they operated by the users, or regionally?	One centralized location for the entire building	On multiple locations throughout the building	Building services are operated on regional level (e.g. district heating)	10	Share, Optimize
To what extent can the installation components be uncoupled?	In case the installations needs to be changed, does this influence other building layers?	The installation components can not be uncoupled	The installation components can partly be uncoupled	The installation components can easily be uncoupled	0	Share, Optimize, Loop
Are there possibilities for rainwater harvesting and recycling?	On the building plot or nearby.	No	Yes, but it has a lot of disadvantages	Yes	0	Loop
To what extent can the installations be reused?	Assuming all building layers operate independently*.	The installations are not reusable	The installations are partly reusable	The installations are easily reusable	5	Share, Loop
Score:					38%	

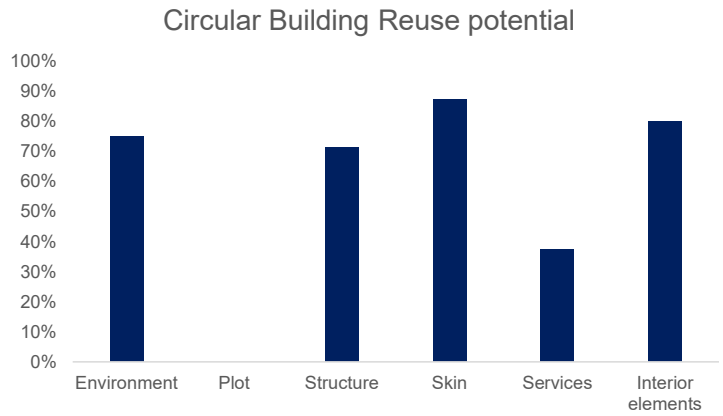
Interior elements

Criteria	Definition	Low performance (0 pt)	Medium performance (5 pt)	High performance (10 pt)	Assessment	ReSOLVE
Is the building layout suitable for multiple functions?	When the building is obsolete, does the layout of the building enable the use of the building for other functions?	The building layout is suitable for only one function	The building layout is suitable for 2-4 functions	The building layout is suitable for 4+ functions	10	Loop
Can interior walls be moved?	Possibly by taking it down and reassembling it.	No, this is too expensive or structural challenging	Interior walls can be demolished and rebuilt	Interior walls can be easily moved (e.g. demountable partition walls)	10	Share, Optimize, Loop
Can building components (interior walls, floors, ceilings) be reused or exchanged?	Assuming all building layers operate independently*.	No	50-80% is reusable or exchangeable	All building components are easily reusable or exchangeable	10	Share, Optimize, Loop
Are biodegradable or compostable materials used?	Like bamboo or timber.	No	Partly	Yes	0	Regenerate, Loop
Are there possibilities for video and virtual conferencing?	To encourage hybrid working.	No	In some parts of the building	Yes	10	Virtualise
Score:					80%	

Step 4. Determination of the circular building reuse potential

The fourth step defines the circular building reuse potential of the building. The score is expressed in percentages, and scoring is done per building level and for the entire building. Since the intention is that all building layers operate independently, the scoring of one building layer does not have to influence the scoring of other layers.

Building layer	Potential
Environment	75%
Plot	0%
Structure	71%
Skin	88%
Services	38%
Interior elements	80%
Average	59%



Step 5. Risk inventory

Based on the answers provided in the third step, the risks of this project can be determined. All the scores from the third step are summarized in this step, so there is an overview of the criteria that could form a risk for the project. Some of the low performance scores – and therefore risks – are inevitable. This risk inventory does not require further actions to be taken, it provides the user of the framework with awareness on the risks of the project.

Environment

Criteria	Assessment	Cause	Potential risk
What is the distance to the closest public transport station?	10		
Are there physical barriers blocking daylight to the facades?	10		
Is the location of the building suitable for other functions?	5	Little outdoor space.	The location is suitable for a specific type of building functions.
Does the location use localised renewable energy sources?	5	There are solar panels on the roof.	The building is dependent on external energy sources.

Plot

Criteria	Assessment	Cause	Potential risk
Are there possibilities for expanding facilities <u>outside</u> the plot?	0	The plot is entirely surrounded by other building plots.	Facilities can not be added outside the building plot, therefore the location is suitable for a specific type of functions.
Are there possibilities for expanding facilities <u>inside</u> the plot?	0	The majority of the building plot is occupied by the building.	Facilities can not be added inside the building plot, therefore the location is suitable for a specific type of functions.
Can (part of) the plot be disposed?	0	The majority of the building plot is occupied by one building.	The size of the plot is hardly adjustable, therefore the location is suitable for a specific type of functions.

Structure

Criteria	Assessment	Cause	Potential risk
What is the positioning (of barriers) of the loadbearing structure?	10		
How is the building circulation organised?	10		
Are there possibilities for moving the building circulation?	10		
What is the horizontal grid size?	10		
What is the floor height?	5	The floor height is around 3 meters.	Some building functions might require higher floor heights.
To what extent can components of the structure be reused?	5	Some components of the structure are made of reusable materials, like steel, some of materials that are harder to reuse, like concrete.	The demolition of (part of) the building would lead to the creation of waste.
Are low-impact materials used in the construction?	0	There are no, as far as known, low-impact materials used in the construction.	At the EoL stage of the building, materials are harder to recycle.

Skin

Criteria	Assessment	Cause	Potential risk
How are windows placed in order to provide natural daylight to the building?	10		
Can windows be opened?	5	Around 20% of the windows can be opened.	Natural ventilation is limited.
How is the operation of sun shading organised?	10		
To what extent can elements of the skin be reused?	10		

Services

Criteria	Assessment	Cause	Potential risk
What is the location of building services?	10		
To what extent can the installation components be uncoupled?	0	The installation components, as far as known, can not be uncoupled.	Possibly, other building layers will be influenced due to the changing of installations.
Are there possibilities for rainwater harvesting and recycling?	0	There are no possibilities, as far as known, for rainwater harvesting and recycling.	All water consumption of the building is dependent on potable water resources.
To what extent can the installations be reused?	5	Some of the installations, as far as known, could be reused.	The demolition of (part of) the building would lead to the creation of waste.

Interior elements

Criteria	Assessment	Cause	Potential risk
Is the building layout suitable for multiple functions?	10		
Can interior walls be moved?	10		
Can building components be reused or exchanged?	10		
Are biodegradable or compostable materials used?	0	There are no, as far as known, biodegradable or compostable materials used.	At the EoL stage of the building, materials are harder to recycle.
Are there possibilities for video and virtual conferencing?	10		

Appendix 6. AI statement

During the writing of this thesis, generative AI has barely been used. However, to some extent, AI helped me write some things or helped me find certain sources. This AI statement will explain how generative AI has been used in this thesis.

First of all, generative AI helped me to translate words into the right terms for the field of expertise this thesis is written for. For example, the criteria in the CBR framework that derived from the toolbox from the Netherlands Police, that is written in Dutch, has been translated using generative AI. Besides, the quotes from the interviews, that were conducted in Dutch, have been translated using AI, in order to get the most objective translation. Also, generative AI has helped me to rewrite sentences, whenever I felt that a sentence did not express the meaning it was supposed to express.

Besides this, the generative AI tool of Elicit was used as a search engine to find academic papers on specific topics. This AI tool allows to provide the search engine with complete sentences and more detailed explanations on the papers you need to find, in stead of only using a few keywords. This allowed me to find papers on topics that were harder to find on 'regular' search engines like Scopus. This tool was only used after trying to find the right papers using other search engines, and all the sources were carefully checked before being used in the thesis.

The Potential for Circular Building Reuse: How a Circular Building Reuse Framework Can Be Used to Implement Circular Ambitions in the Portfolio of the Netherlands Police.

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