THE FUTURE OF OUR PAST

Current implementation of circular economy strategies in the adaptive reuse of heritage buildings and mitigating remaining barriers

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May 2023

Colophon

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Master track: Management in the Built Environment
Graduation theme: Circular-Adaptable Real Estate Reuse to React to Societal Changes

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Abstract

The construction industry imposes significant pressure on the natural environment, making it essential to transition to the circular economy. A step towards this goal is the adaptive reuse of existing buildings, more specifically, heritage buildings. Adaptive reuse of heritage is a difficult procedure that seeks to maintain the qualities of historic structures while modifying them for usage in the present and the future.

The aim of this research is to identify what circular economy strategies are implemented in de adaptive reuse of heritage buildings, find out what barriers still exist, and how these can potentially be mitigated. This in order to help the transition towards the circular economy.

To achieve this, literature review will provide a better understanding of the terms circularity and adaptive reuse within the context of the built environment and heritage, the literature study will also offer the potential barriers for circular heritage renovation. Case studies will explore what strategies are already implemented in adaptive reuse of heritage buildings, and barriers are experienced in the process. Finally a focus group discussion will be conducted in order to find out how these practical barriers can be mitigated in order to move towards the circular economy.

The findings reveal that there is a gap between the strategies implemented in projects and the comprehensive understanding of circular economy . The majority of implemented strategies are related to sustainability, such as reusing and using circular building materials. Barriers to implementation include ambiguities, financial constraints, lack of experience, routine practices, rules and certification, as well as a lack of urgency and social acceptance. To address these challenges, the Circular Economy Strategies for Adaptive Reuse (CESAR) model is developed as a planning and assessment tool.

Furthermore, the study provides advice for stakeholders involved in adaptive reuse projects, emphasizing the importance of collaboration, early involvement of the contractor, and integration of circular economy requirements.

Terminology

Term	Abbreviation	Explanation
Circular Economy	CE	The circular economy is a system of production and consumption that minimises the use of natural resources and the impact on the environment by increasing the lifespan of materials and minimising their consumption and wastage. Through the creation of new products, long-lasting design, waste reduction, resource recovery, and reuse, as well as through reframing consumption to also include sharing and the supply of services rather than private ownership, materials are given an extended useful life. The circular economy stresses the use of materials with the least damaging life-cycle impacts, such as those that are renewable, nontoxic, and biodegradable. As a sustainability idea, a circular economy must be integrated into a social system that supports universal human welfare within the biophysical bounds of the planet Earth (Foster, 2020).
Adaptive Reuse	AR	The process of refurbishing and repurposing an existing building, a "change in use". With the goal of a "performance change," or the act of adapting a structure for a new purpose aside from that for which it was originally designed
Cultural Heritage		Cultural heritage consists of artefacts, monuments, collections of buildings and sites, museums, and other objects that have a variety of values, such as symbolic, historical, aesthetic, artistic, anthropological, ethnological, scientific, or social significance (UNESCO, 2009). Early modern office buildings, royal or aristocratic mansions, community gathering spaces, industrial production sites, and military artefacts are only a few examples of cultural heritage structures.

Content

1. Introduction

1.1 Problem statement

The construction industry is currently responsible for the largest amount of raw materials and resources consumed globally (Ellen Macarthur Foundation, n.d.). Even though the construction sector in the Netherlands uses the largest amount of recycled materials of any sector in the country, only 38% of all construction material comes from reused sources (Centraal Bureau voor de Statistiek, 2019). In the current system, we take virgin resources from the earth, turn them into products, and then eventually discard them as waste, a linear process. This is why, a growing number of programmes, government institutions, and academic research facilities are looking for ways to implement circular economy strategies in the built environment. The circular economy is a framework for systems-level solutions that addresses issues including pollution, waste, biodiversity loss, and climate change (Ellen Macarthur Foundation, n.d.).

One of the ways of implementing circular economy principles in the built environment is to adapt and reuse existing building in the current building stock. The term adaptive reuse, according to its traditional definition, refers to a shift in use. As a result, many of its definitions centre on the idea of "performance change," or the act of adapting a structure for a new purpose aside from that for which it was originally designed (Woodcock et al., 1987).

Heritage buildings provide a good opportunity for adaptive reuse, since according to the heritage council of New South Wales: “The best way to conserve a heritage building, structure or site is to use it …. adaptation links the past to the present and projects into the future” (Heritage Council of New South Wales, 2008). While this is not always the approach towards heritage restauration, blowing new life into these buildings can be perceived as a good measure to safeguard the structures and the values they represent.

Adaptive reuse in itself is a complicated process from concept through completion. Their cultural value, the numerous involved stakeholders, and their diverse objectives and value standards, make this complexity is even greater in respect to heritage buildings (Zijlstra et al., 2022).

1.2 Goals and objectives

The goal of this research is bridge the gap between theory and practise when it comes to the implementation of circular economy strategies in adaptive reuse of heritage buildings and to find out what barriers still exist in this process.

In order to reach this goal there are multiple objectives to this thesis. The first objective is to find out what circular economy strategies are already implemented in adaptive reuse projects. Through case studies an overview will created with strategies that are implemented and ones that are not. Moreover an overview of the barriers will be created. This overview of implementation and barriers will provide the basis for an methodological tool that provides an overview of circular economy strategies that can be implemented in a project. This structural approach of implementation can help mitigate the existing barriers.

The next objective is to discuss with practitioners the model and the reason behind these barriers. By finding out why they exist, recommendations can be done to suggest further approaches to eliminate them.

1.3 Prior research

Prior research has already established the connection between circularity, adaptive reuse and heritage buildings. Yet this research is often limited to literature reviews (Plevoets & Van Cleempoel, 2011), systematic reviews (Foster & Saleh, 2021), or research frameworks (Pomponi & Moncaster, 2017). The produced results are theoretical.

Circularity and adaptive reuse of heritage is also being applied in practise, with increasingly more contractors and developers implementing circular economy strategies in their designs, projects, business operations, and company philosophy (Nico de Bont, 2022).

The goal of moving toward the circular economy is something that both theory and practise are attempting to achieve. While they are working towards the same goal, the translation from theory to practise is something that is not commonly researched. This study aims to investigate what circular economy strategies are currently implemented in adaptive reuse projects of heritage, what barriers are experienced, and what is necessary in order to mitigate them and accelerate the transition to the circular economy. This can also be seen in the conceptual model in figure 1.

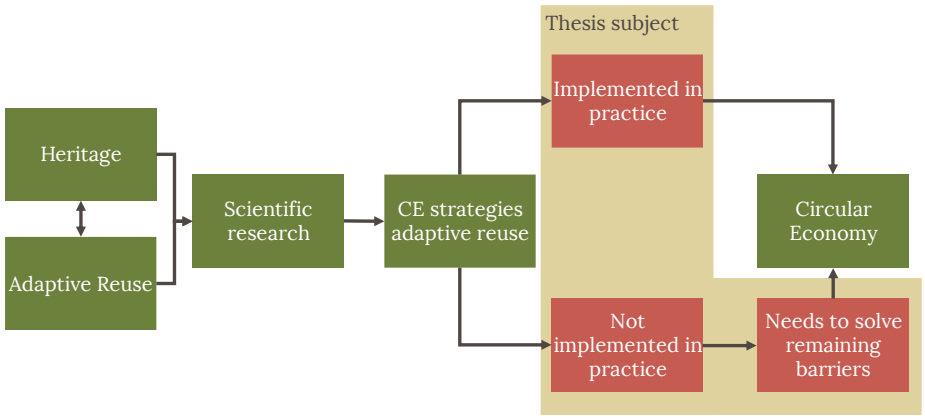


Figure 1: Conceptual framework (own illustration)

1.4 Research relevance

1.4.1 Societal relevance

Churches, city landmarks, schools, and industrial structures are just a few examples of the many different types of cultural heritage structures that have architectural, cultural, or historical importance. Given their representative roles, it is irrelevant whether they should be demolished or not. Nevertheless, the vacancy and disrepair issues are astounding despite the emphasis on the significance of the stated societal value. Currently, there are more than a thousand unoccupied heritage buildings in the Netherlands, totalling 2 million square metres. (Quillettes et al., 2020).

This vacancy is even damaging for monumental structures. Most historic buildings are constructed of bricks, heavy stone structures, and a lot of woodwork. They are relatively heavy and massive buildings. Keeping them warm and dry requires considerable heating. Heaters produce a combination of three types of heat, namely air, conduction and radiant heat . In monumental buildings radiant heat (60-80%) is mostly used. With the effect that walls, ceilings and floors slowly heated up over a number of days. This process is called heat accumulation. Brick and concrete in particular are excellent at storing energy in the form of heat. When buildings are vacant and not being heated, moisture problems inevitably arise. This is because the thick walls lose their

accumulated heat. When the air inside is warmer than the walls, the moisture in the air condenses on those walls. Eventually, the walls can become saturated with moisture. This can result in window frames and other wooden elements being affected by wood rot, façade masonry and brickwork can freeze and break down, and mould can develop (David, 2018).

The need for "conservation through transformation", an approach that emphasises managing changes in the historic urban region, is also mentioned in the UNESCO Recommendation on the Historic Urban Landscape (UNESCO, 2011). Cultural heritage is preserved for a longer period of time through adaptive reuse. Similar to this, by reusing materials and components from the original structure, the circular economy will be stimulated.

Moreover the Dutch government has set to have a completely circular economy by 2050 (Ministerie van Infrastructuur en Waterstaat, 2022). One of the measures towards achieving this, is the *"Grondstoffenakkoord"* (raw materials agreement). This agreement contains transition plans for five different sectors, one of which being the construction sector. The plans include steps which are to be taken in order to achieve this full circular economy by 2050. This thesis can contribute to find out where the implementation of the circular economy currently stands, and show what steps still have to be taken moving forward.

1.4.2 Scientific relevance

A fair amount of knowledge already exist about how adaptive reuse of heritage buildings can add to the circular economy. Yet a lot of this research is limited to theory.
While this gives a good understanding of enablers, barriers, and ways to implement circularity in the built environment, it often does not make the translation to how is it actually implemented into practise.

According to Hamida et al. (2022) a methodological tool with empirical validation, is required through future research. Such a framework can be helpful for practitioners to operationalize circular building adaptability either proactively or reactively. This thesis's goal is to establish that framework and test it, with the focus on heritage buildings. By exploring what circular economy strategies from theory are applied in the adaptive reuse of heritage in practise, a clearer image will be presented about the current state of implementation. This overview will provide information about what is already done but also what still has to be done, in order to accelerate the transition to the circular economy.

2. Research Approach

2.1 Main research question

The main question and numerous related sub-questions are developed in order to accomplish the research goal. The following is this thesis's main research question:

What circular economy strategies are currently implemented in the adaptive reuse of heritage buildings and how can the remaining barriers be mitigated in order to move towards the circular economy?

2.2 Research sub questions

In order to answer the main research question, five sub-questions are specified. The sub questions will be executed through both theoretical and empirical research, which again consists of case studies and a focus group. The first sub question will provide greater understanding of the concepts of circularity and adaptive reuse in order to provide a base for the rest of the research.

SQ 1. How are circularity, adaptive reuse, and heritage defined within the context of the built environment?

The second sub question will provide frameworks or assessment models, established through literature research, in which the circularity of an adapted heritage building can be measured.

SQ 2. What circular economy strategy assessment models exist for adaptive reuse projects of heritage buildings?

The third sub question will go deeper into the challenges when it comes to implementing circularity in construction projects. This can range from governmental regulations to social opinion.

SQ 3. What are the barriers related to circular construction and adaptive reuse of heritage buildings?

The fourth sub question will be executed through case studies and will provide greater understanding of the implementation of circular economy strategies in current adaptive reuse projects. Moreover the case studies will provide an overview of wat barriers are experienced in practise.

SQ 4. What circular economy strategies have been implemented in adaptive reuse heritage projects from practise?

The final sub question has the goal of providing better insight into how different stakeholders perceive the remaining barriers and discuss how they can be mitigated. This question will be answered by conducting focus group discussions.

SQ 5. How can the barriers be mitigated for future implementation in order to help the transition towards the circular economy?

2.3 Research methodology

This thesis will use both theoretical and empirical research. Therefore, during the research process, various research methodologies will be applied. Current circular economy strategies and indicators will be studied through literature review. Moreover using the existing knowledge, insights into the barriers of working with heritage will be discussed, along with ways to asses circularity within projects. The translation of what strategies from theory are implemented in practise, as well as the barriers that are experienced, case studies will be conducted, which will consist of adaptive reuse projects of heritage buildings. This overview of implementation and barriers will provide the basis for a methodological tool or model that provides an overview of circular economy strategies that can be implemented in a project. This structural approach of implementation can help mitigate the existing barriers. This model and the remaining barriers will be discussed in a focus group, containing the interviewees from the case studies, being the plan developers and project leaders from the contractor, architects and clients.

2.4 Theoretical research

The current status, in which circular economy and adaptive reuse are seen as two distinct parts of the built environment will be identified via descriptive literature review. Literature review is used to study previous findings, analyse contributions, explain findings from earlier research, and clarify discrepancies in competing views on the subjects.

2.4.1 Literature review

The first sub-question reads: How are circularity, adaptive reuse, and heritage defined within the built environment? This question's answer will be derived from previously published articles. For the concepts to be properly defined, the articles used required to be related to the built environment. The premise for addressing the following sub-questions is established by answering to this question and defining both the concepts of circularity and adaptive reuse.

The second sub-question will delve further into the application of circular economy strategies in adaptive reuse projects and the measurement of a project's circularity. The literature that will be used to address this question will concentrate on frameworks and assessment models that employ indicators to measure circularity within a project. In order to narrow the scope of upcoming research questions, the literature will focus on heritage buildings as much as possible.

The final question to be answered through literature review is: what are the barriers related to circular construction and adaptive reuse of heritage buildings? This question will use previous research on the matter, but will also include policy documents on the renovation of heritage buildings.

2.5 Empirical research

2.5.1 Case studies

The first part of the empirical research will consist of case studies. Various adaptive reuse projects will be studied to find out what circular economy strategies have been implemented in the transformation process. The case studies' objective is to provide insight into how different parties within the construction process define the circular economy, find out which circular economy strategies are actually applied, and figure out

what barriers are experienced within the process. The case studies are so called instrumental case studies (Stake, 1995). In instrumental case studies the cases are used to understand something else than itself. In this research the case studies are used as an instrument to understand the implementation of circular economy strategies in adaptive reuse of heritage buildings. When multiple case studies are used as an instrument to understand a certain concept it is also considered a collective case study (Stake, 1995).

Case study research makes use of predominantly qualitative methodologies that capture exploratory information (Stake, 1995). Also for this research qualitative data collection will be the primary approach used to access information.

The three main methods to be used are interviewing, observation, and document analysis, which can be supplemented by visuals, videos, photographs, and other types of media (Leavy, 2014).

The decision to go with interviews instead of for example questionnaires is because for the case studies interviews are more effective than questionnaires at eliciting narrative material, which enables to examine people's perspectives in greater detail (Leavy, 2014). This means that interviews are valuable not only because they provide a comprehensive view, and present in-depth perspectives from interviewees, but also because they give interviewees the chance to talk from their own perspectives and convey their own ideas.

Additionally, conducting interviews is a natural manner of engagement that can happen in a variety of contexts rather than just being a tool for data collecting. Mutual understanding can more easily be assured with the interviewer present as the interviewer may rephrase or clarify questions that his or her interviewees did not grasp. More appropriate answers will eventually be found, leading to the production of more precise data (Alshenqeeti, 2014).

2.5.2 Focus group

The case studies will provide an overview of what circular economy strategies are implemented in practise. By comparing these results to existing literature, an indication can be given about what strategies have not been implemented thus far. This information will provide the basis for the development of the implementation tool. The next step is to organise a focus group discussion with all the interviewees from the case studies.

The purpose of this focus group is twofold. On the one hand it seeks validation from the interviewees about the findings from the case studies. The interviewees can confirm certain findings and correct certain misinterpretations. The second reason for the focus group is to shed light on any remaining obstacles. These can include financial or knowledge limitations, as well as restrictions in legislation or other challenges. Interviewees have different roles within a project, which can result in different perspectives on the matter. Moreover the model will be discussed during this part of the focus group.

The findings from this focus group can help determine what steps still need to be taken going forward to increase circularity in the adaptive reuse of heritage buildings and accelerate the process towards a circular economy.

2.6 Research design

This study is divided into multiple distinct phases. The first phase consists of the problematization and formulation of the main research question as well as the sub-questions for the thesis.

The second phase will consist of the theoretical research. This is where previous literature and publications will be studied.

All gathered information will be put to practise in phase three. This phase is meant to be the transition from theory to practise. Both the case studies and focus group will be conducted during this stage.

Figure 2 below shows a schematic representation of the research design.

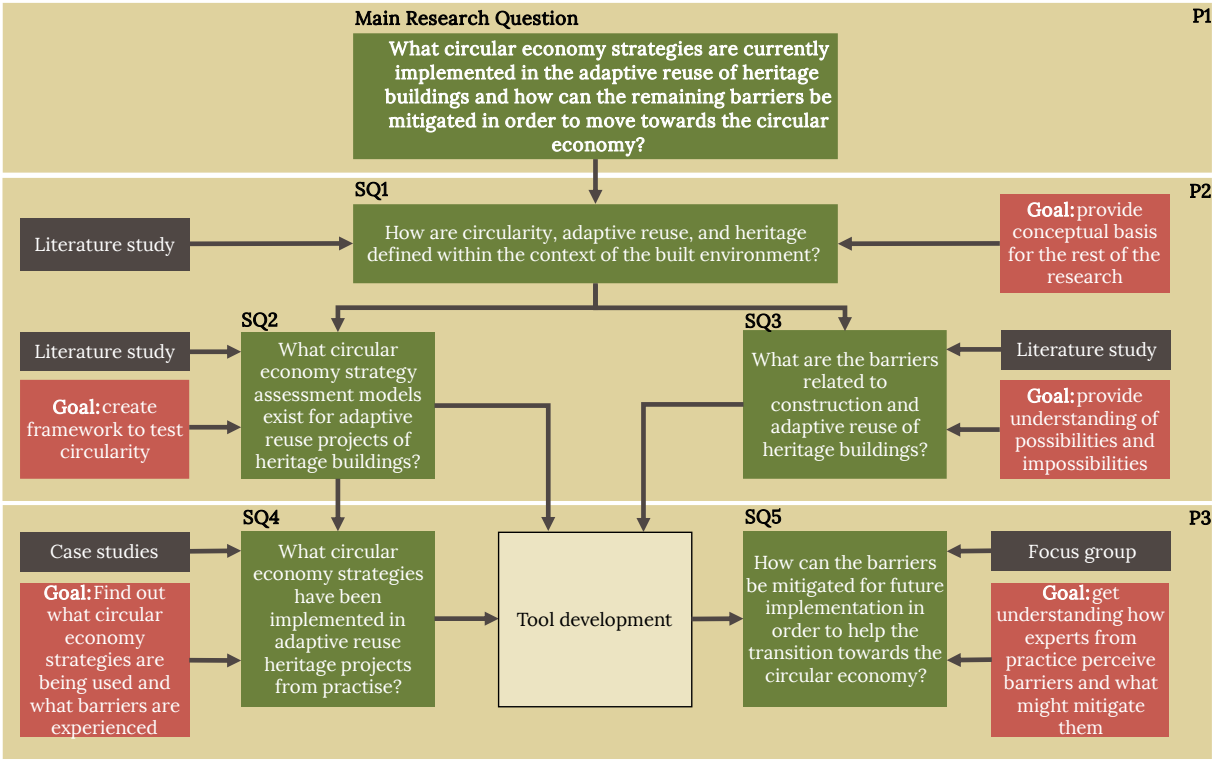


Figure 2: Research Design (own illustration)

2.7 Data collection and analysis

The data collected in this thesis is considered both primary and secondary. The secondary data comes from previously published articles and research, primarily used for the literature study. The primary data, the first-hand information, is everything that is collected in the case studies and the focus group.

The data for the case studies will be a combination of interviews with project plan developers, project leaders, architects, and project clients. Additional information from project documents and project observations can also add to the case studies.

2.7.1 Literature review

The suitable keywords were selected for the literature review for this research based on the thesis's goal and research questions. Keywords that are included are amongst others: adaptive reuse, circularity, (architectural) heritage, built environment, sustainable development, implementation, and construction. Subsequently, a search process was carried out, yielding a number of search results. Based on the research field, title, abstract, and introduction, articles were chosen from these search results. Articles were mostly collected using Scopus. Additionally, other papers were discovered by reading the sources listed in the references of previously downloaded articles, creating an accumulative snowballing effect. The review will be a more narrative literature review. With its primary purpose to provide a solid background for

understanding current knowledge and significant information for the rest of the research (Cronin et al., 2008). Theory evaluation is the main focus of this literature review. Instead of presenting a new theoretical viewpoint, this kind of study examines the literature that is pertinent to the viability of an existing theory. In essence, the published literature offers a foundation from which judgments on the value of current conceptualizations can be made (Baumeister & Leary, 1997). It will not be possible to review all previously published literature. The literature study will completed when enough information has been gathered to provide the context and background knowledge, and when it information is sufficient to conduct the case studies. When during the case studies new information or uncertainties present themselves, which can not be explained with the conducted literature review, more literature will be studied in order to also answer these issues.

2.7.2 Case studies

As mentioned the case studies will be instrumental case studies, where the cases are used to investigate the implementation of circular economy strategies. In order to do this, collected data will be compared to the assessment methods and indicators found in previous literature.

The three main ways of collecting data in the case studies are site visitation, document analysis, and interviewing.

Through site visitation the different characteristics of implementation of the circular economy in a project will be documented. This might not always be possible since some interventions are not visible to the eye, but where possible circular economy strategies will be recorded. The goal is to depict the project "as it is," giving a feeling of what it was like to be there or a foundation for further interpretation.

Another method of data collection used in the case studies is document analysis. These documents can range from designs, articles, correspondence, annual reports, meeting notes, policy documents, and the like (Stake, 1995).

The method that will provide the most information for the case studies will be semi-structured interviews. The interview will be comprised of a range of certain pre-established questions to give the interview direction. The interview protocol used for the interview can be found in appendix 1. The semi structured nature of the interview also provides flexibility because it allows for more in-depth data collection, the documentation of differing viewpoints and experiences, and the exploration of contentious issues (Leavy, 2014). The decision to do semi-structured interviews, as opposed to structured interviews, is because they can better utilize the knowledge-producing potentials of dialogues by giving the interviewee much more freedom to pursue any angles they deem important. Furthermore, compared to unstructured interviews, the interviewer has more control over how the conversation is focused on topics that are significant to the study project (Leavy, 2014).

Conducting the interviews was done in person or through an online meeting in Microsoft Teams. This was dependant on the location and availability of the interviewee. The interviews were conducted in English of Dutch, depending on the preference of the interviewee.

Analysis will initially be carried out through coding. In social science research, two coding steps are generally used: the creation of useful data units, and the classification and ordering of those units (Alshenqeeti, 2014). The creation of the data units will be done by transcribing the interviews from audio or video to text. During transcribing, names of persons will be anonymised in order to ensure privacy.

Transcripts are coded in the computer according to various categories. The coding will be done with the help of the software Atlas.ti. This software can be used to analyse vast volumes of data qualitatively.

The codes will be pre-established based on existing circular economy indicators related to the adaptive reuse of heritage buildings, and will be derived from the literature research. These codes are then applied to deepen the significance of the interviews. The codes are divided into different categories or so called groups. This will give an overview of the strategies that are implemented in practise.

The data will then be analysed to find out how the term of the circular economy is defined, what strategies are not implemented (yet), and what barriers still exist in the practical implementation of circular economy strategies in the adaptive reuse of heritage buildings.

2.7.3 Focus group

The final question is answered through a focus group. To both validate the findings from the case studies and discuss the remaining barriers within the implementation of the circular economy within the adaptive reuse of heritage buildings. A focus group involves a group discussions in which participants focus collectively on a topic chosen by the researcher and presented to them most frequently as a set of questions, although occasionally as a film, a presentation, or a "game" to play (Wilkinson, 1998). The participants, typically 6 to 8 people, may already be in groups like work colleagues or they may be gathered together especially for the research.

The focus group participants are chosen because they share particular traits related to the discussion topic, the shared trait for this research is the involvement of the participant in an adaptive reuse project of a heritage building. Without pressing them to cast votes or come to an agreement, the researcher fosters a permissive environment where participants are free to express their opinions and ideas (Krueger & Casey, 2014). The focus group's questions are planned out and asked in a certain order. The way the questions are worded and organised makes it simple for the participant to comprehend and make sense. Open ended questions are posed by the researcher/moderator. The questions asked at the start of the group are more broad in nature. The questions get more focused and detailed as the group goes on. The opening queries encourage discussion and consideration of the subject. The most insightful answers are frequently provided by questions asked toward the end of the meeting. The researcher/moderator does not exert any pressure on the group to come to an agreement. Instead, emphasis is placed on comprehending participants' thoughts, feelings, and opinions as they discuss the topics. Because participants are affected by others but also affecting others themselves in the focus group, it offers a more natural atmosphere than a one-on-one interview. In the focus group, the researcher performs a number of roles, including moderator, listener, observer, and ultimately analyst (Krueger & Casey, 2014). During a focus group discussion, the basic means of data collecting are audio and video recording, taking notes, and participant observation (Stewart et al., 2007).

Data analysis from the focus group will be similar to that of the case study interviews. The information will be transcribed. It might not be possible to get a complete transcript of the entire group because the focus group was conducted later on in the research process. Therefore, producing an abridged transcript might be necessary. It takes less time than the full transcript-based. This strategy involves listening to an audio recording of the focus group and creating a condensed transcript of the pertinent and helpful dialogue (Krueger & Casey, 2014).

The transcript will then be coded. In contrast to the case studies where all the codes are previously established, the codes for the focus group results will be created whilst coding. This is done because there is no way to predict the results from the focus groups and therefore no possibility to create the codes beforehand.

After the focus group session, the participants will receive a questionnaire to give feedback on the topic discussed in the group. Here they can provide feedback, comments, and suggestions that came to mind after the session. The questionnaire can be found in appendix 2.

The focus group's findings will result in a series of suggestions on how to mitigate the remaining barriers in the transition to the circular economy. These suggestions can be utilised in practise and in upcoming research and eventually to accelerate the shift to a circular economy.

2.8 Data management

A data management plan is created for this study. Since the research requires human study participants, this is necessary. Additionally, it adheres to the Findable, Accessible, Interoperable & Reusable (FAIR) data standards (Wilkinson et al., 2016). Data management plan can be found in appendix 3. The strategy goes into detail on how the data will be gathered, managed, and finally published. As this report describes the techniques used to analyse the data, transcripts will be used to collect the data, and Atlas.ti software will be used to apply codes. By using a encrypted project drive, the information will be retained. Finally, the actual anonymous data will be kept in a private storage area. The research findings that are included in the research report will be made available to the public in a repository. The data management plan is submitted to the human research ethics committee (HREC). The application is concerned with making sure that the research is designed and carried out in a way that will not cause unnecessary harm or take excessive risks that could have a detrimental impact on human research subjects, society, the environment, or even researchers themselves. It entails doing so while also adhering to any legal requirements and any ethical and professional standards that apply to the research you plan to perform (Human Research Ethics, n.d.). The HREC letter of approval can be found in appendix 4.

2.9 Ethical considerations

For the research it is not only of importance to show integrity towards the participant, but also towards the scientific field. The purpose of this study is to close the gap between theory and practise regarding the application of circular economy strategies in adaptive reuse of historical structures and mitigate the remaining barriers in order to accelerate the shift to a circular economy. In order to achieve this goal, different moments of validation will be applied in the research. The literature study provides different indicators to measure the application of the circular economy. These indicators will be validated during the case studies where they are tested against projects from practise. The case studies will in their turn provide an overview of what circular economy strategies are implemented and what barriers are experienced in practise, this information is gathered through amongst other things document analysis and interviews. While the goal of these case studies is to base the analysis purely on factual information, there is room for misinterpretation, especially during the interview analysis. This is why the second moment of validation is to confirm the findings of the case study, with the interviewees. This will take place as a part of the focus group session to both validate the results from the case studies and start of the focus group discussion about possible ways to mitigate the remaining barriers. Finally, in order to prevent any harm to people, transparency of the study objectives, methods, and data collection and processing is guaranteed. Participants are asked to consent, and they have the option to change their minds at any time while the research is being conducted. The consent form can be found in appendix 5.

3. Research output

3.1 Deliverables

This thesis aims to gain knowledge by exploring what circular economy strategies are implemented in the adaptive reuse of heritage.

The case studies will produce insight in circular economy implementation in practise and form the basis for the focus group about why some strategies are not (yet) implemented and how they can be mitigated n the future.

The research will produce a framework or model for circular economy strategy implementation that contractors, developers, architects, and other parties in the construction sector can use and modify to fit their organisational and production strategies in order to better implement circular economy strategies in their projects.

Finally the research will provide a set of recommendations about what practical barriers still exist in the implementation of circular economy strategies in the adaptive reuse of heritage projects, and how these can potentially be eliminated. These recommendations can be used speed up the transition towards the circular economy.

3.2 Timeline

For this thesis, the phases are separated into what are referred to as "P moments". P1 will be delivered on October 28 2022 and will contain the problem statement, research objectives, research questions, and social and scientific relevance. January 20 2023 will be the deadline for P2. Towards this deadline the literature study will be performed, this will also be the main milestone in this phase, also the case study projects will be selected. Additionally the research method will be further elaborated upon in order to directly start the case studies after the P2. Besides selecting the case study projects, interviewees will also be contacted in order to plan the first interviews.

Working towards P3, the case studies and focus group will be conducted, these are the main milestones in this phase. The tasks for the case studies consist of document analysis and interviews. The findings from the case study interviews will be compared to the literature study and the outcome will be discussed during the focus group. This focus group session will also be used in order to answer the final research question.

For the P4 deadline the final conclusions, discussions and reflection will be included in the report. P5 will mark the moment where both the final report and presentation are completed. The general research timeline for this thesis is depicted below in Figure 3. The important milestones in this figure are indicated by the beige boxes. The green boxes contain the primary tasks. The location of the red boxes on the study timeline indicate when specific sub-questions will be addressed.

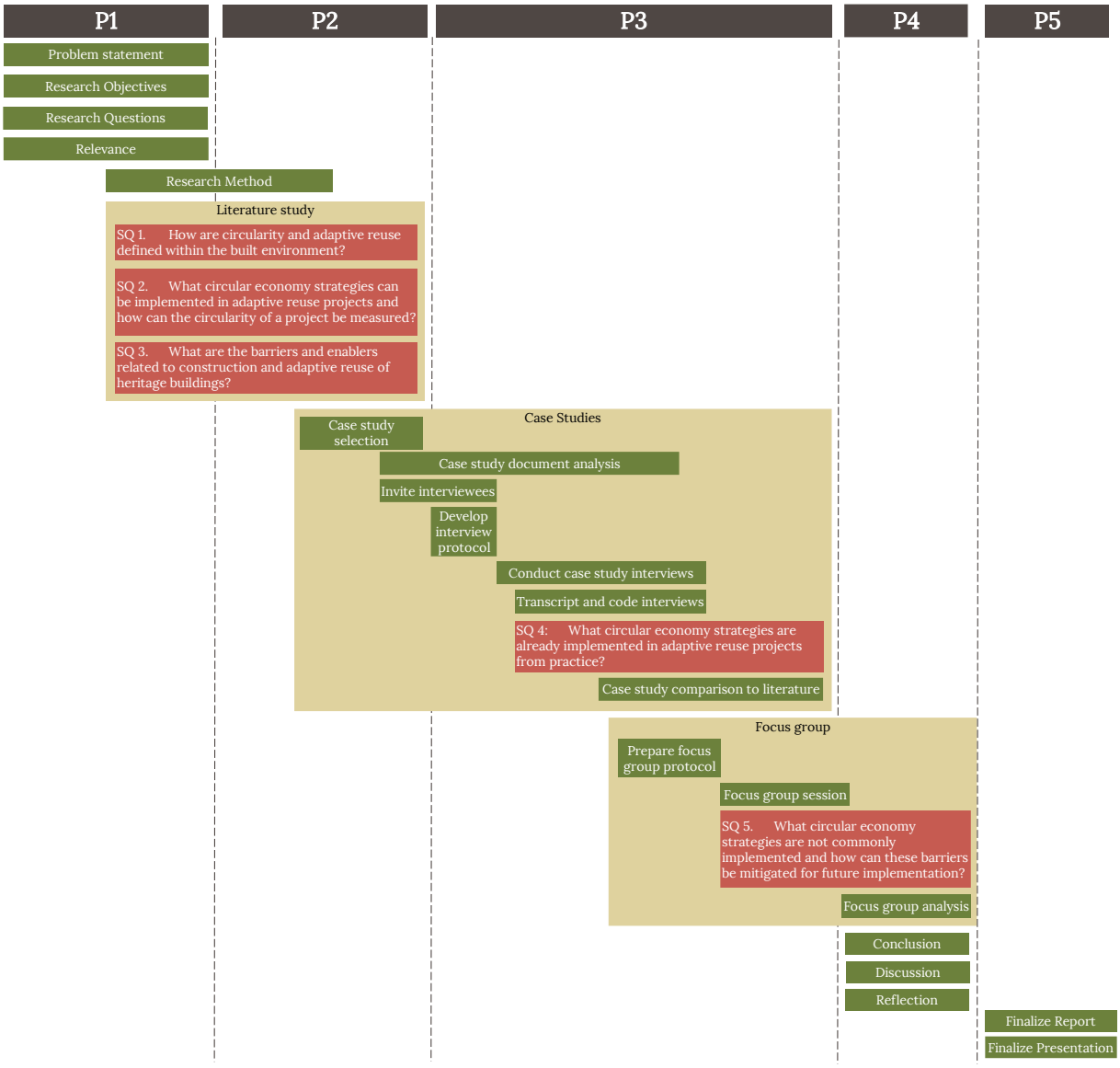


Figure 3: Research Timeline (own illustration)

3.3 Dissemination and audiences

This study is aimed at both organisations who research the subject of circularity in adaptive reuse and organisations who practice reuse of buildings. Information about how circular economy strategies are implemented in practise can be used to further stimulate research on the topic and how theories from research are translated to practise.

Understanding as to how circularity can be evaluated in projects is useful for adaptive reuse practitioners, such as developers, contractors, clients, and architects. The framework for implementation of circular economy strategies can be modified to fit their organisation and production strategies in order to better implement them in future projects. By researching what barriers still exist in the implementation of circularity and how these barriers can be mitigated, practitioners can better implement these strategies in the future.

Although the research is focused on the adaptive reuse of heritage buildings, the information provided can also largely be applied on other types of buildings. Therefore

this thesis can also be of benefit for organizations who for example aim to improve circularity within other renovation projects.

3.4 Personal study targets

This thesis will explore multiple personal interests. Throughout the master we have learned about the circular economy and the ways of how it can improve the future. During the course "The Urban Redevelopment Game", I got the chance to go even deeper in the subject of the circular economy, while portraying the role of circular economy manager. Even then I only scratched the surface of all the ways circularity can be implemented. This thesis provides the perfect opportunity to explore the subject even more.

The subject of heritage is also a big personal interest. The fact that some buildings have stood the test of time has always intrigued me. By researching how these buildings are being repurposed through adaptive reuse is a beautiful way of giving the structures a new and bright future.

4. Literature review

4.1 Defining circular economy and the adaptive reuse of heritage

4.1.1 The circular economy

The search of more sustainable techniques, like the circular economy, resulted from the recognition that human interventions have adversely affected the environment, destroyed habitats, and altered ecosystems that threaten human wellbeing. In the current economy, a linear product supply chain is commonly used, where natural resources are converted into goods. These commodities are used by consumers, who then discard them as waste. A linear economy model is in complete contrast with the circular economy supply chain model (Foster, 2020)(figure 4)

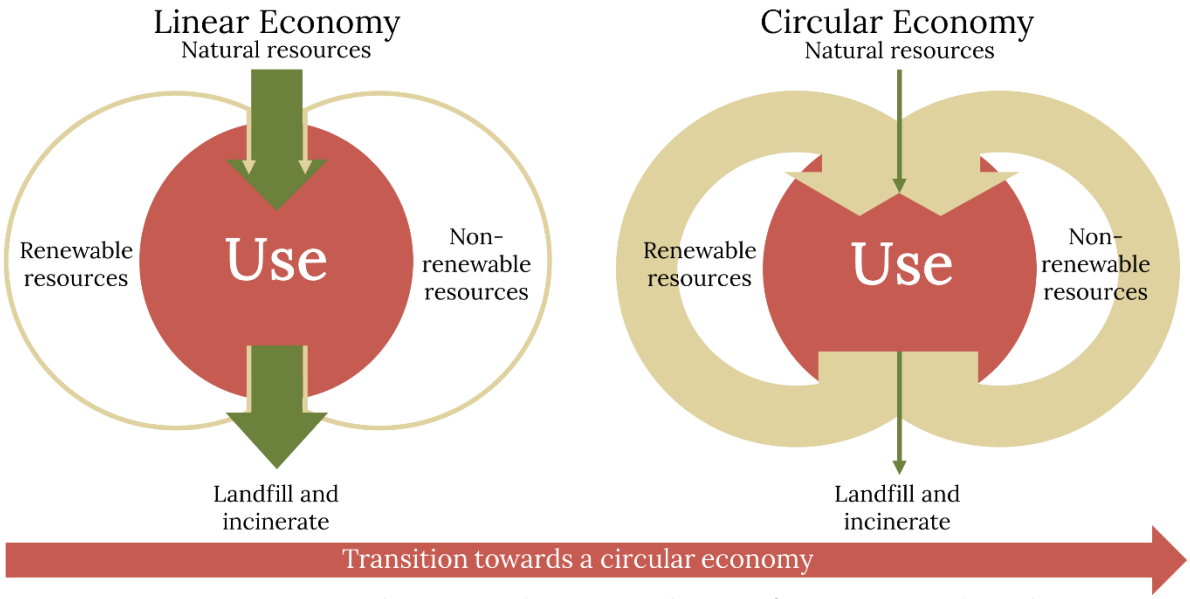


Figure 4: From a circular to a circular economy (adapted from Potting et al., 2017)

The circular economy aims to resolve these conflicts. There are numerous diverse schools of thought regarding the circular economy, yet, the better management of resources and closed loops are some of its fundamental basic principles (Ellen MacArthur Foundation, n.d.). Due to its considerable environmental effects, which can also present important prospects for reducing energy use, greenhouse gas emissions, and waste creation, the built environment can play a critical role in the circular economy (Pomponi & Moncaster, 2017).

The relationship between human and nature is described by a variety of tactics, strategies, and descriptions under the umbrella term of circular economy, which lacks a clear definition (Kirchherr et al., 2017). The closed-loop production and material consumption patterns are already well known. The concepts alone, however, are insufficient; circular economy must be defined in greater detail. According to Foster (2020), who offered circular economy strategies for lessening environmental impact for architectural heritage, the circular economy and circular economy strategies can be defined as followed:

The circular economy is a system of production and consumption that minimises the use of natural resources and the impact on the environment by increasing the lifespan of materials and minimising their consumption and wastage. Through the creation of new products, long-lasting design, waste reduction, resource recovery, and reuse, as well as through reframing consumption to also include sharing and the supply of services rather than private

ownership, materials are given an extended useful life. The circular economy stresses the use of materials with the least damaging life-cycle impacts, such as those that are renewable, nontoxic, and biodegradable. As a sustainability idea, a circular economy must be integrated into a social system that supports universal human welfare within the biophysical bounds of the planet Earth (Foster, 2020).

Implementation of the circular economy is crucial in the building and construction industry since it not only consumes a lot of raw materials but also reflects human demand for basic necessities like a place to live, a place to gather with others, and a place to work. Additionally, fundamental aspirations for social inclusion, community, and organisation are represented through the built environment (Foster & Kreinin, 2020).

Previous research has shown the circular economy's environmental advantages. Utilizing what is already there to maximise the use of embodied energy and materials in the current building stock is one of the pillars of circular economy. Embodied energy refers to the total amount of energy used during construction and operation of a structure (Hammond & Jones, 2008). Embodied energy takes advantage of a structure's longevity and is estimated as carbon dioxide avoided by reuse or as the carbon dioxide equivalent of the energy and materials used to construct the existing building (Foster, 2020). The difficulty is that in order to achieve this objective of maximising the embodied energy, the existing building stock, including cultural heritage structures, must be refurbished and potentially repurposed (Foster & Kreinin, 2020).

Developers have usually preferred building demolition over building re-use because demolition offers the best chances to maximise plot ratios. Buildings are frequently demolished because it is believed that they should be replaced since they are inefficient or old. With heritage buildings this is not a possibility. Luckely there are indications that this perspective is shifting because more funds are being spent on renovating and reusing existing buildings than on creating new ones, and reuse is becoming a popular technique (Bullen & Love, 2009)

4.1.2 Adaptive reuse

This proces of refurbishing and repurposing existing building stock is also known as adaptive reuse. While the concept has already been used throughout history, the term Adaptive Reuse (AR) first appeared in the twenty-first century. Its traditional meaning is "change in use". As a result, many of its definitions centre on the idea of "performance change," or the act of adapting a structure for a new purpose aside from that for which it was originally designed (Woodcock et al., 1987).

The fundamental difficulty in adaptive reuse is balancing building preservation and environmentally friendly design. Depending on the time period and/or region of creation, historic structures embodied a variety of building methods and materials. Major building upgrades are expensive and even though they require less material than new buildings, they demand a lot of resources. However there are a variety of tactics that may be used to strike an ideal balance between initial investments, energy cost reductions, and minimising environmental consequences over the building life-cycle. When adaptive reuse of buildings is approached from a life-cycle viewpoint, it can dramatically lower waste and costs during the whole life of the structure as well as increase its functionality (Bullen & Love, 2011).

Moreover through adaptive reuse, the wasteful demolition and construction process is avoided. Reuse is a crucial aspect of sustainable development because of this environmental advantage, as well as the energy savings, reduced carbon emissions, and social and economic benefits of recycling a precious historic structure (Yung & Chan, 2012).

4.1.3 Cultural heritage

Cultural heritage consists of artefacts, monuments, collections of buildings and sites, museums, and other objects that have a variety of values, such as symbolic, historical, aesthetic, artistic, anthropological, ethnological, scientific, or social significance (UNESCO, 2009). Cultural heritage is seen as a crucial component of the identities and distinctiveness of cities and regions, with the ability to improve people's wellness and health, as well as job development, environmental regeneration, and place attractiveness (European Commission, 2014). Early modern office buildings, royal or aristocratic mansions, community gathering spaces, industrial production sites, and military artefacts are only a few examples of cultural heritage structures which can benefit from adaptive reuse. (Foster, 2020).

Cultural heritage has value as it is distinctive and irreplaceable. People are aware of this value, primarily in an emotional and social context. The importance of cultural heritage cannot be summed up in a single term or idea. Cultural heritage has many different values, some of which are subjective. There is a difference between assessing the value of cultural heritage in terms of price (economic value) and valuing cultural heritage in terms of content (non-economic value) (Persoon, 2019).

It is challenging to pinpoint a building's cultural historic value in general. The building's appeal, authenticity, and rarity must be taken into account when determining its market worth. For the housing market, as opposed to, say, the corporate real estate market, the added value of heritage is even harder to establish (Barentsen, 2015).

For instance, the image and surroundings of a historic building may drive up the cost of office space. This impression is based on the idea that historic structures can draw more clients and workers, which will boost business profits (Koppels et al., 2009).

Shipley et al. (2006) researched the added value of heritage buildings. They concluded that transformed heritage buildings have four important advantages.

The uniqueness of the building is the first advantage. Heritage carries with it a particular beauty and rarity, although this is quite subjective. This may result in a passion and pride for using or owning a specific building. This phenomenon is also called the bequest value of a building (Barentsen, 2015).

The second benefit is that heritage buildings are frequently located in desirable areas. Historic buildings typically date from a time before zoning regulations were implemented by communities. As a result, they are typically situated in eye-catching settings where they can strikingly contrast their environment. Moreover since they are located in existing areas, infrastructure is already available.

Heritage structures that have been renovated also offer a high potential return. This does have the drawback that it also carries more potential risks.

The final advantage is that government organisations are more often willing to support the transformation of heritage buildings (Ministerie van Onderwijs, Cultuur en Wetenschap, 2022). Governmental interest in heritage is increasing since historic structure are seen as a way to comply to the current social and cultural demand from society (Wilkinson et al., 2014).

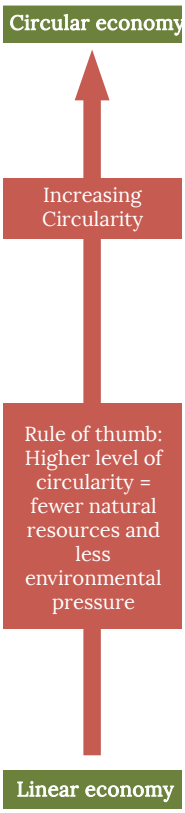
The commercial value of the cultural heritage buildings can also be positively impacted by the adaptive re-use of those structures. The most significant aspect of cultural heritage, however, and what distinguishes it from newly constructed structures, is a building's narrative or the story behind it (Persoon, 2019). This advantageous effect does more than only raise its own value. An average 7.1% price premium can be recorded for homes located within 1500 metres of a cultural heritage site, which indicates the worth and added value that can be provided by the adaptive re-use of cultural heritage (Persoon, 2019).

4.2 Measuring and assessing circular economy implementation

Assessing the circularity of a construction project is difficult. The multiple dimensions of the circular economy make it challenging to create one type of framework where the circularity of an adaptive reuse project can be measured.

The most often used indicators for the circular economy assessment, are those that deal with waste management, raw materials, recycling rates, the financial success of circular firms, energy, toxicity, and clean material cycles (Bosone et al., 2021).

One of the most used frameworks to asses circularity is the R-ladder model, depicted in figure 5 (Potting et al., 2017). This model is built using different methods, or R-strategies, that have been created to reduce resource and material consumption in supply chains and promote a circular economy. Usually, they offer a selection of tactics arranged from low circularity (high R-number) to high circularity (low R-number). By using fewer products to perform the same purpose, R0 and R1 methods reduce natural resource consumption and commodities used in a product chain. Therefore, even while they may not always involve enhancing the reuse of products and components or the reapplication of recycled materials, R0 and R1 are typically regarded as full circular methods (Potting et al., 2017).



Smarter product use and manufacture	**R0** Refuse	Make product redundant by abandoning its function or by offering the same function with a radically different product
	R1 Rethink	Make product use more intensive (e.g. through sharing products, or by putting multi-functional products on the market)
	R2 Reduce	Increase efficiency in product manufacture or use by consuming fewer natural resources and materials
Extend lifespan of product and its parts	**R3** Re-use	Re-use by another consumer of discarded product which is still in good condition and fulfils it original function
	R4 Repair	Repair and maintenance of defective product so it can be used with its original function
	R5 Refurbish	Restore an old product and bring up to date
	R6 Remanufacture	Use parts of discarded product in a new product with the same function
	R7 Repurpose	Use discarded products or its parts in a new product with a different function
Useful application of materials	**R8** Recycle	Process materials to obtain the same (high grade) or lower (low grade) quality
	R9 Recover	Incineration of materials with energy recovery

Figure 5: Circular strategies within the production chain, in order of priority (adapted from Potting et al., 2017)

Another framework used for circular implementation is the ReSOLVE framework (McKinsey & Company, 2016). This framework (table 1) proposes six steps that businesses and governments can take to move toward a circular economy: regenerate, share, optimise, link, virtualize, and exchange. These activities all improve the use of physical assets, extend their useful lives, and switch from using finite to renewable energy sources. Additionally, each action boosts and quickens the execution of the others. They could have a significant influence both individually and collectively, raising cost competitiveness (McKinsey & Company, 2016).

Table 1: Circular economy principles (adapted from McKinsey & Company, 2016)

CE Principles	Description
Regenerate	Use renewable resources, such as energy and materials, and restore depleted biological resources to the biosphere
Share	Utilize items to their fullest potential by sharing privately held goods, reusing them, and prolonging their useful lives through maintenance, repair, and durable design
Optimise	Enhancing product effectiveness and efficiency while cutting down on or doing away with waste
Loop	Keep parts and materials in closed loops and give internal ones priority
Virtualise	Offer virtual tools and other services
Exchange	Substitute more modern, renewable materials and technology for the oldest ones now being used

While suggesting different strategies to move towards a circular economy, both of these models have the drawback of not being tailored to heritage or even the built environment. They concentrate on circularity in a more general sense. A more precise framework needs to be developed in order to evaluate the circularity of a building or heritage structure that has undergone transformation.

López Ruiz et al. (2020) proposed a theoretical framework from the viewpoint of waste minimization and waste management effectiveness in building and demolition operations (table 2). Major lifespan stages of the industry like material and component production, design, and end-of-life are taken into account in this framework.

Design concepts offer a waste minimization strategy and make it easier to salvage resources when buildings reach the end of their useful lives. End-of-life selective deconstruction is advantageous for the environment and the economy. However, its use and advantages depend on certain elements including managerial, technological, and operational considerations. Due to the fact that the majority of existing structures were not intended for disassembly, this method is also not very popular. Since the environmental and financial advantages of various CDW categorisations vary, the implementation of recovery strategies during the material recovery and production stage depends on the kind of material. In addition, the type of transportation and travel distances affect the advantages of recovery options versus landfilling. Reuse, recycling, and other material recovery processes all help to close and shorten loops in the industry, making it a critical stage in the CE process (López Ruiz et al., 2020).

Table 2: Overview of circular strategies for three lifecycle phases (adapted from López Ruiz et al., 2020)

Lifecycle phase	Material and component production	Designs	End of life
Circular strategies	Use fewer hazardous materials	Design for disassembly	Disassembly
	Design for recycling	Design for adaptability and flexibility	Selective demolition
	Prolonged lifespan	Design for standardisation	Enable reuse of products and components
	Design for product disassembly	Design out waste	
	Design for product standardisation	Design for modularity	Open-loop recycling
	Take-back schemes	Specify recyclable materials	Closed-loop recycling
		Design to reintegrate secondary production	

The BCI is the measuring instrument with which can determine the circular potential of their property (BCI gebouw, n.d.). The BCI fulfils one of the key objectives of the Circular Construction Economy transition agenda: making circularity measurable to create awareness among those involved. Whereas other measurement tools focus mainly on raw material and material use, the BCI also provides insight into the detachability of a building.

Circular economy indicators are often shown side by side, the BCI Building combines all these aspects together in one score for the degree of circularity for your real estate object. The BCI score is expressed as a percentage between 0% and 100%, with 0% being fully linear and 100% being fully circular. This makes it simpler to compare properties and steer for circularity during development.

The Building Circularity Index (BCI) is a scientifically based and field-tested measurement methodology to determine the circular potential of a structure. The BCI consists of two Critical Performance Indicators (CPIs). These CPIs are material usage and detachability. The Building Circularity Index determines the circular potential of a structure in four steps: MCI, PCI, ECI, BCI.

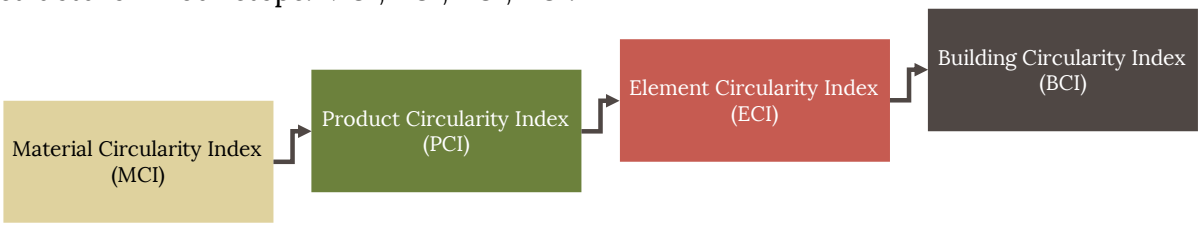


Figure 6: steps towards BCI (BCI gebouw, n.d.)

The origin of materials, future scenario of materials and the utility factor together determine the Material Circularity Index (MCI). The MCI represents the circular potential of a product regardless of how it is assembled in a structure.

The Material Circularity Index (MCI) and the Detachability Index (DI) together form the Product Circularity Index. The PCI represents the circular potential of a product when assembled in a structure.

A composite element has its own detachability index. The composite MCI and the detachability index of the element determine the ECI.

The Building Circularity Index (BCI) is the average circular potential of the building based on all applied products and elements. The environmental impact is used

as a weighting factor for the average. This means that products with a relatively high environmental impact have a higher share in the BCI score. To determine the environmental impact, the Environmental Cost Index (ECI) is used. The ECI represents the total environmental impact of a product from cradle to grave based on environmental impact categories.

Foster (2020) also created a framework with strategies for adaptive reuse of cultural heritage buildings to reduce environmental impacts. The study created a framework for circularity measures for existing buildings that takes into account both environmental effects and cultural heritage preservation. Throughout each phase of a building's life cycle, it is meant to be a tool for project teams made up of both participants and nonparticipants. It could be used by project teams as a planning and assessment tool at the outset of the project, as an exploratory scoping exercise in conjunction with other participatory approaches, and as a post-project circularity review tool as well. Non-participants may utilise the framework to establish policies and programmes for education. This framework is shown figure 7 on the next page.

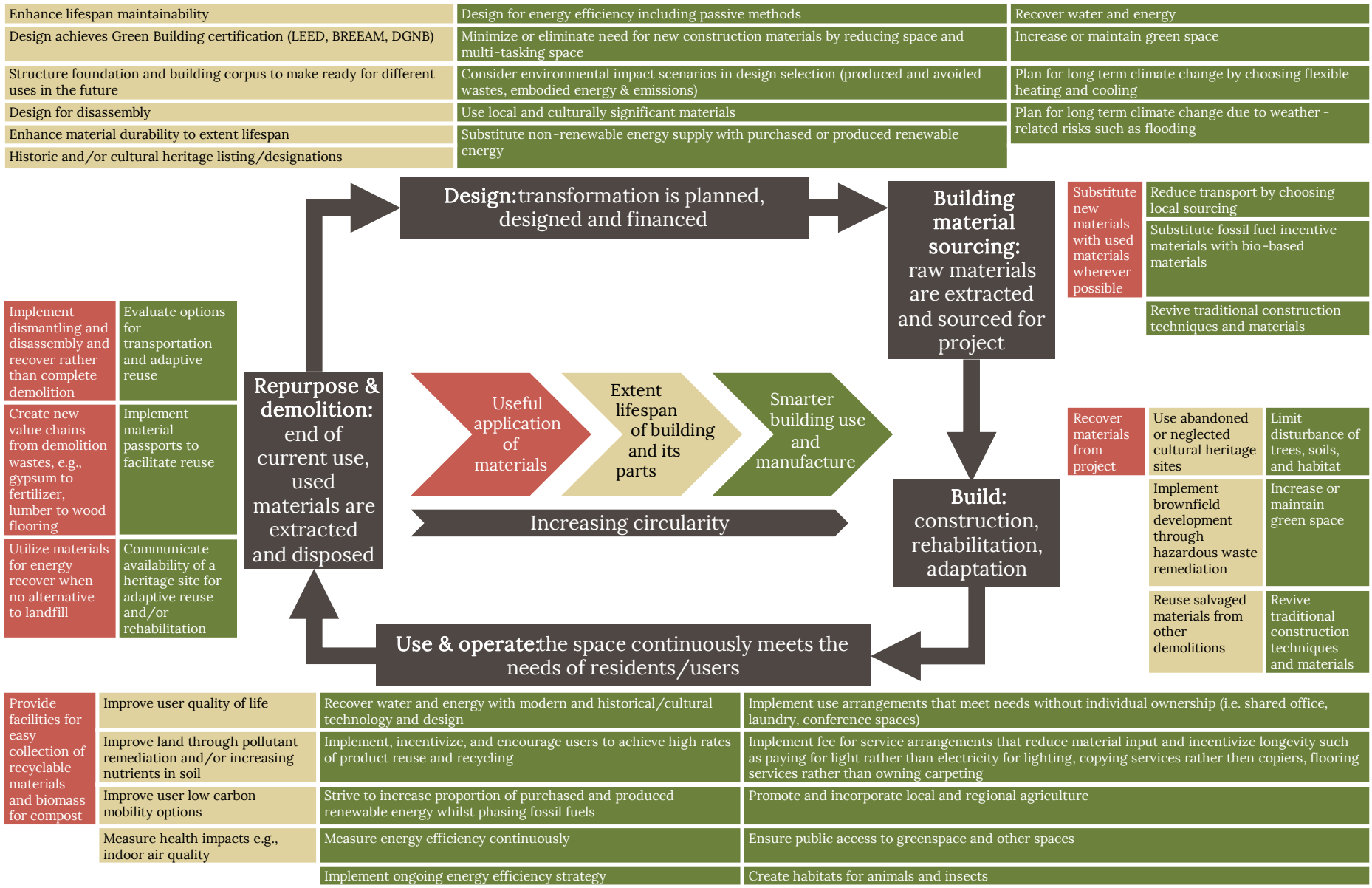


Figure 7: Circular economy strategies for adaptive reuse of cultural heritage buildings to reduce environmental impacts (adapted from Foster, 2020)

Foster & Kreirin (2020) researched what environmental impact indicators are used in adaptive reuse of heritage buildings. They also researched if these indicators actually reflect the circular economy concepts. They concluded that despite the policy environment favouring the circular economy, concrete and quantified environmental indicators are not widely used. Although ideas about environmental protection are frequently found in literature, environmental indicators have not yet become widely used.

In their framework they clustered the indicators in four different groups:

1. Indicators of direct reductions to new natural materials extraction due to the adaptive reuse;
2. Indicators of direct reductions to energy use due to the adaptive reuse;
3. Indicators of direct environmental improvements due to the adaptive reuse; and
4. Indicators of indirect reductions to energy use or pollution due to the adaptive reuse.

Groups 1, 2, and 3 concentrate on the direct effects of adaptive reuse on materials, energy, and the environment, accordingly. Group 3 contains environmental advantages owing to adaptive reuse as well as emission reductions. Group 4 includes indirect ways to reduce energy use or pollution.

The distinction between direct and indirect environmental impact has been made as it is consistent with LCA boundary-setting standards and International Organization for Standardization advice (ISO, 2006). Because of this, practitioners from a wide range of fields are able to understand the rubric (table 3).

Table 3: Key circular environmental indicators (adapted from Foster & Kreirin, 2021)

Key environmental impact indicators for ARCH			
1. Indicators of direct reduction to new natural materials extraction due to the adaptive reuse	2. Indicators of direct reductions to energy use due to the adaptive reuse	3. Indicators of direct environmental improvements due to the adaptive reuse	4. Indicators of indirect reductions to energy use or pollution due to the adaptive reuse
Maintain embodied energy in reused concrete, stone, brick, steel, etc. (CO2 equiv. GHGs per ton avoided or tones avoided/reused)	Greenhouse gas emissions (CO2 equiv. GHGs tons/year)	Reductions to air emissions including CO2, nitrogen oxides, (Nox), sulphur oxides (SOx), and particulate matter	Maintain embodied energy in reused concrete, stone, brick, steel, etc. (CO2 equiv. GHGs per ton avoided)
Increase water efficiency/fresh water consumption (kilolitres/person/year)	Increase energy efficiency/ consumption per (megawatt hours or kilojoule/user/year)	Improve water quality measured as eutrophication potential based on nutrient loads (phosphorous or nitrogen g/litre of dissolved oxygen)	Limit land use change (farmland maintained or reduction to urban sprawl in hectares)
Reduce C&D waste to landfill through recovery and reuse on or off-site (cubic meters)	Increase amount of non-renewable vs. renewable energy use (megawatt hours or kilojoules)		Indirect emission reductions due to the adaptive reuse e.g., reduction in vehicle use (CO2 equiv. GHGs per year avoided)
Increase land use efficiency due to the adaptive reuse (square meter reductions to space requirements of new purpose)			

Bosone et al. (2021) performed a thorough literature assessment, which showed there is no defined and widely accepted technique for assessing the many effects of cultural heritage adaptation and reuse from a circular economy perspective.

Their results indicated that although some circularity indicators for measuring cultural heritage impacts are available, many pertinent circularity factors are not taken into account. Several indicators with varying degrees of linkages to cultural heritage have been established, however, there is still no consensus on the best set of indicators to utilise in order to evaluate the effects of cultural building adaptive reuse from a circular viewpoint.

Bosone et al. (2021) therefore created a framework which elaborated on the research of Gravagnuolo et al. (2021) who identified three primary fundamental drivers or "building blocks" for circularity, placing adaptive reuse of cultural heritage from the standpoint of the circular city model:

- a "regenerative capacity" (Gravagnuolo et al., 2021), that is connected to the self-regeneration of heritage buildings as well as the environmental, economic, and social resources required for maintaining them over time.
- a "generative capacity" (Gravagnuolo et al., 2021), which is related to the territory's overall positive effects in terms of the economy, environment, and society, some of which are directly related to the heritage building.
- a "symbiotic capacity" (Gravagnuolo et al., 2021), associated with cooperative and collaborative methods that allow for the more effective use of resources (like those realised in "industrial symbioses") as well as clustering activities in the area (implementing a "economy of relationships").

A total of 40 indicators were connected to each building block. Figure 8 shows how the three kinds of circularity criteria are organised: "Resources" connected to regenerative capacity. "Outcomes" related to the generating capacity of the heritage system and "Circularity enabling factors" linked to the symbiotic capacity in the context region (Bosone et al., 2021).

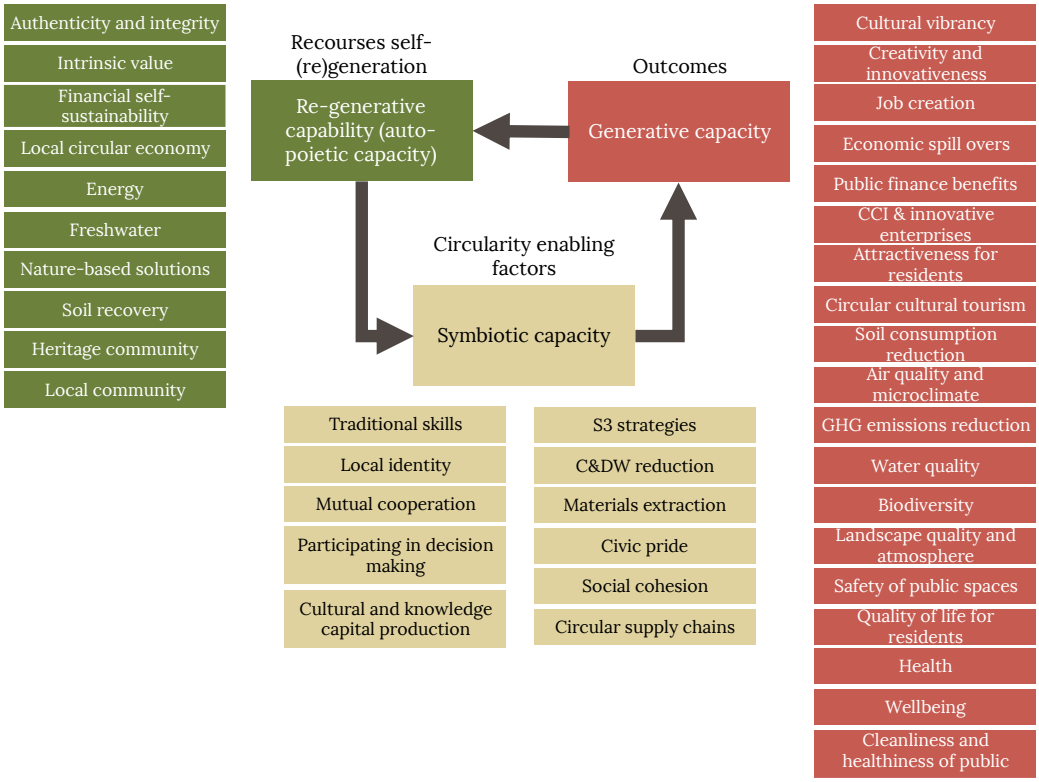


Figure 8: visualization of circular cultural heritage adaptive reuse (CHAR) database of criteria (adapted from Bosone et al., 2021)

4.3 Barriers and enablers for implementing the circular economy

Heritage structures and the traditions they stand for can be used to showcase the numerous facets of diversity within communities. One way to safeguard historic structures and the values attached to them is through adaptive reuse. However, in reality, stakeholders still struggle to assess the adaptability of historic structures and make wise choices regarding their adaptive reuse (Yazdani Mehr & Wilkinson, 2021).

Adaptive reuse of heritage buildings experience multiple challenges or barriers, which can retain stakeholders from applying adaptive reuse. On the other hand, there are the driver, or enablers, of solutions of adaptive reuse, which can stimulate the refurbishment of heritage buildings. This next section will provide an literature overview of the barriers and enablers that exist when opting for adaptive reuse of heritage buildings and existing real estate.

To give a thorough analysis of the variables influencing the decision to choose an adaptive re-use strategy, Bullen and Love (2011) conducted research on the drivers and barriers of adaptive reuse (Figure 9).

Their research revealed that lifecycle difficulties, shifting attitudes about buildings, and governmental incentives are the main drivers behind adaptive reuse. On the other hand, the perceived higher maintenance costs, building codes, the inertia of construction standards, and the inherent risk and unpredictability associated with older building stock are barriers to re-use.

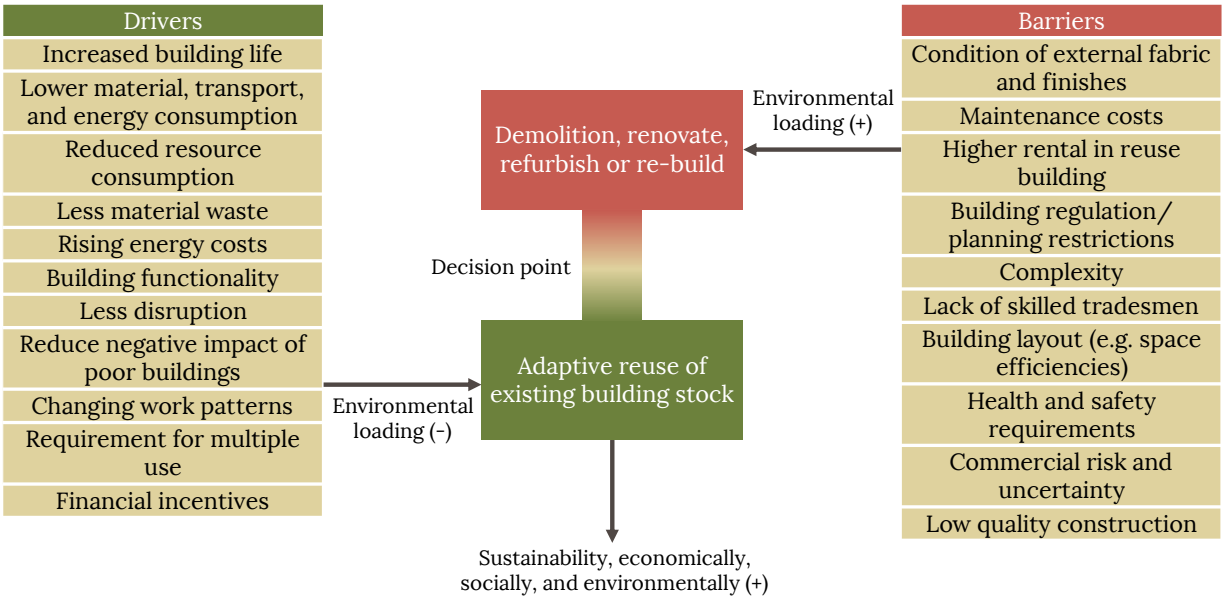


Figure 9: Drivers and barriers of adaptive reuse (adapted from Bullen & Love, 2011)

Yazdani Mehr and Wilkinson (2021) concluded that the adaptive reuse of buildings is hampered by a variety of challenges. Challenges are important in decision-making because, even though they are not barriers to adaptive reuse, they must be addressed to lessen the chance that an existing structure will suffer from obsolescence. The difficulties of adapting historic structures for new uses range from meeting user expectations for modern technical and regulatory standards to balancing compatibility between old and new demands. Reusing heritage buildings adaptively can be difficult for a number of reasons. The adaptive reuse of buildings may be somewhat impeded by one, several, or a combination of problems. The majority of obstacles to the adaptive reuse of historic structures are financial, legal, and technical, while the fewest are geographic, physical, and environmental. The categories of challenges faced by adaptive reuse of historic structures are shown in Table 4.

Table 4: Challenges to adaptive reuse (adapted from Yazdani & Wilkinson, 2021)

Challenges to adaptive reuse	
Environmental	Attaining the desired levels of standards
	The existence of hazardous materials
Social	Being on the heritage list
Economic	Lack of financial support
	High costs of adaptation
Legal	Receiving approvals for any work on heritage listed buildings
	Compliance with building codes and regulations
	Compliance with heritage guidelines
	Being on the heritage list
Political	Local government support
Physical	Finding a suitable function
	Lack of accurate drawings and information
	Poor quality of the building
	Poor physical and structural condition of the building
Locational	Complying with parking norms
Technical	Improvement of technical aspects of existing building
	Providing disability access
	Providing required performance standard and preserving the visual quality
	Installation and upgrade of mechanical and electrical systems
	Lack of experience and knowledge
	Specific construction techniques and materials in existing building
	Lack of skilled tradesmen

Springvloed (2021) created a framework with drivers and barriers based in the six dimensions of circularity in the building sector (figure 10). These six dimensions are: governmental, economic, technological, environmental, societal, and behavioural. The governmental dimension, also known as the institutional dimension, focuses on governmental actions and policies that either impede or facilitate the adoption of circular economy practises by companies. The economic component will concentrate on models of profitability, specifically how beneficial a circular business model can be for businesses. The technological dimension is primarily concerned with plans for technological innovation in the form of improvements to operations or manufacturing. Additionally, it might apply to measurement equipment as well as technical challenges or advantages in industrial processes. The key factors influencing the execution of circular initiatives or impeding their implementation were barriers and drivers in the environmental dimension. Resource shortage, environmental impact, and environmental harm are a few examples of such environmental variables. Instead of focusing on people's behaviour, the societal dimension is largely concerned with existing social structures like schooling systems. The behavioural component, in contrast to the social dimension, which relates to societal structures, does focus on individual behaviour rather than the behaviour of entire structures.

Drivers	
Governmental	Policy support
	Regulatory reform
Economic	Financial incentives
	Circular business models
	Tools to measure value of materials and products
	Information metrics
Technological	Web-based innovation
	Efficient designs
	Development of enabling technology
	Technology to enable close-loop materials
Environmental	Development of environmental assessment metrics
Societal	Recognition
	Support from demand network
	Collaboration
	Networking
	Multi-stakeholder connections
Behavioural	Leadership
	Company environmental culture
	Personal knowledge
	Intrinsic motivation

Circular initiatives	
R0 Refuse	Non-reusable materials
	Hazardous materials
	To use disparate binders
R1 Rethink	Processes using R-strategies
	Business models (PSS)
R2 Reduce	Consumption of new materials
	Non de-constructable constructions
R3 Reuse	Of components
R4 Repair	Entire constructions
	Constructions elements/components
R5 Refurbish	Older constructions (renovation)
	Structural elements
R6 Remanufacture	Resource from construction components
R7 Repurpose	Materials from outside the construction sector
	Entire buildings for residential housing
R8 Recycle	Materials for larger components
R9 Recover	Energy from materials
	Materials after incineration to be used as secondary raw materials

Barriers	
Governmental	Obstruction laws and regulations
	Lack of regulation and laws
	Lack of regulatory mechanisms
Economic	High upfront costs
	Inadequate financial resources
Technological	Technical challenges related to material recovery
	Lack of adequate technology
	Lack of standardisation
	Fragmented and linear supply chain
Environmental	-
Societal	Lack of knowledge and engagement throughout the value chain
	Lack of collaboration
Behavioural	-

Figure 10: Drivers and barriers to circular initiatives (adapted from Springvloed, 2021)

The strength of this framework is that it shows how each dimension can be both a driver and a barrier. Take the governmental dimension for example. One major driver from this dimension is financial support through subsidies. The government has multiple subsidies for maintenance, conservation and transformation (Monumenten.nl, 2021).

- Housing subsidy (Woonhuissubsidie): This is a yearly subsidy for owners of monuments with a living function. It is meant for upkeep of het monument like renovating paintwork, roofs, windows, and other activities.
- Conservation subsidy national monuments (Instandhoudingssubsidie rijksmonumenten (Sim)): This subsidy is meant for monuments that do not have a living function. The subsidy is also meant for the maintenance of the building, based on a 6 year conservation plan.
- Transformation subsidy (herbestemmingssubsidie): When transforming a heritage building, this subsidy can be filed for. It is to be used in order to fund a feasibility study and for methods to make the building wind and water proof the building.
- Municipal and provincial subsidies: municipalities and provinces often also have their own subsidies for renovations on heritage buildings. These subsidies do often differ per municipality since they do often not have the same monument policy.

Heritage buildings are generally considered important because of their beauty, significance to science, or cultural historic value. They represent the way how people used to live. In order to safeguard this tangible piece of history, the government started to protect these monuments. In the Netherlands there a mainly two types of monuments, national monuments and municipal monuments. National monuments are appointed by the prime minister or the national service for cultural heritage. Municipal monuments are buildings that are of local or reginal importance. Municipalities in the Netherlands can appoint these

buildings and put them on the municipal monuments list, which will provide them with the protective status of a monument (Monumenten.nl, 2022).

Municipal monuments present a challenge because not all municipalities adhere to the same monument policy. It is challenging for developers and contractors to design renovation projects for historic buildings because each municipality has various regulations regarding what interventions can be made to heritage buildings and what interventions require permits or not.

4.4 Literature review conclusion

Literature has shown that there are different ways to define the circular economy. For this research the definition of Foster (2020) will be used, which states: The circular economy is a system of production and consumption that minimises the use of natural resources and the impact on the environment by increasing the lifespan of materials and minimising their consumption and wastage. Through the creation of new products, long-lasting design, waste reduction, resource recovery, and reuse, as well as through reframing consumption to also include sharing and the supply of services rather than private ownership, materials are given an extended useful life. The circular economy stresses the use of materials with the least damaging life-cycle impacts, such as those that are renewable, nontoxic, and biodegradable. As a sustainability idea, a circular economy must be integrated into a social system that supports universal human welfare within the biophysical bounds of the planet Earth (Foster, 2020).

When discussing the adaptive reuse it relates to the process of refurbishing and repurposing an existing building, a "change in use". With the goal of a "performance change," or the act of adapting a structure for a new purpose aside from that for which it was originally designed

The last definition that clarified was cultural heritage , which consists of artefacts, monuments, collections of buildings and sites, museums, and other objects that have a variety of values, such as symbolic, historical, aesthetic, artistic, anthropological, ethnological, scientific, or social significance (UNESCO, 2009). Early modern office buildings, royal or aristocratic mansions, community gathering spaces, industrial production sites, and military artefacts are only a few examples of cultural heritage structures.

Moreover literature has shown that there are various methods for assessing and evaluating the circular economy within a construction project. Yet some of the models are inappropriate for this particular research question. The Potting and McKinsey models only evaluate circularity in the general sense. These models are not aimed towards heritage or even the construction sector. The López Ruiz model is more concentrated on the construction industry and offers many indicators that are applicable to various phases of a building's lifecycle. However, this model is still too rudimentary and does not take into account heritage initiatives. The same goes for the BCI measuring system. This model is very concrete for putting a label on how circular a building is. However, the emphasis is on the quality of the materials and the structure rather than what the circular economy can do for social and cultural issues. For this study, the circularity assessment models from Foster (2020), Bosone (2021), and Foster & Kreirin (2021) are more suited. They were developed with the construction industry in mind, with a special emphasis on historic structures, but they also take into account the circular economy's multiple dimensions.

Finally while barriers differ for every project. Some barriers are somewhat straightforward and will apply to alsmost every construction project. The financial aspect will influence every

building project, both positively and negatively. This two-sidedness is very well represented in the research of Springvloed (2021) where it is shown how an aspect of a project can both function as an enabler or a barrier. This insight into the various manners a project can be hindered or driven, will provide a solid foundation for the interviews and focus group on why certain circular economy strategies are not implemented in an adaptive reuse project. They can steer and help the identify what the reason is behind not implementing certain circular economy strategies. The barriers and enablers can help identify what step still need to be taken to mitigate the remaining barriers.

5. Case study research

5.1 Case study selection

Various case studies have been chosen in order to determine the extent to which circular economy strategies are applied in adaptive reuse of heritage projects.

In order for a project to be eligible for the case studies they have to be heritage buildings, this means the building has to be on either a municipal monuments list or the governmental monuments list. Moreover the project has to be an adaptive reuse project, in the sense that they all have different functions after their renovation.

Furthermore the project has to be initiated within the last eight years. This is when the Dutch government first introduced the goal to transition to the circular economy (Ministerie van Infrastructuur en Waterstaat, 2023). Preferably, the projects are also either currently under construction or just recently completed. This has to do with the fact that the interviewees are still engaged with the project, which makes it simpler for them to recall details about the project during the interview. The selected project for the case studies are shown in table 5 below.

Table 5: Case study project (Own table)

Project	Location	Transformation
Vincentius	Udenhout	Former monastery to apartment building
Groot Tuighuis	's-Hertogenbosch	Church to modern cultural heritage centre
Het Zuider	Rotterdam	Pre-war hospital to apartment building
Veerhuis	Rotterdam	Former ferry service location into writers location
Oudezijds Voorburgwal	Amsterdam	Canal warehouse into apartments and offices

In each project, three distinct parties are subjected to interviews. The first interview is conducted with a plan developer or project leader representing the contracting company. This individual has been involved from the early stages of the project and possesses extensive knowledge regarding the development of the final plan. Furthermore, they possess insights not only into the design phase but also the execution phase of the project. Consequently, this individual is well-equipped to provide a comprehensive overview of how circularity has been incorporated throughout the entire project timeline.

The second party to be interviewed is the client of the project. The objective of this interview is to ascertain the degree to which circularity was prioritized by the client during the project's initiation.

Lastly, the architect responsible for the project is interviewed. This interview aims to uncover the specific circular economy strategies that have been integrated into the project's design. These parties have been selected for interviews due to their status as key stakeholders in a construction project (Jin et al., 2017).

Table 6 provides an overview of the companies that have been interviewed for each project. Regrettably, it should be noted that, in the case of two projects, the architect was unable to participate in the interviews.

Table 6: Case study interviewees (Own table)

Project	Contractor	Client	Architect
Vincentius	Nico de Bont & BOEi		
Groot Tuighuis	Nico de Bont	Municipality of Den Bosch	VB Erfgoed & Architectuur
Het Zuider	Nico de Bont	BOEi / Impact vastgoed	Molenaar & Co
Veerhuis	Nico de Bont	Company from Rotterdam	-
Oudezijds Voorburgwal	Nico de Bont	NV Zeedijk	-

5.2 Case study description

5.2.1 Vincentius - Udenhout

The original initiators of the Vincentius project were the Sisters of Choorstraat, who were affiliated with the Congregation of the Daughters of Mary and Joseph. It was common for congregations in Noord Brabant to collaborate with their own in-house architect, and the Sisters of Choorstraat followed this practice by selecting J.J.M. van Halteren to design the Vincentius building, as he was well-known to the sisters. The architectural design, inspired by the Amsterdam School style, incorporated the concept of adaptive reuse by considering the potential changes in the function of spaces within the building. This foresight increased the building's chances of survival, as spaces could be repurposed as dormitories, classrooms, or playrooms (BOEi, 2022b).

Image 1: Vincentius 19th century (van Leeuwen, n.d.)

The striking tower in the main building with a height of 35.5 meters was originally built as a water tower. In the absence of a water supply system in Udenhout, both care facilities provided their own drinking water supply, and a water tower was therefore part of the building brief. The clockwork at the top of the tower and the angelus bell were both donated by will in February 1928 by one of the sisters. The Vincentius is a very remarkable and robust building in a village like Udenhout where there are mainly single-story residential houses. After its construction it towered high above its surroundings, defining the visual identity of the then still small village (BOEi, 2022b).

The restoration and transformation of the water tower at the former monastery will create a habitat for barn owls, swallows, and bats, contributing to the enhancement of local biodiversity. The tower, known as the "Faunatoren" (wildlife tower), will also serve as a site for research purposes. The restoration of the water tower marks the initial phase of the Vincentius housing project, which encompasses a total of 92 homes, including 28 apartments in the listed monumental main building, 13 manor houses in the wings, 22 sustainable owner-occupied apartments, and 29 rental apartments managed by a housing corporation (BOEi, 2022b).

Image 2: Vincentius present day (Van Gerven, n.d.)

The collaborative effort behind the Vincentius project involves Nico de Bont and BOEi. The historical significance and location of the site have strongly influenced the project's vision, which is reflected in the residential program. The national monument will be meticulously restored and repurposed as high-quality apartments, while preserving important characteristic elements such as the distinctive staircase and high ceilings. The aim is to provide modern comfort while honoring the building's architectural heritage (Nico de Bont, 2022b).

5.2.2 Groot Tuighuis – ‘s-Hertogenbosch

The Groot Tuighuis, also known as the Oude Sint Jacobskerk, is a historic building located on Bethaniëstraat in 's-Hertogenbosch, the capital of Noord Brabant. Originally a Catholic church, the Groot Tuighuis exemplifies adaptive reuse and has undergone various transformations throughout its history.

Image 3: Groot Tuighuis circa 1900 (Erfgoed ’s-Hertogenbosch, n.d.)

Around 1430, a chapel and guesthouse were constructed at the site, serving as a resting place for pilgrims en route to Santiago de Compostella. Over time, the fraternity chapel expanded and evolved into a three-aisled nave with a single-aisled choir. In 1569, it became a parish church (Gemeente ’s-Hertogenbosch, n.d.).

Following the city's capture in 1629, the building was expropriated and repurposed as a Protestant church, carriage house, and horse stable. In 1752, it underwent conversion into a military arsenal, featuring storage attics for weaponry and other supplies. During the 19th century, the building acquired its current name, the "Groot Tuighuis" or "Great Rigging House" (Gemeente ’s-Hertogenbosch, n.d.).

After its military function ceased in 1924, the building was transformed into the Noord Brabant Museum under the architectural design of Oscar Leeuw. Internal reconstruction took place, accompanied by the renewal of the front facade. Subsequently, the museum relocated to Verwersstraat, and in 1988, the Groot Tuighuis became the headquarters of the municipal Building History, Archaeology, and Monument (BAM) department (Gemeente ’s-Hertogenbosch, n.d.).

Since 2015, the Groot Tuighuis has served as the office and depot of the municipal Heritage Department of 's-Hertogenbosch (Gemeente ’s-Hertogenbosch, n.d.).

Image 4: Groot Tuighuis present day (Nico de Bont, n.d.)

The building is currently under construction in a in a project commissioned by the municipality of ‘s-Hertogenbosch. Contractor Nico de Bont, together with VB Erfgoed & Architectuur work on the renovation of the Groot Tuighuis. The structure will be transformed into a modern Heritage Center during a sustainable renovation. VB Erfgoed & Architectuur have been responsible for the design, Nico de Bont is responsible for the technical elaboration of this design and the realisation. The monumental building will have a public function on the entire ground floor. Residents and visitors will soon be able to experience and contribute to the story of 's-Hertogenbosch through unique historical sources (Nico de Bont, 2022c).

5.2.3 Het Zuiderziekenhuis - Rotterdam

During the late 19th century, the urban expansion of Rotterdam-Zuid proceeded swiftly. Consequently, the municipal authorities commissioned the construction of a new hospital on Groene Hilledijk in 1929. The initial design was entrusted to W.G. Witteveen, who was later joined by municipal architects B. Cramer, W. de Groot, and Chief of Buildings Ad van der Steur (BOEi, 2022a).

Image 5: Zuiderziekenhuis 19th century (Algemeen Dagblad, n.d.)

The realization of the project progressed at a sluggish pace, and the plans underwent constant adjustments. Oftentimes, sections of the building were dismantled and reconstructed due to changing requirements or insufficient funding for certain design elements. A notable instance of this is the boiler house, which was initially conceived as part of the comprehensive plans to provide heating for all the hospital buildings. However, a decision was made at a certain stage to incorporate the boiler house within the "Poorthuis" structure. Consequently, a portion of the "Poorthuis" was demolished and subsequently rebuilt. Other parts of the building were also modified during the construction process in response to evolving medical perspectives (Molenaar, n.d.). The project was not completed until 1939, with an official inauguration on August 1, 1939, shortly before the outbreak of World War II (BOEi, 2022a).

The war period posed significant challenges not only to the operations of the hospital but also to the structural integrity of the building itself. In 1941, the Zuider Hospital endured severe damage due to an incendiary bomb attack, reflecting the turbulent nature of the time and fostering a unique bond with the residents of Rotterdam-Zuid.

Following the fires at the nearby Shell facility in Pernis, the hospital shifted its focus to the treatment of burns, starting in 1974. This specialization led to the establishment of a dedicated facility in 1986. Eventually, due to a merger, the hospital relocated to a new site in 2011 (BOEi, 2022a).

The Zuiderziekenhuis is currently undergoing a transformative project commissioned by BOEi, in collaboration with the esteemed architects from Molenaar & Co. Following the restoration and repurposing, the expansive grounds and buildings of the Zuiderziekenhuis will be transformed into a multifunctional space for residential, educational, and professional purposes.

Image 6: Zuiderziekenhuis present day (Adebo, n.d.)

In a significant development, the Poortgebouw now serves as the home of the prestigious Het Zuider Gymnasium, making it the first specialized gymnasium in the Rotterdam South region. Additionally, a wing of the Poortgebouw has been designated as office space, catering to the needs of small independent companies. The pavilions within the premises will accommodate approximately 30 townhouses at the ground level, while the Carré, formerly the main building of the hospital, will house around 70 apartments. Moreover, the surrounding land, once vacant, will be transformed into a new residential area known as Zuiderhof (BOEi, 2022a).

"The pre-existing hospital structure of the building proved very workable when transforming it into apartments. In fact, only the exterior walls and an interior longitudinal wall are load-bearing elements. In between, rooms, halls and other spaces were already frequently shifted: a wall here and a wall there. Because these can be removed, an open structure is created that provides space for the apartments, varying in size, layout and location. In which, of course, we respected the architectural characteristics and historical peculiarities of the building such as the characteristic brick facades, rhythmic series of windows, glass staircases with beautiful robust staircases, bay windows and tower accents" (Molenaar, n.d.).

5.2.4 Veerhuis - Rotterdam

The Veerhuis, situated on the Schiemond in Rotterdam, historically operated as the embarkation point for the ferry service connecting the northern bank with the wharf of the renowned "Rotterdamsche Droogdok Maatschappij" (Rotterdam Dry Dock Company) (RDM).

Image 7: Veerhuis 19th century (Droom en Daad, n.d.)

The historic RDM Veerhuis, dating back to 1917 and designed by architect H.A.J. Baanders, has always served as a vital connection point to the RDM area across the Maas River. With its distinctive Swiss chalet-inspired architecture, the Veerhuis stands out as an architectural gem, juxtaposed against its urban surroundings—a symbolic "island" within the cityscape (Veerhuis, n.d.).

For many years, the Veerhuis facilitated the daily transportation of hundreds of workers who commuted via ferry to the RDM site on the southern bank. At its peak, the ferry boasted a capacity of 1,300 passengers, including workers and the transfer of small equipment between the Veerhuis and the opposite shore. However, following RDM's bankruptcy in 1983, the ferry service ceased its operations. The iconic Ferry House holds significant cultural value as the last tangible testament to the illustrious maritime history of this area (Het Cuypersgenootschap, 2021).

Currently, the structure has been vacant for almost fifteen years. It has become quite dilapidated and the municipality has long planned to demolish it. This was prevented by the Cuypersgenootschap, an organization dedicated to preserving heritage (FIEN, 2020).

Image 8: Veerhuis present day (Van der Pal, 2022)

The client is currently undertaking plans to establish the Veerhuis as a dedicated haven for writers—a place on the banks of the Maas River where the art of writing is revered and open to all who aspire to engage in this craft or develop their skills. Furthermore, a portion of the building will be allocated for a restaurant function, enhancing the overall experience (Stichting Droom en Daad, n.d.).

Architects Donna van Milligen Bielke and Ard de Vries have been entrusted with the extensive renovation, transformation, and additional extension of the Veerhuis. Their objective is to restore the Veerhuis to its original design while thoughtfully incorporating contemporary and future requirements. Through this meticulous process, the Veerhuis will emerge as a serene sanctuary on the Maas, welcoming individuals to gather, write, listen, and learn (Veerhuis, n.d.).

5.2.5 Oudezijds Voorburgwal – Amsterdam

The building at Oudezijds Voorburgwal 136 has a rich history. Before the current building was constructed, a beer merchant was located at the address. In this earlier building lived beer merchant Hendrick Lenertsz Pot from 1585. The *"bierkaai"* (Beer Quay) was the quay in Amsterdam where the barrels of beer arrived and the hauliers worked loading and unloading the heavy barrels of beer. This had to be done here to facilitate the levying of excise duty. The quay was a part of the Oudezijds Voorburgwal, located near the Oude Kerk (De Bierkaai, 2018).

Image 9: Oudezijds voorburgwal 136 circa 1950 (Van Gool, n.d.)

In 1733 the current structure was built in the stately Louis XIV style. The building has had various functions, for example, From the 1930s to the 1950s, printing firm 'De Hoop' was located here and in the 1980s it housed a sex shop. The building is currently a national monument.

NV Zeedijk acquired the property in the summer of 2018 with the goal of preserving the monumental heritage for the future. It prompted the founding of Green Light District, a collaboration of De Groene Grachten, NV Zeedijk, Municipality of Amsterdam, De Gezonde Stad, Rooftop Revolution, TU Delft and EIT Climate-KIC. The initiative has the goal of making the city centre a future proof, sustainable, and iconic piece of Amsterdam (Green Light District, n.d.). Until the renovation, the building formed Green Light District's headquarters for a short time.

Image 10: Oudezijds Voorburgwal 136 present day (Schollaardt, n.d.)

Together with the initiative a preservation plan was drawn up and elaborated by architects van Stigt, authority on sustainable restoration and renovation of monument listed buildings. Sustainability is therefore central to the award-winning architectural firm's design.

Solar panels have been installed on the premises, harnessing renewable energy. To optimize energy efficiency, the windows and walls have been outfitted with improved insulation. Notably, the chosen insulation materials prioritize natural and bio-based components, aligning with environmentally conscious practices. Moreover, the building has been disconnected from the natural gas supply and instead employs a heat pump and floor heating system. To further enhance sustainability, a "green pole" has been implemented, enabling the direct extraction of energy from the ground (Nico de Bont, 2022d).

The renovation process was executed with a steadfast commitment to sustainability. Notably, transportation of building materials was strategically conducted via waterways, utilizing electric transport. This approach serves multiple purposes: alleviating strain on the vulnerable quay walls, minimizing inconveniences for the local community due to restricted street space, and curbing CO2 emissions.

The finished project seamlessly incorporates residential units across the upper four floors, while the ground floor accommodates well-appointed office spaces.

5.3 Case study analysis

5.3.1 Coding

The interview transcripts have been systematically coded based on the established indicators proposed by Bosone et al. (2021), and can be found in figure 11. This framework was chosen due to its comprehensive and well-elaborated description of all the indicators in the database. By employing this framework, the analysis and coding process is streamlined and facilitates better comprehension. The indicators have been categorized into four distinct groups, namely: environmental, economic, social, and cultural. These four dimensions are commonly used to encapsulate the pillars of sustainability (Najjar, 2022). The distribution of the codes across these groups is visually represented in Figure 11.

It is noteworthy that the interviewees' responses varied for each code. In cases where an interviewee's response aligned with a specific indicator or code, it was consistently reiterated to ensure validation and eliminate any potential misunderstandings regarding the implementation of a particular strategy.

The existing codes offered a comprehensive framework for capturing the circular economy strategies implemented across the various projects. However, in instances where additional strategies were discussed and not covered by the predetermined codes, they were assigned new codes for subsequent analysis.

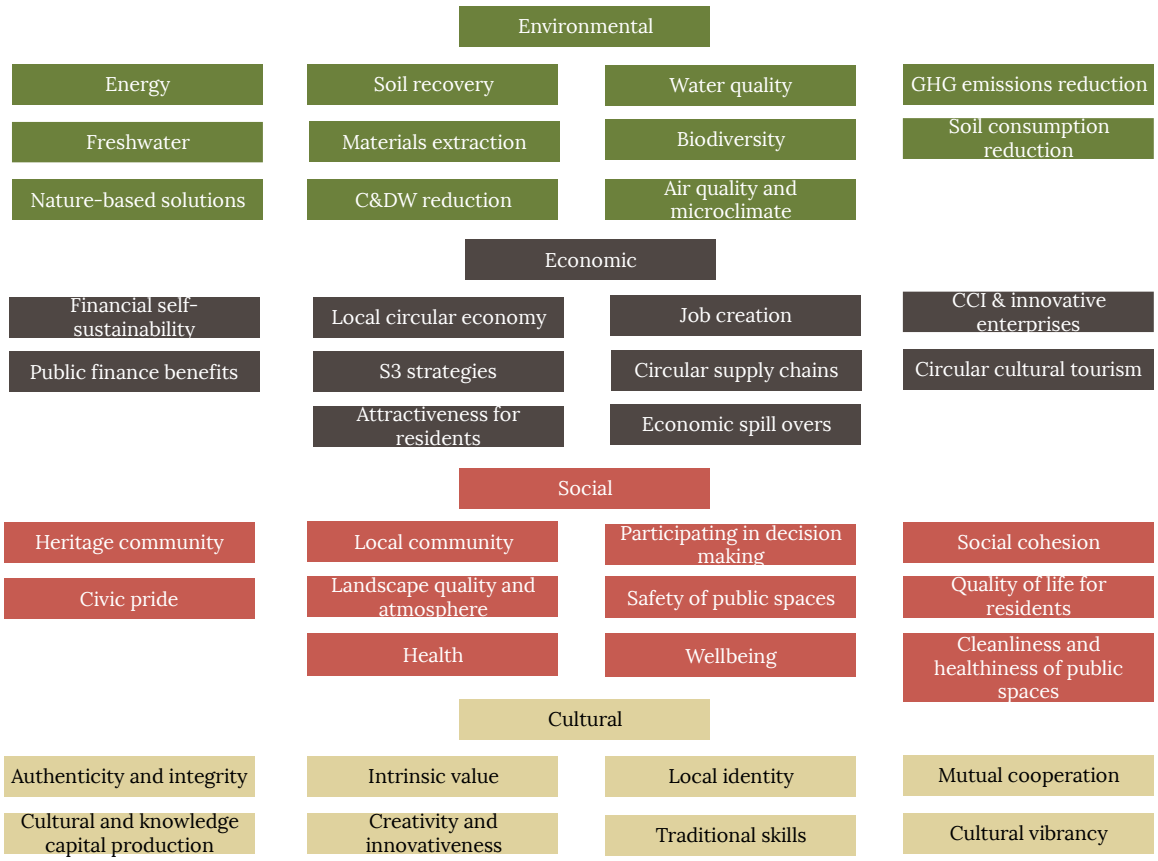


Figure 11: Coding tree (own illustration based on Bosone et al., 2021)

5.3.2 Analysis

The interviews conducted for the case studies have undergone coding and analysis using Atlas.ti software. The interviews served three primary objectives. Firstly, the aim was to explore and understand how each interviewee defined the concept of the circular economy. To achieve this, key words within each definition were marked and coded, enabling the identification of differences and similarities.

Secondly, the goal was to gain insight into the implemented strategies. This was accomplished by employing the aforementioned codes. A secondary objective was to examine whether personal definitions of the circular economy influenced the strategies that were implemented. The analysis was conducted through code-document analysis, where the codes representing various circular economy strategies were linked to the respective roles of the interviewees (such as plan developer, project leader, architect, client).

Lastly, the objective was to identify the barriers encountered in implementing circular economy strategies in the adaptive reuse of heritage. Each mentioned barrier was coded and categorized, as presented in Table 7. Subsequently, these barriers were subjected to a code-document analysis against the same roles of the interviewees. Pie charts were then created for each role to visualize the distribution of barriers among the interviewees.

Table 7: Barriers (Own table)

Ambiguities	Lack of urgency
Design difficulties	Money
Hard to measure	Poor execution
High demands	Routine
High risk	Rules & certification
Lack of experience	Scepticism
Speed of process	Small scale

5.4 Case study results

5.4.1 Definitions of the circular economy

All interviewees were requested to provide their definition of the circular economy during the interviews. This was undertaken to gain insights into the various perspectives held by different stakeholders.

In general, the plan developers, project leaders, and architects exhibited a shared understanding of the circular economy throughout the interviews. Their responses predominantly revolved around three key themes: reuse, circular material utilization, and waste reduction.

Reuse and circular material utilization were the most frequently discussed subjects. This encompassed the reuse of structural components and building materials. For instance, one project leader stated, "Circular means that you reuse the materials coming out of the building, but also that everything you put in is reusable. So the cradle to cradle concept, and that you can take part of the building out and later reuse it. So it's a combination of everything we harvest that can be reused" (Project Leader B). When addressing building materials, the focus often shifted towards circular, bio-based, and recyclable materials. A plan developer stated, "I think of natural materials, materials that are pleasant for myself as a human being, that have less burden or inflict less burden on my environment" (Plan Developer A). The responses frequently emphasized the environmental benefits, improved health aspects, and future recyclability of such materials. An architect expressed, "As far as I'm concerned, when it comes to circularity, it's about new materials being as natural as possible and also reusable again in the future" (Architect A).

The other prominent topic frequently discussed was the reduction and elimination of waste. A plan developer described the circular economy as "an economy in which there is basically no waste. So waste no longer exists because everything is in a circular flow, without linear processes or degrading processes where waste is created" (Plan Developer C). Waste reduction can be achieved through the reuse of materials from existing structures and the implementation of products that generate less waste and can be recycled in the future.

As is evident, these responses frequently relate to sustainability and the practical implications of circular economy strategies. When interviewing the clients of the projects, the definition of the circular economy took a slight shift. Regarding the use of circular materials, material reuse, and waste reduction, they raised the same points as the architects, plan developers, and project leaders. ‘’The circular economy, well the most obvious that comes to mind has to do with material use and how you deal with it. Avoiding large waste streams and reusing materials. Either from the building itself or from another building that is being demolished. Or where it is harvested. Of course, it's actually much broader than just material use” (client C).

In addition to these subjects, the social aspects of the circular economy were frequently addressed by clients. ‘’But the circular economy is also about the society we live in, in which there is room for everyone. And in that, we have to think about what there is, what can be, and how we are going to achieve that.” (client A). In addition to mentioning the social approach, they also explain how the client is accountable for achieving this. ‘’There is social responsibility in that, which also says something about how we, as a company deal in a sustainable way with our own people, with the parties we work with? But that also applies, for example the tenants we try to get in our building, we try to fill them with social functions as of often as possible” (client D).

Besides the social relevance of the circular economy they also mention the cultural significance of it. This is also especially important when dealing with heritage

buildings. "But what I think also fits best from (our organisation's) point of view is to make it part of the urban fabric again. And creating a place which is part of the city again." (client E).

Plan developers, project leaders, and architects put more focus on the practical circular and material side of the circular economy. Clients have also put the focus on the economy and social part. The science of economy deals with people's efforts to achieve prosperity. (Van Dale, n.d.). In the case of the circular economy this can be translated to generating capital in the form of sustainability, economic, social and cultural perspectives.

The fact that clients also mention the circular economy's social and cultural aspects may be due to the fact that social relevance is a more important tenet in their business strategy. It could also result from the fact that they are less familiar with a project's sustainable initiatives and practical implications.

5.4.2 Implementation of circular economy strategies

The interview's following section covered the circular economy strategies that were put into effect for each project. Finding out which strategies have been used was the main objective here, but it was also intended to determine whether the different interviewees' interpretations of the circular economy had an impact on the strategies that they used.

Table 8: Implemented circular economy strategies (Own table)

	Contractor (5)	Architects (2)	Clients (6)	Total
Cultural	9	3	5	17
Economic	4	0	5	9
Sustainability	38	12	12	62
Social	9	0	19	28
Total	60	15	41	116

Table 8 shows how many times different implemented strategies are mentioned by each interviewee. Since not all the interviewed parties have been represented equally, table 9 shows the weighted of the same table.

Table 9: Implemented circular economy strategies weighted average (Own table)

	Contractor	Architects	Clients	Total
Cultural	1,8	1,5	0,8	4,1
Economic	0,8	0	0,8	1,6
Sustainability	7,6	6	2,2	15,8
Social	1,8	0	6,5	8,3
Total	12	7,6	16	35,6

The table is divided in the four dimensions that have also been used for the coding of the interviews. As can be seen, the dimension that is most often mentioned throughout the interviews is sustainability.

Figure 12 shows that within the dimension of sustainability, circular material (re)use is the most often mentioned. "We reused the wooden floorboards from the ground level for finishing the stairwell. We also used hemp insulation in the walls, shells as floor insulation and bio-based retaining walls." (Plan developer C). The fact that this strategy is most often mentioned is in line to the definition of the circular economy that was often given in the interviews.

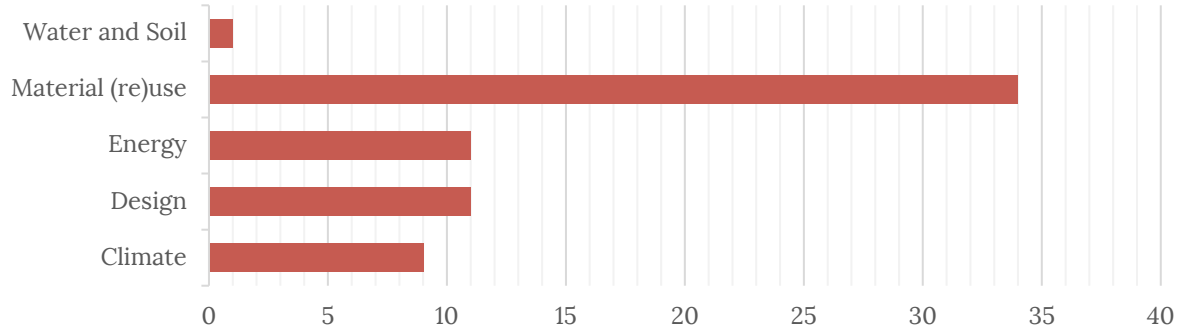


Figure 12: Implemented sustainability strategies (Own figure)

Table 9 additionally shows that when asked about what circular economy strategies are implemented in the project, client do often mention the social dimension. They go in to depth on ways that the project also benefits the surroundings of the project. "Part of the agreement with the municipality is not just that we restore the building, but that we also make an investment in the outdoor space. And that is actually not just the garden of the building, it is much bigger. It is a big part of the are and surroundings and something that the local residents will also very much benefit from." (Client E).

Other social strategies that were implemented were related to improving for example health, not just for the final users but also the construction workers during the process. "We did tests with different types of insulation. The workers explained that they really liked the hemp and jeans insulation. It does not irritate the eyes and lungs, like more traditional material. It is really nice that they can also benefit from this." (plan developer D).

An example of a strategy related to the cultural dimension is the generation of cultural knowledge. "It is not a true museum, but we use elements of it. By integrating archaeology, building history, and archive any interested resident van visit us and learn about their history and the of the city." (client C)

The findings from the interviews revealed that an individual's definition of the circular economy significantly influenced the strategies they mentioned in relation to it. Specifically, the plan developers, project leaders, and architects predominantly discussed circular economy strategies aligned with the sustainability dimension. This alignment can be attributed to their definition of the circular economy, which often emphasized sustainability and materials utilization and reuse. On the other hand, clients also mentioned social circular economy strategies during the interviews, which corresponded to their definition of the concept that placed emphasis on the social aspect.

The observation that most interviewees mentioned circular economy strategies consistent with their own definition may be attributed to their limited awareness of the range of strategies falling under the umbrella of the circular economy. Consequently, they tended to mention only those strategies they believed were unquestionably covered by the term. This pattern emerged frequently, as the document analysis of the case studies revealed the presence of strategies aligned with the circular economy that were not mentioned during the interviews. For instance, the realization of a wildlife tower in the Vincentius project, aimed at improving and promoting biodiversity, aligns with the principles of the circular economy but went unmentioned. While it is encouraging to see strategies being implemented even in the absence of awareness, the lack of recognition may hinder their incorporation in future projects, as their initial adoption relied somewhat on coincidence

5.4.3 Experienced barriers

The interview's final goal was to ascertain what obstacles people encounter while putting circular economy strategies into practise. Figure 13 illustrates the obstacles that each type of interviewee faces during the process.

Five out of the total of 13 barriers experienced make up for 64% of the total obstacles encountered in the process. These barriers are ambiguities, money, Lack of experience, routine, and rules & certification.

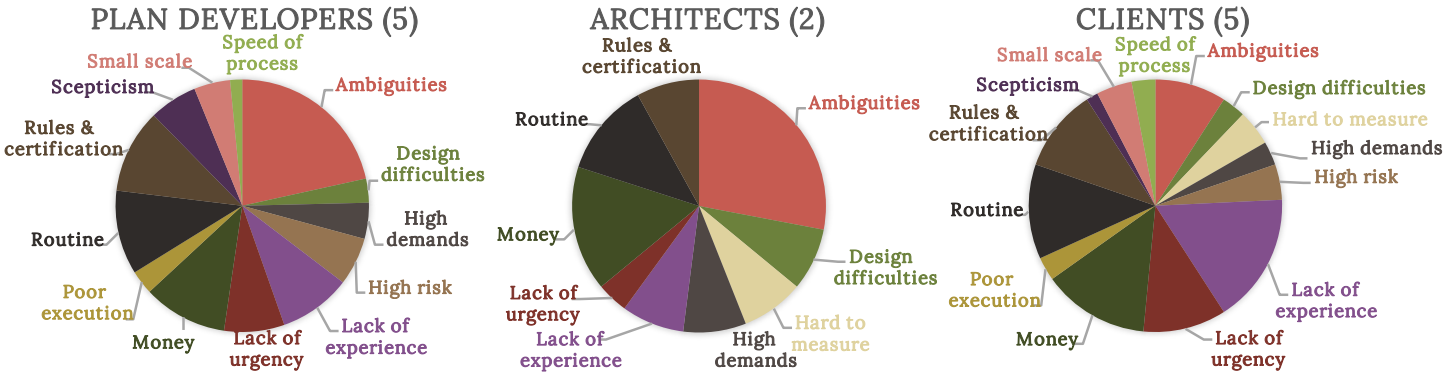


Figure 13: Experienced barriers (own figure)

Ambiguities

The ambiguities that are experienced in the process relate to uncertainties and problems that arise due to different interpretation, "in practise it's more sustainable than on paper" (plan developer C). An example of this is implementing recycled wood in a CO_2 calculation. "When you use wood in your construction you can deduct a certain amount of CO_2, because wood absorbs CO_2 when growing. But when you reuse an existing piece of wood in your construction you are not allowed to deduct this amount of CO_2 because the piece of wood has already absorbed it's CO_2 in their first life. So on paper it is more sustainable, or CO_2 beneficial, to use new wood in stead of reused wood. Yet we can all agree that reusing wood is actually more sustainable" (plan developer D).

Other uncertainties are often related to the complexity that can come from the transition to the circular economy. "What I currently see in this transition to the circular economy is that there are many different parties with so-called expert advisors, that speak in a language that is not understandable for us normal people. (...) There are no clear answers to, when you do this (implement certain strategy), you get that result, and I can help you achieve this. Those are very practical questions, but the answers often are not." (client A).

Money

Money related barriers often had to the perception that circular interventions are more expensive than more traditional ones. "I think that there is still the fear that tendering for a sustainable project is per definition more expensive" (plan developer B). Other problems are related to the fact that some circular economy interventions do not have direct financial benefits. "I think all sustainability measures are mainly wallet-driven and I think that's a shame, that's both with private individuals and with the government I think, so It's very much about the energy bill, so it would be nice if we talked to each other a bit more about a circular society, say or in our case heritage preservation or something like that, where it's about more than labelling" (architect B).

These wallet-driven decisions usually still have the priority within a project. ‘’It wasn't a priority in the beginning, I have to be honest, so when we started the project, the financial feasibility and square metres were really paramount” (architect A).

The lack of experience

This barrier is often a result of the fast evolution of the circular economy within the building sector. ‘’We as the client think we know, to a very large extent, all the ins and outs, but in reality we are still very far from real innovation on the construction site” (client C). The rapid pace at which circularity is progressing results in less knowledge in client organisations, ‘’because what you see, as the client, is that we have less and less of our own expertise'' (client D).

Routine

‘’There is no sector more traditional than the building and construction sector, and that’s when you fall back in your routine” (client C). Routine is frequently mentioned by every interviewee. ‘’One is quickly tempted by the power of habit. Like when you need something. I order those building materials, from that building materials supplier, because I call them all my life, so I call them again now” (plan developer B). The responses are related to both building techniques and building materials. Tradition and routine can make it difficult to imply change in the process. ‘’You have to be on top of everything to make change happen. The process is still fairly in the traditional way” (plan developer C). ‘’It is a very pragmatic problem, mind you, but it is very much present and it is an additional bump in the ease with which you can achieve sustainable and circular results.” (client C).

Rules and certification

The final large barrier that was mentioned concerned rules and certification. These rules could be specific to renovation and construction in relation to heritage buildings, ‘’you also need a third Party for it, which in this case is the municipality, the permit. They have different principles. They purely aim to preserve what is already there, that should stay as it is” (client A). On the other hand they also consisted of rules and demands that are specific to the new function of the building, like for example housing. ‘’Because housing construction is just very strict.

‘’On the one hand, there are all the requirements from the Building Decree and, on the other, there are lots of new products to do with sustainability. These have not yet been certified or tested, so you can't take them into account, and Gyproc has simply stated in its Gyproc-wall-booklet with this type of plasterboard and insulation, that you have that DB value or that fire-resistant value.” (Plan developer D). The aforementioned problem here is double. The requirements from the building decree are very strict, which can create a barrier in itself. I also means that all the materials that are used require certain certificates in order to use it within the construction. New circular and sustainable building materials do not always have these certificates (yet). ‘’That's the thing in the Netherlands. Everything has to have a certificate, test report, piece of paper on it that says it’s safe to use. It has to be fire-resistant, it has to be flame-extinguishing, it has to be acoustically satisfactory, it has to be, I don't know what all the tests have to be. But everything has to be tested on a material before they want to use it.” (plan developer B).

5.5 Barrier mitigation

5.5.1 CESAR model

The case studies demonstrated that the circular economy strategies suggested by the interviewees were significantly influenced by the interviewees' personal definition of the circular economy, with many definitions related to the reuse of material and use of circular building material. This definition with the focus on materialisation is often also translated in the circular economy strategies that were mentioned as implemented in the project. Yet, literature has shown that the concept is much more comprehensive than only material use.

The case studies further showed that projects do not consistently employ circular economy principles. In certain projects, theme sessions were conducted where various opportunities for applying circular economy techniques were examined. However, this was only the case for a small number of initiatives.

Additionally, there have been instances where certain strategies were put into practise without the person who implemented them being aware of their contribution to the circular economy. These strategies have been implemented in the projects, but the interviewees would not directly place these interventions under the term of the circular economy. This means that there is a gap between the strategies that people implement and what they actually think that falls under the circular economy. All of this added up to a fairly widespread adoption of the circular economy across all scenarios.

This prompted the development of the Circular Economy Strategies for Adaptive Reuse model (figure 14), also known as the CESAR model. The purpose of the model is to increase awareness of the possibilities for integrating circular economy strategies within a project.

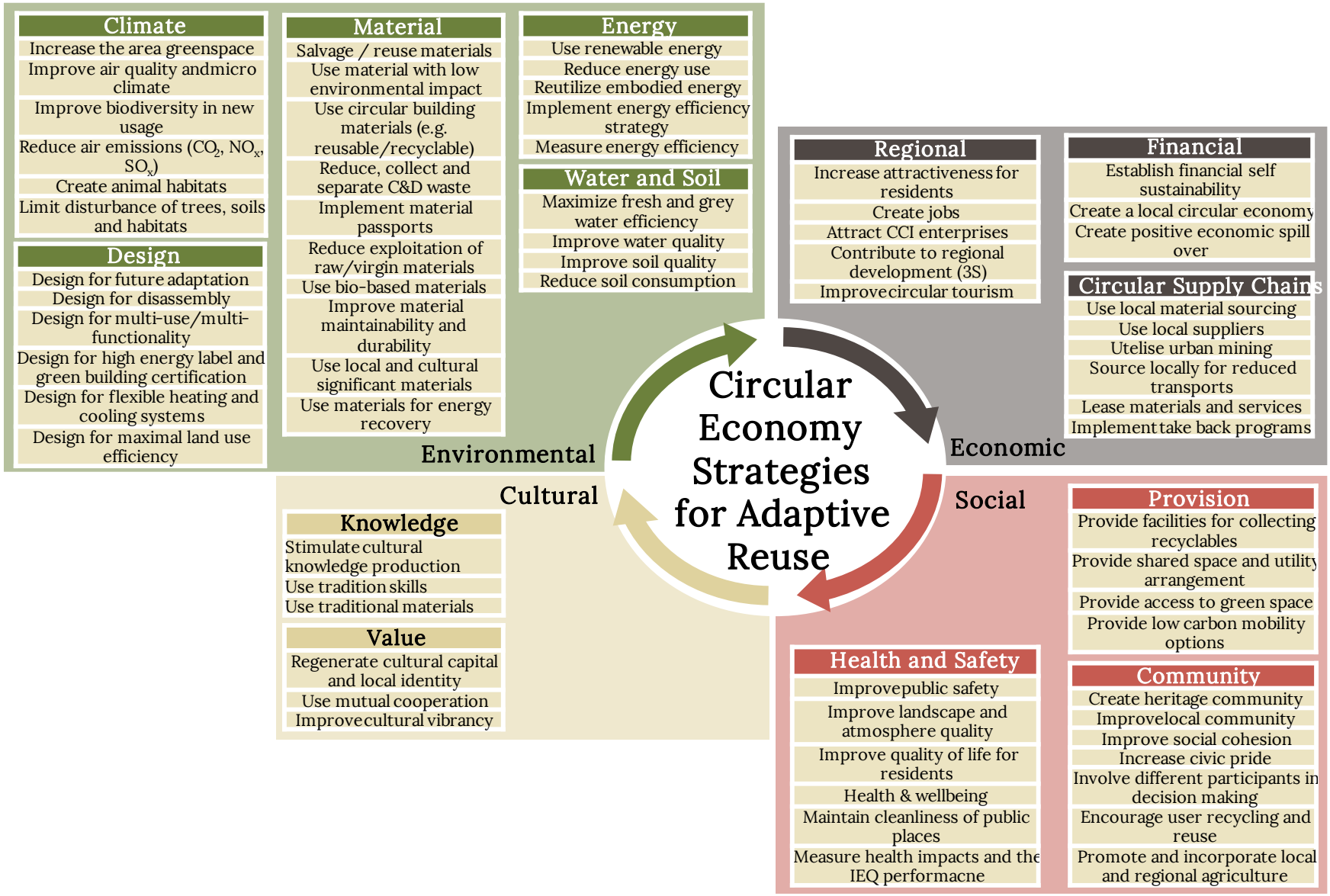


Figure 14: Circular Economy Strategies for Adaptive Reuse (CESAR) model (Own figure)

Creating the model

The creation of the CESAR model is shown in figure 15. The CESAR model is an amalgamation of various theoretical models discussed in Chapter 4, specifically integrating the adaptive reuse strategies and indicators proposed by Foster (2020), Bosone (2021), and Foster & Kreirin (2021). These strategies and indicators were consolidated in a comprehensive Excel sheet, with similar strategies merged to avoid redundancy. In cases where strategies were overly broad, they were divided into separate components.

The initial version of the sheet, comprising approximately seventy strategies, was reviewed by the sustainability expert at Nico de Bont. Feedback indicated the need for clarification and a clearer overview of the strategies, as well as the inclusion of accompanying explanations for better understanding. Additionally, the strategies were categorized into the four main dimensions of sustainability (environmental, economic, social, and cultural) as commonly utilized (Najjar, 2022), aiming to enhance comprehensibility even for those less familiar with the concept of the circular economy.

Further feedback from the sustainability expert and other company employees contributed suggestions to improve the clarity of strategy explanations and to make the model more measurable, as it currently represents a compilation of implementable strategies. The suggestion was made to make a checklist of the model, in order to give an overview of what is implemented and what is not. Besides the feedback from company employees, the model was also updated with information and strategies that have been implemented in the case studies.

The final version of the model incorporates categorized strategies within each dimension, presented in an Excel checklist format. Each dimension has its own sheet, with every strategy accompanied by an explanation and a checkbox to indicate implementation.

The score summary sheet provides an overview of the selected strategies in each dimension, displaying the number of ticked strategies in relation to the total and offering a "circularity score" as an indication of overall strategy implementation. It is important to note that while all strategies are treated equally in the scoring, their circularity levels may vary. The scoring tab primarily aims to provide insights into the relative priority given to each dimension, and facilitating identification of areas for potential improvement.

The CESAR model has also been tested and discussed during the focus group discussions. The results from the focus groups are discussed in detail in the next chapter. One of the main points of feedback on the model was that some of the strategies are project specific and not applicable to every project. The recommendation was suggested to provide the option to exclude strategies that are irrelevant to the project. However, a drawback of this approach is that if a strategy is excluded, it will not be considered in the final score, potentially inflating the overall score. Addressing this issue relies on the integrity of the individual filling out the model. The individual has to be honest about what strategies are not applicable and which ones are not implemented.

The option to exclude strategies was eventually implemented in the model. When a strategy is marked as not applicable it will be removed from the eventual score. Moreover the strategy will be coloured red in the sheet. If a significant number of strategies are marked as non-applicable in the model, it will result in a predominantly red representation of the sheet, indicating that the individual filling out the model may not be fully committed to implementing circularity in their project.

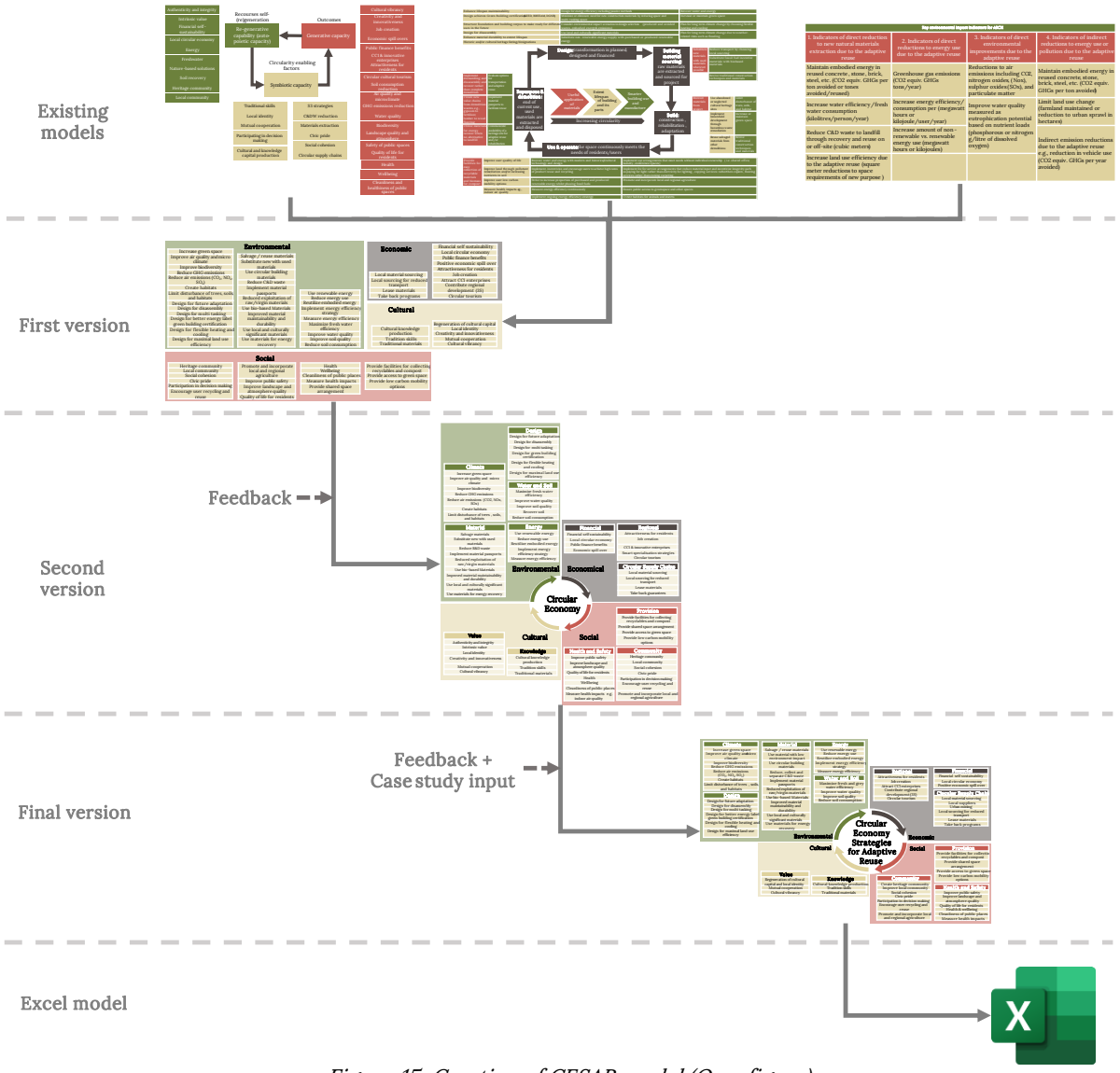


Figure 15: Creation of CESAR model (Own figure)

Using the model

The CESAR model serves multiple purposes, functioning as an initial planning and assessment tool, an exploratory scoping exercise, and a post-project circularity review tool.

As a planning tool, it can be employed during the project initiation phase to establish the strategies to be implemented. In this setting the model will serve as a way to inspire and structurally create understanding of the opportunities that there are within the project.

As an assessment model, clients can utilize it during the tender process to indicate their desired strategies for project implementation. The model can then be integrated as a tender criterion, enabling evaluation of participating parties based on the number of strategies incorporated in their submissions.

Lastly, the model can be utilized as a post-project evaluation tool, providing an overview of the strategies implemented throughout the project, both intentionally and unintentionally. In this evaluative capacity, it not only highlights the actions taken, but also identifies missed opportunities for further improvement in future projects.

5.5.2 Provisional advice

In addition to the prevalent definitions and implementation of the circular economy, the case studies have revealed several significant barriers that continue to be encountered.

One prominent barrier is the lack of experience in circular economy practices. Successful adoption of circular economy principles has been observed in projects where the client, architect, and contracting firm collaborate from the early stages of the process. The integration of circular economy strategies becomes more feasible when these three parties work together from the outset. In such cases, the architect can employ specific circular design techniques, while the contractor can provide insights on the processing requirements and associated costs of particular design elements and materials. Consequently, the client benefits from enhanced clarity right from the start.

However, when the contracting party gets involved late in the process, a substantial portion of the design has already been finalized. Introducing new items and materials at this stage necessitates reverse engineering, which can consume additional time and incur higher costs. Furthermore, contractors often apply additional charges for processing circular materials when utilized in architectural designs, owing to their unfamiliarity with working and processing such materials and their desire to account for potential risks. As one client expressed, "They will just say, well, I'll just put factor 1.3 in my budget, and it will work out" (client E). This, in turn, leads to significantly higher costs. Early involvement of contractors allows for sufficient time to research materials, acquire proficiency in their handling and processing, or explore alternative materials as viable options. This can potentially mitigate the problem of over-estimating the construction costs, since the contractor is familiar with the material and its risks.

As far as recommendation for the parties that contributed to the case studies a few things stood out.

Client

Most projects typically originate from the client's vision. To maximize the realization of circularity in the final outcome, it is crucial for the client to prioritize this aspect. Including specific circular economy requirements in the initial request for tender is essential to achieve this goal. The CESAR model can serve as a valuable tool, offering guidance, inspiration, and setting ambitious targets for incorporating circularity in the tender process.

Another significant driver for clients is building with trust. As expressed by one client, "In this project, we really built with trust, that's what I call it. Because a lot of things are different than usual. They work out differently than you'd think" (client A). Building with trust entails placing confidence in the knowledge of the contractor and architect regarding circularity, as well as being open-minded and willing to consider circular interventions that may be more challenging to quantify. For instance, the use of installations to achieve a specific energy label is a measurable intervention in terms of the label itself and potential cost savings. However, when budget constraints arise, it is often the non-quantifiable aspects of circularity that face cutbacks. As highlighted by an architect, "Whenever cuts have to be made, it's always on the (non-quantifiable) circular side, if the choice is between using a sustainable material or a circular material, which doesn't directly yield anything, or the installation. In that case, the choice goes to the installation, despite the fact that the installation will be written off or no longer usable in 20 years' time and will eventually end up back in the bin, while the circular products will last for years to come. So, there's still a misalignment there, and that's only going to get worse in my experience" (architect B).

Therefore, it is highly recommended that clients maintain an open mind, actively engage in the conversation, and look beyond solely quantifiable approaches when implementing circularity.

Architect

The primary recommendation for architects is to actively seek and accumulate experience in designing with circularity. While the circular economy is still a relatively new concept, particularly in the realm of construction execution, more clients are striving to implement it whenever possible. "I have to be honest, the structural framework is still being developed, but in the policy plan 2, 3 years back we said we are going to put more emphasis on this (circular economy)" (client C). Through experimentation and practical experience, architects can acquire valuable knowledge that will prove invaluable when the circular economy becomes the standard practice.

The case studies revealed that architects possess a substantial amount of knowledge regarding the architectural value of heritage buildings. This knowledge has already resulted in the preservation and reuse of significant elements from the original structures, seamlessly aligning with the principles of the circular economy. The next phase involves expanding the application of circular economy strategies to other areas of projects, and the CESAR model can provide guidance and inspiration for these advancements. The most effective approach to practical implementation is through collaboration with the contracting party. "Because sometimes architects do find it (the circular economy) interesting. They have heard of it. We can, of course, say right away, this is how much it costs, and this is how we can make it, so you take away a lot of the uncertainty" (plan developer D). By leveraging and combining each other's expertise, greater goals can be achieved.

Contractor

The contracting party possesses extensive expertise in the execution stage of building projects. They possess knowledge regarding the time and resources required for handling and processing different materials, as well as the labour involved. The same fundamental recommendation given to architects applies to contracting parties as well. By accumulating as much experience as possible with circular building materials at present, valuable knowledge will be developed for the future when the circular economy becomes the standard practice.

It is strongly advised for the contractor to be involved as early as possible in the project to effectively apply this knowledge throughout the process. This enables the simultaneous development of the visual design and functional development design in collaboration with the architect. By adopting this approach, unforeseen issues and subsequent costs can be avoided later in the project.

5.6 Case study conclusion

The case studies revealed distinct patterns in the perception and implementation of the circular economy among architects, project leaders, plan developers, and clients. Architects and project leaders from the contractor predominantly focused on the practical aspects and material aspects of the circular economy. Conversely, clients placed greater emphasis on the economic and social dimensions. This discrepancy may indicate a higher consideration for social relevance in their corporate strategies or a lack of familiarity with the concrete applications, materialization, and sustainable initiatives of circularity in projects.

Furthermore, the case studies demonstrated that the majority of implemented strategies were aligned with the sustainability dimension. Specifically, the most frequently employed strategies involved material reuse and the use of circular building materials. These strategies corresponded with the contractors' and architects' definition of the circular economy, which emphasized materials and sustainability.

On the other hand, clients mentioned strategies that focused on societal issues, such as improving the neighbourhood, enhancing the health and well-being of residents and workers, and enhancing overall quality of life. This social-oriented implementation aligns with the definition of the circular economy provided by the clients during the interviews.

The interviews also indicated that the interviewees' definition of the circular economy significantly influenced the strategies they mentioned. This may be attributed to their lack of awareness regarding the broader scope of strategies falling under the circular economy umbrella. Often, interviewees only mentioned strategies they believed unquestionably aligned with the term, while the document analysis of the case studies revealed additional strategies that indeed fell within the purview of the circular economy. This highlights a discrepancy between the strategies being implemented and the interviewees' perception of what constitutes the circular economy.

The barriers identified in the interviews exhibit a notable correlation with the barriers discussed in the literature review. The most frequently mentioned barriers in the interviews encompass areas of ambiguity, financial constraints, lack of experience, entrenched routines, and regulatory requirements and certifications. These findings align with the research conducted by Springvloed (2021), as referenced in Chapter 4 (Figure 10), which utilized the framework proposed by Pomponi and Moncaster (2017) and identified various dimensions of drivers and barriers in circular initiatives, including governmental, economic, and technological factors. These dimensions bear striking resemblance to the barriers revealed during the interviews.

Furthermore, Springvloed (2021) deduced that economic barriers pose the most significant limitations. This observation aligns with the outcomes of this case study, where economic barriers emerged prominently. The governmental dimension was frequently cited as a barrier in relation to the rules and certifications required for the adaptive reuse of heritage structures, as well as the ambiguities inherent in governmental regulations

The case studies also revealed that circular economy principles are not consistently employed in projects, and that there is a gap between what is implemented and what people perceive as circular strategies. To bridge this gap, the Circular Economy Strategies for Adaptive Reuse (CESAR) model was developed. This model is a combination of different theoretical models and includes strategies divided into four main dimensions of sustainability. The CESAR model can serve as a planning and assessment tool, an exploratory scoping exercise, and a post-project circularity review tool to increase awareness and facilitate the integration of circular economy strategies within projects.

Finally the case studies led to the establishment of the provisional advice. The implementation of circular economy strategies in the construction industry requires collaboration among the client, architect, and contractor. The client plays a crucial role by placing a high priority on circularity and including circular economy requirements in the initial request for tender. For architects, it is recommended to gain experience in designing with circularity and to extend the use of circular economy strategies to other project areas. The contractor possesses the greatest expertise regarding the execution stage and should be involved as early as possible in the project. Overall, it is important to keep an open mind, engage in conversation, and look beyond quantifiable ways of implementing circularity in order to achieve successful results.

6. Focus group

6.1 Focus group set-up

The final phase of the research comprised a focus group involving the participants from the case studies. The primary objective of the focus group was twofold: to present and validate the findings derived from the case studies with the involved parties, and to introduce the CESAR model and provisional recommendations. Given the participants' extensive professional backgrounds, their valuable insights and feedback were sought to gauge the feasibility and practicality of the model and advice in real-world scenarios.

To ensure accessibility and maximize attendance, the decision was made to conduct the focus group online, considering that the participants were located in various regions across the Netherlands. Two separate focus group sessions were scheduled on different dates and at different times to further enhance participation rates. To maintain a balanced representation of clients, architects, and contractors within the focus groups, individuals who indicated their availability for both dates were assigned to the sessions accordingly. Consequently, two focus groups were formed, each comprising five to six participants. Prior to commencing the focus group discussions, a comprehensive presentation was delivered, outlining the research's methodology and structure. Subsequently, the results derived from the case studies were presented and examined in detail.

6.1.1 Barriers

The case study yielded a range of barriers encountered during the implementation of circular economy strategies in the adaptive reuse of heritage buildings. These noteworthy barriers were subsequently presented to the participants of the focus group. Following the presentation, participants were prompted to share their perspectives on whether they could personally relate to the identified barriers, and if there were any additional barriers that warranted further discussion, inclusion, or clarification.

6.1.2 CESAR model

The CESAR model was shared with the participants prior to the focus group. An instructional video that walked viewers through the model's operation and application was included along with the model. By distributing the model in advance, attendees had the chance to try it out and become familiar with its operation.

The model was again introduced to the participants after all of the case study conclusions had been given. The model was discussed with the participants, which allowed them to mention aspects of the model that they did not understand or that they felt were missing. The goals here is to gather both the strengths and weaknesses of the model, in order to improve it in the next version.

All participants were asked to complete a questionnaire regarding the CESAR model when the focus group came to a close. Before they could respond to the questions, they had to complete the CESAR model for the project they were being interviewed for. The questionnaire included questions about the reference project's score, what respondents liked and disliked about the model, and what they would change or add to the model. This questionnaire can be found in appendix 2.

6.1.3 Provisional advice

Following the discussion of the model, the provisional advice was presented to the participants. The recommendations were revisited to determine their applicability and to explore if any additional advice was needed. The case study interviews involved clients, architects, and project leaders or plan developers from the contractor, and therefore, their perspectives were taken into account when presenting the provisional advice. In the focus group, various strategies for receiving support from other parties during the transition to a circular economy were discussed. The aim was to identify ways in which clients, architects, and contractors can assist each other and explore potential support from external entities.

6.2 Focus group results

6.2.1 Barriers

The focus group participant agreed with the five biggest barriers being the main obstacles in the transition towards the circular economy. "I think the list is fairly comprehensive" (plan developer A). Another obstacle that was brought up for debate, was the lack of urgency. The group initiated this discussion since some of the participants were unable to comprehend that this was still an obstacle in today's society. "I don't understand the lack of urgency. From our point of view the urgency is really there" (client D). The group discussed the two main areas that this barrier originated from.

On the one hand, this barrier originated from developers who frequently struggle to close their business cases. "Developers aim to make a profit. Take for example this project, calculations and estimations have failed multiple time, and they have to pull every string to make it feasible, there is not enough time and money to make an extra step and implement more circularity and sustainability. I think that might be a reason behind the lack of urgency in some situations." (project leader B). Making an estimation of building expenditures is challenging given the shifting prices of products such as building materials. This has several times resulted in failed business cases. After that, the emphasis is solely on making the business case feasible, and the pressing need to apply circular economy ideas is pushed to the margins.

Moreover the lack of direct added value that circular economy strategies bring is difficult to express in monetary value. "When I look at plan development, there is not that much urgency at the moment because it also doesn't create direct value, there needs to be more social acceptance and demand in order to mitigate this." (project leader A). Lack of urgency may continue in the absence of social acceptance and demand from the customer to add circularity.

The other reason for lack of urgency that was mentioned comes from the privileged position of heritage buildings. "When working with a monument, you don't have to adhere to the strictest rules, because preserving the monument is actually the main goal and the circular economy is secondary to preservation. That's more of a bonus that comes with it. " (client E). Heritage is in the exceptional position where restoring the original features of the building have priority above almost everything else, like an energy label and other requirements that are obligated in standard projects. Implementing circular economy strategies are seen as an extra.

6.2.2 CESAR model

Since the participants of the focus group had received the CESAR model and had the chance to practice with it prior to the session, they had the opportunity to gain some experience and ask questions and give feedback.

The most mentioned positive aspect of the model was that the focus group participants looked at their projects from a new perspective. ‘’It lets you look at your project from a new perspective’’ (client E). The model gave them an understanding of what they implemented in the project consciously, but also what strategies had unknowingly implemented. This served as an encouraging reminder of just how widespread the circular economy notion really is. ‘’When filling in the model I often came across strategies where I was like, oh we also implemented this, and we unconsciously also did this, so it did generate more awareness when filling in the model’’ (plan developer C)

Another benefit from this new perspective was that ‘’it (the model) removes the monument from it’s privilege position.’’ (architect A). While the model is aimed towards implementing circular economy strategies in heritage buildings, it can also be used for other types of projects. Because of this, the model generalises the project in a way and offers the chance to perceive it as existing piece of property rather than a historically significant building. This might alleviate the barrier of the lack of urgency that results from the predicament that heritage buildings are in, where preserving the structure allows for an exemption from enforcing certain building regulations. ‘’It should be the last refuge to invoke exception.’’ (architect A)

When discussing aspects of the model that could be improved, the notion that certain strategies in the model were particularly applicable to the type of project you would be working on was made the most frequently. ‘’ On the contrary, because I am doing a social welfare project, there are some boxes I would never be able to tick, so the weighting of some aspects very much depends also on the type of project’’ (client E). Because of this, certain strategies could never be used on specific projects, resulting in a score that was lower than it could possibly have been. Two suggestions were made to mitigate this problem.

The first suggestion was to group part of the strategies together as generic strategies that are applicable to every project. The other additional strategies are viewed as a perk or bonus because they are project-specific. ‘’The generic values we all have to adhere to and, in addition, specific ones that serve your case. That together then makes the model fit for you’’ (architect A). The other suggestion was to give to option to exclude strategies if they are irrelevant to the project. This does have the disadvantage that all the strategies that are not included in the project are excluded from the model and still result in a high score. Mitigating this problems relies on the honesty of the person filling in the model. ‘’You can also visualise this and colour every excluded strategy red. when you start excluding all the strategies from the model and the whole thing colours red, that shows that you are not being serious. The model also has to motivate you to included as much as possible and colour everything green.’’ (client C). It is discouraging to receive an inadequate score on a project because some tactics could not be applied. This suggestion of marking the non applicable strategies red was implemented in the final version of the CESAR model.

The second biggest point of improvement was to implement more nuance in the model. The original version of the model was a checklist in you could either implement a strategy or not. This hard separation makes it hard to make a distinction to what extent a certain strategy is implemented. Reusing one wooden beam in a project would be sufficient to check the box salvage or reuse materials. Nevertheless this is much less circular than reusing the entire structure of a building. Yet in the model they would way the same amount.

Not only was there a need for more nuance within one strategy. In the model every strategy as a whole also has the same weight or importance. ‘’I do still miss some kind of weighting of the various factors included in the model’’ (project leader A). Some

of the strategies might contribute more to the circular economy than others. Thus the suggestion was made to implement some more refinement between the strategies. This does create the problem on how to establish which strategy is more circular than others

When asked if the participant would use the model in practise, they agreed that the tool could be especially useful in the initiation phase of a project. ‘’I think the sooner you start working with this, the greater the results will be” (plan developer A). This way multiple parties can discuss the opportunities and ambitions for a project. The group agreed that the model would be the most useful at the start of the project. ‘’It can clarify the ambitions of initiators at the beginning of a project, and if complemented by measurable targets, it can guide planning and implementation, as well as management and use.” (architect A)

Another useful application of the model would around the completion phase, in order to evaluate and rapport. ‘’We are an organisation that has to report to shareholders and supervisory boards and they never have a very clear picture of what has happened during a project. This way, we would be able to report very comprehensively and in several areas on what has been involved during a project and what strategies have been applied. That was we don't just get stuck in finance, but the picture becomes a lot more comprehensive, with a kind of social return. so it could help us a lot. Especially in completion” (client A).

‘’But it can also be used in a tender as an award criterion or as a requirement in the award process. That is also interesting. Because then, as a client, you can adjust the model in such a way, so that you rank certain themes more highly than others, so that the tenderer knows how they can score higher, then you start using it in a different way.” (client C). The model can also be used to help circular tendering. Clients can indicate what strategies they find important and the this then provides different criteria that tenderers have to implement in their bid.

6.2.3 Provisional advice

The focus group participants mostly agreed with the provisional advice. The parties acknowledged that when alle three parties start working together from the start, circular economy implementation has the highest chance of succeeding. ‘’When you work on a project with a team, it does give you a lot of tools to work with” (project leader B) When sharing knowledge, ambition, and information, uncertainties and ambiguities can be reduced to a minimum.

When asked about what other parties might be able to help them transition to the circular economy, the government was mentioned most often, for example the RCE (state department for cultural heritage). Government support could be helpful in a number of ways, including through prescription, stimulation, and promotion.

‘’The government can also contribute to this in various ways. In prescriptive ways for example” (project leader B). In this scenario the government has a prescribing role where they can implement requirements for certain circular economy strategies, just as they do with other building requirements. The difficulty here is that is hard to measure the level of circularity in a project. Moreover this is not very stimulating for developers since a project can become more expensive and might for this reason not see completion.

The problem financial feasibility can partially be negated through the use of stimulation in the form of subsidies ‘’ a subsidy might be very helpful in getting this (circular economy implementation) going.” (plan developer D). This will stimulate developers to implement more circularity within a project, since it will be easier to make a project financially feasible.

The final way that the government can support the transition to the circular economy is through promotion. ”For example, highlighting best practices. The government can do a lot in that way” (architect A). By presenting so called ”best practices” the government can highlight projects where circular economy strategies have been implemented successfully. This can improve societal acceptance and understanding as well as raise circularity awareness among the general public. ”By increasing social acceptance, you are allowing society to also recognise what is beneficial about it (the circular economy) and how it works.” (project leader A). The demand for and value of the implementation of the circular economy can grow as society becomes more aware of it. Implementation of circular economy strategies can then be seen as an added value, the same way that solar panels on top of a building are currently seen as an added value to a piece of real estate.

6.3 Focus group conclusion

The goal of the focus groups were to present and validate the results form the case study and discuss ways to mitigate the remaining barriers in order to help the transition towards the circular economy.

The focus group was presented the five most significant barriers that hinder the transition towards a circular economy, with which the group agreed upon. They also discussed the lack of urgency, which some participants had difficulty understanding.

The lack of urgency was believed to be due to the need to close business cases, making it challenging to implement sustainability and circular economy strategies. The lack of direct monetary value that circular economy brings was also mentioned, as well as the absence of social acceptance and demand. Additionally, the privilege of heritage buildings was highlighted, where preservation takes priority over circular economy strategies.

The CESAR model was positively received by the focus group as it provided them with a new perspective on their projects, allowing them to recognize the strategies they had consciously and unconsciously implemented. This served as a reminder of how widespread the circular economy notion is.

Another benefit was that it removed heritage buildings' privileged position, allowing them to view the project as an existing piece of real estate rather than historically significant buildings. However, the participants suggested that certain strategies were project-specific, a solution would be to group the strategies together as generic strategies that apply to all projects, with specific strategies that serve as a bonus.

Finally, when discussing the provisional advice, the focus group participants agreed that when all parties involved in a project work together from the beginning, there is a higher chance of successfully implementing circular economy strategies.

Government support was identified as an additional crucial factor in transitioning to a circular economy. Financial feasibility was identified as a challenge to circular economy implementation, which subsidies could partially negate. Lastly, promotion of best practices by the government could improve societal acceptance and understanding of the benefits of the circular economy, potentially increasing the demand and value of it.

7. Conclusion

This thesis aimed to identify what circular economy strategies are implemented in de adaptive reuse of heritage buildings, find out what barriers still exist, and how these can potentially be mitigated. This is to help the transition towards the circular economy.

This research had multiple purposes. However, before achieving these objectives, it was important to establish the terms the circular economy, adaptive reuse, and heritage. To do this, literature research was used.

The first objective was to determine the degree to which the strategies that have been shown in scientific studies are translated into actual practise. This has been accomplished through literature research, to explore the existing strategies that have been established by scientific research. The empirical research was conducted through case studies, where a mix of site visits, interviews, and document analysis revealed the strategies that are used in projects in practise.

The second purpose was related to the barriers that are experienced in the transition to and implementation of the circular economy. This goal has been achieved by exploring what barriers are found in literature. Moreover, the interviews from the case studies revealed what barriers actual practitioners run into when working on a project.

This objective is also discussed in the focus group. The goal of this focus group was to discuss the barriers found, and argue about different ways that these barriers could be solved.

To reach these goals and answer the main research question, the following sub-questions have first been answered.

SQ 1. How are circularity, adaptive reuse, and heritage defined within the context of the built environment?

Scientific literature showed the definition of the circular economy according to Foster (2020), which emphasizes the minimization of natural resources and environmental impact by increasing the lifespan of materials and reframing consumption to include sharing and the supply of services. The circular economy is integrated into a social system that supports universal human welfare within the biophysical bounds of the planet Earth.

Adaptive reuse is defined as the process of refurbishing and repurposing an existing building for a new purpose, and cultural heritage as a variety of objects that have symbolic, historical, aesthetic, artistic, scientific, or social significance.

The case studies demonstrated that when referring to and defining the circular economy, architects, project leaders, and plan developers from the contractor focused more on its material and practical aspects. Clients have emphasized the social and economic aspects.

This can be because the client's company strategy places a greater emphasis on social relevance. It can also be a result of their lack of familiarity with the execution and materialisation part of the circular economy.

Because there are so many different definitions of the term circular economy, it is clear that not all industry practitioners are acquainted with its broad scope.

SQ 2. What circular economy strategy assessment models exist for adaptive reuse projects of heritage buildings?

Prior research showed that there are multiple methodologies for assessing and evaluating the circular economy within a construction project, according to the literature. However, not all models could be applied when assessing circular economy strategy implementation in the adaptive reuse of heritage buildings. Some models are not focused on the building industry and are too general. Other models geared toward the construction industry are either overly material-focused or unsuitable for heritage. The Foster (2020), Bosone (2021), and Foster & Kreirin (2021) circularity assessment models were more suited for this research. They were created with the building sector in mind, with a focus on historic structures in particular. They take into account the various facets of the circular economy. Overall the literature showed that the circular economy and the adaptive reuse of heritage have been connected in prior research.

SQ 3. What are the barriers related to circular construction and adaptive reuse of heritage buildings?

This question discussed the barriers to the adaptive reuse of heritage buildings. The barriers to adaptive reuse can include higher costs, building codes, risk, and unpredictability associated with older building stock. The challenges of adapting historic structures for new uses range from meeting user expectations for modern technical and regulatory standards to balancing compatibility between old and new demands.

The framework by Springvloed (2021) identifies barriers based on six dimensions of circularity in the building sector: governmental, economic, technological, environmental, societal, and behavioural. The governmental dimension focuses on governmental actions and policies that either impede or facilitate the adoption of circular economy strategies by companies. The economic component concentrates on models of profitability, while the technological dimension is primarily concerned with plans for technological innovation. The environmental dimension includes resource shortage and environmental impact. The societal dimension is largely concerned with existing social structures, and the behavioural component focuses on individual behaviour.

When discussing the barriers the interviewees reported several barriers to the implementation process, including ambiguities, money, lack of experience, routine, and rules and certification. Ambiguities refer to uncertainties and problems that arise due to different interpretations, while money-related barriers stem from the perception that circular interventions are by definition more expensive than traditional ones. Lack of experience relates to the fast evolution of the circular economy within the building sector, resulting in less knowledge in client organizations. Routine describes the tradition and habits of the building sector, which can make it difficult to bring about change in the process. Lastly, rules and certification refer to the strict requirements from the building decree and the lack of certifications for new circular and sustainable building materials.

During the focus group, the participants also added the lack of urgency as an important barrier. The lack of urgency was believed to be due to the need to close business cases, making it challenging to implement sustainability and circular economy strategies. The lack of direct monetary value that a circular economy brings was also mentioned, as well as the absence of social acceptance and demand. Additionally, the privilege of heritage buildings was highlighted, where preservation takes priority over circular economy strategies.

SQ 4. What circular economy strategies have been implemented in adaptive reuse heritage projects from practise?

The case studies showed that when discussing circular economy implementation within a project, architects, plan developers, and project leaders also focused more on practical circular and material aspects, while clients emphasized the economy and social part.

The majority of implemented strategies were related to sustainability, such as reusing and using circular building materials, while clients mentioned strategies that benefit society, such as improving the quality of life for users. The definition of the circular economy, which the interviewees had given had a significant influence on the strategies they mentioned when discussing implementation, showing that there is a gap between the strategies implemented and what is actually covered by the circular economy.

This appears to be because they don't realise that some of the strategies they used also fall under the definition of a circular economy, so they only brought up the ones they thought are clearly included by the term. This was frequently the case since the case studies' document analyses revealed that the projects did actually employ strategies that fall under the umbrella of the circular economy.

SQ 5. How can the barriers be mitigated for future implementation in order to help the transition towards the circular economy?

The case studies highlighted the importance of personal definitions of the circular economy in shaping strategies for implementing circular principles in projects. While material reuse was a commonly identified strategy, it is important to note that the concept of circularity is much broader. The case studies also revealed that circular economy principles are not consistently employed in projects and that there is a gap between what is implemented and what people perceive as circular strategies. In addition to that the barriers from the case studies showed that amongst others ambiguities, lack of experience, and routine hinder the transition toward the circular economy.

To help mitigate these problems, the Circular Economy Strategies for Adaptive Reuse (CESAR) model was developed. This model is a combination of different theoretical models and includes strategies divided into four dimensions. The CESAR model can serve as a planning and assessment tool, an exploratory scoping exercise, and a post-project circularity review tool to increase awareness and facilitate the integration of circular economy strategies within projects.

The CESAR model was positively received, providing the group with a new perspective on their projects. The participants suggested dividing the strategies as generic and specific regarding each project to improve the nuance.

Besides the CESAR model, the provisional advice was developed as a result of the case studies. Collaboration between the client, the architect, and a contractor is necessary for the construction industry to optimally circular economy strategies. By prioritising circularity and integrating circular economy requirements in the initial tender, the client plays a significant part. It is advised that architects develop their circular design skills and apply circular economy principles to different project aspects. The contractor should be included in the project as early as feasible because they have the most knowledge about the execution phase. To obtain good results, it is crucial to retain an open mind, engage in conversation, and look beyond measurable approaches of adopting circularity.

The focus group agreed that working together from the start is essential. Moreover, they mentioned the government as another crucial stakeholder in successfully implementing circular economy strategies. Financial feasibility was identified as a challenge to circular economy implementation, which subsidies from the government could partially negate. Lastly, the promotion of best practices by the government could improve societal acceptance and understanding of the benefits of the circular economy, potentially increasing its demand and value of it.

The main research question of this thesis states:

What circular economy strategies are currently implemented in the adaptive reuse of heritage buildings and how can the remaining barriers be mitigated in order to move towards the circular economy?

The adaptive reuse of heritage buildings is a way to safeguard historic buildings and their values, but stakeholders still struggle to structurally implement circular economy strategies in the process.

This research showed that when discussing circular economy implementation within a project, architects, plan developers, and project leaders focused more on practical circular and material aspects, while clients emphasized the social part. The barriers to circular economy implementation in the adaptive reuse of heritage buildings include ambiguities, money, lack of experience, routine, and rules & certification. Moreover, lack of urgency is also a barrier in the transition toward the circular economy.

The CESAR model is developed to help mitigate these barriers and is meant as a planning and assessment tool to increase awareness and facilitate the integration of circular economy strategies within projects. The model can serve as a planning and assessment tool, an exploratory scoping exercise, and a post-project circularity review tool.

In addition to the CESAR model, the advice states that collaboration between the client, the architect, and the contractor, prioritizing circularity, integrating circular economy requirements in the initial tender, developing circular design skills, and retaining an open mind by engaging in conversation, and looking beyond measurable approaches of adopting circularity, will all contribute to successfully transitioning towards the circular economy.

8. Discussion

8.1 Research contribution

This thesis makes a significant contribution to the circular adaptable reuse of real estate, with a specific focus on heritage buildings. The research conducted aimed to explore the circular economy strategies that have been implemented in practise, identify the barriers experienced during the process, and propose strategies for mitigating these barriers to improve the implementation of circular economy practices.

The findings of this research shed light on the extent to which circular economy strategies from scientific research are applied in practise. The study provides an overview of the current state of knowledge regarding circular economy strategies in the adaptive reuse of heritage buildings, identifies the key barriers to implementation, and recommends measures for overcoming these barriers, including the use of the CESAR model.

The research has significant implications for various stakeholders in the construction sector, particularly those involved in heritage building preservation. It highlights the comprehensive nature of circular economy principles and reveals numerous opportunities for implementing circularity in this field.

8.2 Limitations

8.2.1 Research scope

Nico de Bont was the exclusive source for all case study projects in this thesis. The company's strong commitment to sustainability and circularity has a profound impact on the nature of its projects, potentially yielding a higher-than-average implementation of circular economy strategies. Conducting this thesis with a different organization that placed less emphasis on sustainability and circularity could have resulted in substantially different outcomes. Although other companies were interviewed, they also worked with Nico de Bont and, therefore, may have placed a high priority on circularity, possibly one of the reasons for their collaboration with the company. Nevertheless, the inclusion of multiple companies in the study helps mitigate these limitations to some extent.

8.2.2 Research timeframe

All the data collected for this research was obtained within a narrow timeframe of approximately ten weeks, posing a significant temporal challenge. Nonetheless, the planning and execution of interviews, as well as the organization of the focus group, proceeded smoothly. Throughout the case studies and focus groups, participants offered recommendations of additional entities and organizations to approach for further inquiry, such as municipalities, the RCE, or other political parties. However, due to the restricted schedule, these parties were regrettably unable to be included in the study, despite the potential theoretical benefits of doing so. With more time at hand, these parties could be incorporated to expand the scope of the research.

8.2. 3 Participants

One of the limitations encountered was the unavailability of participants, which was primarily attributed to the limited timeframe for data collection. A few participants exhibited delayed responses to emails or phone calls inviting them to partake in the interview, which, coupled with their busy schedules, resulted in a considerable time gap between the initial contact and the actual interview. Furthermore, if an unforeseen

event arose on their agenda and they had to reschedule, a few more weeks would be lost. Additionally, interviewee selection proved to be another limitation as one of the potential candidates was recognized for their reluctance to grant interviews. This fact was acknowledged beforehand and, in retrospect, could have prompted the selection of an alternative case study project.

8.2.4 Methodology

There were several limitations pertaining to the literature research, semi-structured interviews, coding, and focus group in this study.

Since the literature research was not a fully integrative systematic review, there is a possibility that some information on the topics discussed may have been overlooked. Instead, the review was a narrative literature review, primarily aimed at providing a strong foundation for comprehending current knowledge and relevant information for the rest of the research. However, this approach poses a risk of excluding essential information.

During the interviews, an interview protocol was established, which inevitably influenced the results as it could not encompass all aspects. The protocol was reviewed by multiple supervisors to ensure its comprehensiveness.

Moreover, it was a challenge during the interviews to balance following the interview protocol while also exploring the interviewee's answers and directions they steered towards, as this can lead to straying off topic, particularly when the interviewee had limited time.

Since pre-established codes were utilized in the analysis, there is a possibility of overlooking some aspects during the process. Although this risk was partially mitigated by coding other strategies or barriers during the analysis, there is a potential for the researchers to view the transcripts from a specific perspective.

Finally, during the focus group, made up of the participants from the interviews, there was a likelihood that they would agree with the case study results more readily since the conclusions were based on their experiences. Additionally, due to time constraints, only certain topics were discussed during the focus group, which may have resulted in the omission of interesting perspectives.

8.3 Recommendations for further research

The primary recommendation for future research is to conduct practical trials of the CESAR model. At present, the model has only recently been developed and has been used to evaluate a limited number of projects as an evaluation tool to measure circular economy implementation after completion. To truly evaluate the model, the model should also be employed as an initial planning and assessment tool, or as an exploratory scoping exercise during the initiation phase of a project. The model could be used as a planning tool to establish the circular ambition at the beginning of a project. It could also be used to create a circular tender by clients, where it strategies chosen by the client can serve as tender criterion during the assessment phase. Conducting multiple trials of the model in different scenarios, on diverse projects, and with varying objectives would reveal its true strengths and weaknesses. This information could then be used to enhance and refine the model further.

The second recommendation is to investigate how the government can aid parties such as clients, architects, and contractors in transitioning to the circular economy. The focus group discussion highlighted the crucial role that the government can play in the

process adaptive reuse of heritage buildings, and how they can either facilitate or impede the implementation of the circular economy. In this process the RCE (state department for cultural heritage) plays a big role in this process. Potential future research could examine various collaboration models among construction parties, as well as governmental bodies.

9. Reflection

The topic of this thesis concerned the current implementation of circular economy strategies in the adaptive reuse of heritage buildings, the barriers that come along with that, and potential ways to mitigate the barriers. This research was performed in the graduation lab: ''Circular-Adaptable Real Estate Reuse to React to Societal Changes''. The thesis fits in this lab quite well since it researches circular economy strategy implementation in adaptive reuse. As far as the master track management in the built environment the relations lie most in the stakeholder management. Both the thesis subject and the master track aim to direct different stakeholders toward high-quality and feasible development. The master's programme in architecture urbanism and buildings sciences hold relation the to thesis in the fact that both combine scientific and social sciences to create more sustainable development.

Relevance

Regarding its social relevance, the CESAR model holds significant value as it offers a practical tool for practitioners to implement circular economy strategies in their projects. To aid them in this regard, I have delivered presentations to various organizations, explaining how the model functions and how it can be applied to their business cases. This has provided me with valuable feedback, enabling me to refine the model's functionality. The CESAR model represents the most effective means of transferring the knowledge acquired from this research to practise, where it can be put into effect by businesses.

In terms of scientific relevance, this research has predominantly explained the translation of theoretical research into practise, while also identifying the steps that must be taken in the future. This translation is regarded as the research's most significant strength. By conducting interviews with stakeholders from diverse companies, filling various roles, and obtaining multiple perspectives, a comprehensive understanding of the matter has been achieved. However, the research's weak point may be the limited number of case studies and interviews examined. With more case study projects and interviews, the research could have potentially yielded more reliable findings.

Methodology

A variety of research methods were employed for this study. From the outset, it was evident that conducting interviews with professionals from the construction sector would be advantageous, as they possess valuable experience in the area of this thesis and could provide insights into their respective roles and the industry as a whole. One of my supervisors suggested that validation of the interview and case study findings could be achieved through a focus group. In this forum, participants could not only affirm the results of the case studies but also address other research inquiries.

Despite the online format of the focus group sessions, which is not an optimal medium for conducting discussions, they proved to be exceptionally valuable. Participants not only engaged in conversations with me, the researcher but also with one another. The dialogue was natural, and everyone offered comments and responses. By enabling participants to converse with one another in addition to speaking with me, the focus group format facilitated a comprehensive understanding of "why and how" participants undertake and perceive various aspects of their work.

During the data collection process of this research, several challenges were encountered. Some interviewees cancelled their appointments at the last minute or

were unresponsive for an extended period, causing delays in the research process. However, with careful management, most interviews were conducted within the given timeframe. In cases where an interviewee declined or was unable to participate, an alternative interviewee was identified, such as another project leader or a representative from the same company.

In the context of ethical considerations and dilemmas, the research encountered few instances. To safeguard the confidentiality of the data obtained from the case study interviews, all the information was anonymised in the report and during the presentations. Furthermore, during the data collection process, no sensitive information was collected. The same holds for the outcomes of the potential implementations of the research findings in practise. It is noteworthy that the CESAR model is an independently created tool that is not aimed at promoting any particular company or product.

Personal reflection

Up until p2 most of the research was done through a literature review, this could be a challenge at some times. Since I am not the best reader, sometimes scientific writing is fairly complicated. With reading more this did get better and I started understanding more of the papers I read, also because I knew more about the topic. What also really helped is writing down phrases in my own words to better understand what was meant by the researcher. This approach is also something that was of benefit during the feedback moments with my supervisors. Whenever they would suggest something that I did not quite understand I would rephrase it and repeat it in my own words to make sure I understood them right. By doing so the feedback moments were very useful and my supervisors both at the university and at the company helped me in shaping my research proposal.

What my supervisors also helped me with was understanding that case study research takes quite some time and selecting case studies and contacting all the interviewees to plan the interviews can take quite some work. This is why I tried to select all the case study projects before the P2 and even before my graduation internship started at the company. This was in hindsight a really good decision since I could start the case studies straight away after my P2 presentation.

At the beginning of the case study interviews, I had a hard time balancing the interview protocol and making sure that the conversation went smoothly and that we also had room to explore other directions. This could either lead to really stiff interviews because I strictly followed the protocol or interviews where I forgot the ask certain question because we drifted off too much. I tried to mitigate this by doing the first interviews within Nico de Bont with people I already knew so that I felt at ease and when I forgot some questions during the interview, I could easily ask them afterwards. After a couple of interviews, I got better at balancing the protocol and the conversation and I feel like I got better at conducting interviews. I might even have gotten the most interesting results from the parts that were not in the protocol but were discussed anyway because the conversation allowed us to. This made the interviews fun and that made me and the interviewees very enthusiastic.

The peak for me was the focus group sessions. All the interviewees from the case studies would gladly participate in the focus group and were very enthusiastic. The session was incredibly useful and the participants provides me with so much information. They did not only discuss the problems with me but also with each other which was nice to see. They discussed ways I could help them with my research but also how they could help each other.

Analysing all the data was quite difficult sometimes. Working with Atlas.ti for the first time and coding interview transcripts was new to me. At the start, it was quite difficult to make sure that all the relevant information was coded and that all the important parts were taken into account. This did also get better after working more and more with the program and the transcripts.

Writing the report was the next challenge. The interviews contained a lot of energy and enthusiasm, and I wanted to transfer this to the report. This was however quite difficult in combination with writing a report that was written in proper formal English. I tried to deal with this by including many quotes from the interviews and focus group sessions, to give a feeling of how they were. The quotes had to be translated into proper English, while also being somewhat formal, but without losing their essence. This was quite challenging but I feel like it came out quite well.

In the end, I am very happy with the result. I really enjoyed my time at the company and the people I got to meet and work with. I am proud of the results and everybody who helped me with it.

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Appendix

Appendix 1: Interview protocol

Interview protocol

Implementatie circulaire economie bij transformatie erfgoed

Instituties: TU Delft (interviewer), Organisatie X (Geïnterviewden)
Project: XX
Deelnemers: XX
Interviewers: Dylan Besten

Introductief

- Kunt u iets vertellen over uzelf? Wat is uw functie bij organisatie XXX?
- Kunt u een beschrijving geven van project XXX en de geschiedenis?
- Wat is uw functie binnen het project van XXX?
- Hoe bent u/zijn jullie betrokken geraakt in dit project?
- Wat houdt deze functie precies in?
- In welke fase bevind het project zich momenteel?

Circulaire economie

- Kunt u mij omschrijven wat het concept circulaire economie voor u precies omvat?
- Heeft uw organisatie bepaalde ambities of doelen rondom circulariteit?
- In hoeverre was circulariteit in uw project een doel/prioriteit?
- Wat is jullie aanpak als jullie kijken naar wat voor circulaire ingrepen er gedaan kunnen binnen een project, bijvoorbeeld themasessies, een raamwerk/model?
- Wat voor circulaire economie strategieën zijn er bij uw project allemaal toegepast?
    - Op milieu niveau, denk hierbij aan duurzaam materiaal, verminderd bouw en sloopafval, toename in biodiversiteit, maar ook wateropvang enz.
        - Zijn er qua materialisatie bepaalde circulaire ingrepen gedaan?
        - Is er voor het milieu rondom het gebouw iets gedaan, biodiversiteit enz.
        - Zijn er ingrepen gedaan voor water en grond opvang/reining.
    - Op economisch niveau, zoals het creëren van nieuwe banen, toename in bezoekers van de omgeving
        - Is er lokaal materiaal verzameld om transport te verminderen
        -
    - Op sociaal niveau, zoals de gezondheid en welzijn van mensen, toegenomen veiligheid in de omgeving of sociale cohesie
        - Hoe zijn de omwonende bij het process betrokken of hoe is er rekening met ze gehouden?
        -
    - Op cultureel niveau,
        - Heeft de culturele waarde van het pand nog uiting in de functie?
        - Het is een oud pand met bouwtechnieken van vroeger. Hebben jullie hier nog problemen mee gehad of bepaalde expertise voor moeten inwinnen?
- Wat was de reden voor het niet implementeren hiervan, welke barrieres ondervond u?
- Wat zijn volgens u de grootste hindernissen die nog overwonnen moeten worden in de transitie naar de circulaire economie?
- Het implementeren van de circulaire economie is soms nog best pionieren. Hoe staan hier voor open en hoe gaan jullie hier mee om?
- Wat zijn volgens u de grootste hindernissen of barrieres die nog overwonnen moeten worden in de transitie naar de circulaire economie?

Appendix 2: Focus group questionnaire

Vragenlijst CESAR model

Het CESAR model is ontwikkelt om het bewustzijn te vergroten van de mogelijkheden die er zijn wat betreft het implementeren van circulaire economie strategieën. Het model kan worden gebruikt als een eerste plannings- en beoordelingsinstrument, een verkennende inventarisatie oefening, alsook een instrument voor een evaluatie van de circulariteit na afloop van een project. Het CESAR-model is een combinatie van de verschillende theoretische modellen die terug te vinden zijn in de wetenschappelijke literatuur. Daarnaast is het model uitgebreid met informatie die is voortgekomen uit de interviews.

Het model toont verschillende circulaire economie strategieën voor het herbestemmen van erfgoed. De strategieën zijn onderverdeeld in de vier hoofddimensies van duurzaamheid, te weten: milieu, economie, sociaal-maatschappelijk en cultureel. Elke dimensie kent verschillende categorieën die weer verschillende strategieën bevatten.

Voordat u deze vragenlijst invult zou ik willen vragen of u her Excel bestand van het CESAR model zou willen invullen met het project waarover u bent geïnterviewd als referentie project.

Vraag 1: Wat is het project dat u als referentie heeft gebruikt?

Klik of tik om tekst in te voeren.

Vraag 2: mijn rol is …

☐Opdrachtgever
☐Architect
☐Aannemer
☐Anders, namelijk Klik of tik om tekst in te voeren.

Vraag 3: Na het invullen van het model is het project waarover ik geïnterviewd ben

☐Circulairder dan verwacht, omdat Klik of tik om tekst in te voeren.
☐Minder circulair dan verwacht, omdat Klik of tik om tekst in te voeren.
☐Ongeveer wat ik verwacht had, omdat Klik of tik om tekst in te voeren.

Vraag 4: Als u kijkt naar strategieën uit het model die niet in het project zijn geïmplementeerd, ziet u gemiste kansen of zijn er dingen die u volgende keer anders zou doen?

Klik of tik om tekst in te voeren.

Vraag 5: Wat vindt u goed aan het model?

Klik of tik om tekst in te voeren.

Vraag 6: Wat vindt u niet goed aan het model?

Klik of tik om tekst in te voeren.

Vraag 7: Zijn er nog dingen die u aan het model zou willen toevoegen?

Klik of tik om tekst in te voeren.

Vraag 8: Zou u het model in de toekomst voor projecten gebruiken?

☐Ja want, Klik of tik om tekst in te voeren.

☐Nee, want Klik of tik om tekst in te voeren.

Appendix 3: Data management plan

Plan Overview

A Data Management Plan created using DMPonline

Title: The Future of Our Past - Current implementation of circular economy strategies in the adaptive reuse of heritage buildings and remaining barriers

Creator: Dylan Besten

Affiliation: Delft University of Technology

Template: TU Delft Data Management Plan template (2021)

Project abstract:
The construction industry imposes significant pressure on the natural environment, making it essential to transition to the circular economy (CE). A step towards this goal is adaptive reuse of existing buildings, more specifically, heritage buildings. Adaptive reuse (AR) of heritage is a difficult procedure that seeks to maintain the qualities of historic structures while modifying them for usage in the present and the future.
The relationship between heritage structures and adaptive reuse has previously been shown in prior research. However, this research typically sticks to theory. Even though it provides a clear grasp of the enablers, obstacles, and methods for implementing circularity in the built environment, it frequently fails to convey how an to what extent it is actually put into practise.
For this research, literature review will provide a better understanding of the terms circularity and adaptive reuse within the context of the built environment and heritage, the literature study will also offer the potential barriers and enablers for circular heritage renovation. Case studies will explore what strategies are already, or not, implemented in adaptive reuse of heritage buildings. Finally a focus group session will be conducted in order to find what practical barriers still need mitigation and how this could be achieved.
The purpose of this thesis is to close the knowledge gap between theory and practise in the area of the circular renovation and adaptive reuse of heritage, and to find how to what extent theory translates to practise. To goal is to find what barriers still remain and what steps are to be taken to mitigate these, in order to accelerate the process of transitioning to the circular economy. The main deliverable is an overview of the current implementation of circular economy strategies within adaptive reuse of heritage buildings, the practical barriers that still exist and the steps are to be taken to mitigate these barriers in the future.

ID: 115591

Start date: 01-02-2023

End date: 01-06-2023

Last modified: 24-01-2023

The Future of Our Past - Current implementation of circular economy strategies in the adaptive reuse of heritage buildings and remaining barriers

0. Administrative questions

1. Name of data management support staff consulted during the preparation of this plan.

My faculty data steward, Diana Popa, has reviewed this DMP on 30 january 2023.

2. Date of consultation with support staff.

2023-01-30

I. Data description and collection or re-use of existing data

3. Provide a general description of the type of data you will be working with, including any re-used data:

Type of data	File format(s)	How will data be collected (for re-used data: source and terms of use)?	Purpose of processing	Storage location	Who will have access to the data
Data on the implentation of circular economy strategies implemented in the adaptive reuse of heritage buildings	word files	Interviews	Understanding to what extent the circular economy is implemented in adaptive reuse projects of heritage	Project storage drive + backup	Main Researcher
Data on the implentation of circular economy strategies implemented in the adaptive reuse of heritage buildings	video or audio recording	Interviews	Understanding to what extent the circular economy is implemented in adaptive reuse projects of heritage	Project storage drive + backup	Main Researcher
Data on what barriers still exist in the implementation of adaptive reuse of heritage buildings and what steps are to be taken to mitigate these	Word files	Focus group	Find out what barriers still require mitigation in order to move towards the circular economy	Project storage drive + backup	Main Researcher
Data on what barriers still exist in the implementation of adaptive reuse of heritage buildings and what steps are to be taken to mitigate these	Video or audio recording	Focus group	Find out what barriers still require mitigation in order to move towards the circular economy	Project storage drive + backup	Main Researcher

4. How much data storage will you require during the project lifetime?

250 GB - 5 TB

II. Documentation and data quality

5. What documentation will accompany data?

README file or other documentation explaining how data is organised

III. Storage and backup during research process

6. Where will the data (and code, if applicable) be stored and backed-up during the project lifetime?

OneDrive

IV. Legal and ethical requirements, codes of conduct

7. Does your research involve human subjects or 3rd party datasets collected from human participants?

Yes

8A. Will you work with personal data? (information about an identified or identifiable natural person)

No

8B. Will you work with any other types of confidential or classified data or code as listed below? (tick all that apply)

No, I will not work with any confidential or classified data/code

9. How will ownership of the data and intellectual property rights to the data be managed?

The datasets underlying the published papers will be publicly released following the TU Delft Research Data Framework Policy. During the active phase of research, the project leader from TU Delft will oversee the access rights to data (and other outputs), as well as any requests for access from external parties. They will be released publicly no later than at the time of publication of corresponding research papers.

V. Data sharing and long-term preservation

26. What data will be publicly shared?

Not all data can be publicly shared - please explain below which data and why cannot be publicly shared
Interview documents and code will not be shared publicly, interview outcomes will be shared

28. How will you share your research data (and code)?

All data will be uploaded to 4TU.ResearchData

30. How much of your data will be shared in a research data repository?

100 GB - 1 TB

31. When will the data (or code) be shared?

At the end of the research project

32. Under what licence will be the data/code released?

CC0

VI. Data management responsibilities and resources

33. Is TU Delft the lead institution for this project?

Yes, leading the collaboration - please provide details of the type of collaboration and the involved parties below
Other institution is Nico de Bont, through this company other parties will be contacted

34. If you leave TU Delft (or are unavailable), who is going to be responsible for the data resulting from this project?

Main mentor:
Hilde Remoy
h.t.remoy@tudelft.nl

35. What resources (for example financial and time) will be dedicated to data management and ensuring that data will be FAIR (Findable, Accessible, Interoperable, Re-usable)?

4TU.ResearchData is able to archive 1TB of data per researcher per year free of charge for all TU Delft researchers. We do not expect to exceed this and therefore there are no additional costs of long term preservation.

Appendix 4: HREC approval letter

Date 01-May-2023

Contact person Grace van Arkel, Policy Advisor Academic Integrity

E-mail E.G.vanArkel@tudelft.nl

Human Research Ethics Committee TU Delft
(http://hrec.tudelft.nl)

Visiting address

Jaffalaan 5 (building 31)
2628 BX Delft

Postal address

P.O. Box 5015 2600 GA Delft
The Netherlands

Ethics Approval Application: The Future of Our Past - Current implementation of circular economy strategies in the adaptive reuse of heritage buildings and remaining barriers
Applicant: Besten, Dylan

Dear Dylan Besten,

It is a pleasure to inform you that your application mentioned above has been approved.

In addition to any specific conditions or notes, the HREC provides the following standard advice to all applicants:

- In light of recent tax changes, we advise that you confirm any proposed remuneration of research subjects with your faculty contract manager before going ahead.
- Please make sure when you carry out your research that you confirm contemporary covid protocols with your faculty HSE advisor, and that ongoing covid risks and precautions are flagged in the informed consent with particular attention to this where there are physically vulnerable (eg: elderly or with underlying conditions) participants involved.
- Our default advice is not to publish transcripts or transcript summaries, but to retain these privately for specific purposes/checking; and if they are to be made public then only if fully anonymised and the transcript/summary itself approved by participants for specific purpose.
- Where there are collaborating (including funding) partners, appropriate formal agreements including clarity on responsibilities, including data ownership, responsibilities and access, should be in place and that relevant aspects of such agreements (such as access to raw or other data) are clear in the Informed Consent.

Good luck with your research! Sincerely,

Dr. Ir. U. Pesch Chair HREC, Faculty of Technology, Policy and Management

Appendix 5: Informed consent form

De bouwsector oefent significante druk uit op de wereld en is verantwoordelijk voor een grote hoeveelheid uitstoot en afval, daarnaast is het ook de sector ook een van de grootste afnemers van natuurlijke grondstoffen.

Mede hierdoor willen verschillende overheden en organisaties de transitie maken richting de circulaire economie. De circulaire economie is een systeemoplossingen die wereldwijde uitdagingen zoals klimaatverandering, verlies van biodiversiteit, afval en vervuiling aanpakt.

Een van de manieren waarop de bouwsector kan bijdragen aan de circulaire economie is door het herbestemmen en transformeren van bestaande bebouwing. De term die hiervoor ook vaak wordt gebruikt is ''adaptive reuse'', en doelt op een verandering in functie, waarbij een gebouw wordt getransformeerd voor een nieuwe invulling . Een voorbeeld van gebouwen die zich hiervoor lenen zijn erfgoed gebouwen. Hier worden de bestaande gebouwen gerenoveerd voor de inpassing van een nieuwe functie, waarbij de historische kwaliteiten van het gebouw worden behouden.

De term circulariteit en circulaire economie kent vele verschillende definities. Voor mijn onderzoek gebruik ik de volgende definitie: '' De circulaire economie is een systeem van productie en consumptie dat het gebruik van grondstoffen en het effect op het milieu minimaliseert door de levensduur van materialen te verlengen en het verbruik en de verspilling ervan te minimaliseren. Door het creëren van nieuwe producten, duurzaam ontwerp, afvalvermindering, terugwinning van hulpbronnen en hergebruik, alsmede door het herdefiniëren van consumptie zoals delen en het leveren van diensten in plaats van privé-eigendom, krijgen materialen een langere levensduur. De circulaire economie benadrukt het gebruik van materialen met de minst schadelijke levenscycluseffecten, zoals hernieuwbare, niet-giftige en biologisch afbreekbare materialen. Als idee van duurzaamheid moet een circulaire economie worden geïntegreerd in een sociaal systeem dat universeel menselijk welzijn ondersteunt binnen de biofysische grenzen van de planeet aarde.''

Voor mijn onderzoek wil ik uitzoeken wat voor circulaire economie strategieën momenteel worden toegepast bij de transformatie van erfgoed. Zoals de bovenstaande definitie al suggereert is het concept zeer alomvattend en beperkt zich niet alleen tot bepaalde materiaal keuzes. De circulaire economie kan betrekking hebben tot het milieu, met duurzame materiaal gebruikt, verminderd bouw en sloop afval, toename in biodiversiteit. Het kan gerelateerd zijn aan economische indicators, zoals het creëren van nieuwe banen, toename in bezoekers van de omgeving. Het kunnen ingegrepen zijn gerelateerd aan sociaal aspect, zoals de gezondheid en welzijn van mensen, toegenomen veiligheid in de omgeving of sociale cohesie. Circulaire economie strategieën kunnen ook gerelateerd zijn aan culturele waarden zoals de verbetering van sociale identiteit en Verbeterde traditionele vaardigheden.

In het interview zou ik graag meer te weten willen komen over alle strategieën en toepassingen van de circulaire economie binnen het project waarin u was betrokken. Daarnaast ben ik ook heel erg benieuwd tegen wat voor barrières u bent aangelopen wat de implementatie van bepaalde circulaire ingrepen verhinderde of zelfs onmogelijk maakte.

Dit heeft te maken met het tweede doel van mijn onderzoek. Ik wil uitvinden welke barrières voorkomen bij de implementatie van circulariteit, wat de reden hiervoor is en wat er in de toekomst moet worden veranderd of verbeterd om deze belemmeringen te verhelpen.

Graag zou ik het interview op willen nemen om het achteraf uit te kunnen werken en te analyseren. Ik wil graag leren van uw ervaringen.

Vanuit de universiteit zijn we gewend om nog eens apart te vragen of u mee wilt doen aan het onderzoek en of u het goed vindt om dit interview op te nemen. Zodat ik hier een transcript van kan maken om te analyseren. U mag ook nu zeggen dat u liever niet mee doet. U kunt u ook later nog bedenken en uw deelname intrekken zonder opgave van reden. Daarnaast mag u iedere vraag die gesteld wordt weigeren te beantwoorden.

Alleen ik, Dylan Besten, heb toegang tot de verzamelde gegevens. De opnames van de interviews worden verwijderd nadat ze zijn omgezet in transcripties. De transcripten zijn ook niet beschikbaar voor andere mensen. De informatie die uit het onderzoek komt is geanonimiseerd, zodat deze niet te herleiden is tot een van de specifieke projecten of geïnterviewden.

Als u mee doet, dan vraag ik u om uw handtekening onderaan deze brief te zetten en een pdf te retourneren. Ik zet dan ook een handtekening. Dat is zodat u zeker weet dat ik vertrouwelijk omga met uw gegevens en antwoorden. Ook krijgt uw organisatie het interviewverslag niet te zien of te horen. Ik maak een algemeen en anoniem verslag over de toepassing van de circulaire economie in de transformatie van erfgoed. Wanneer antwoorden worden aangehaald in het onderzoeksrapport, zal uw naam niet gebruikt worden. Uw naam- en contactgegevens worden meteen na afloop van het onderzoek vernietigd.

Als u vragen heeft over dit onderzoek, kunt u natuurlijk contact met mij opnemen: Dylan Besten, d.r.besten@student.tudelft.nl, 06-22870774

Als u mee wilt doen aan dit interview, wilt u dan de onderstaande verklaring invullen en ondertekenen?

Met vriendelijke groet, Dylan Besten

In te vullen door de geïnterviewde & student

Ik verklaar op een voor mij duidelijke wijze te zijn ingelicht over de aard, methode, doel en belasting van het onderzoek.

Mijn vragen zijn naar tevredenheid beantwoord.

Ik begrijp dat het geluids- en/of beeldmateriaal (of de bewerking daarvan) en de overige verzamelde gegevens uitsluitend voor analyse en wetenschappelijke presentatie en publicaties zal worden gebruikt.

Ik behoud me daarbij het recht voor om op elk moment zonder opgaaf van redenen mijn deelname aan dit onderzoek te beëindigen.

☐ Ik heb dit formulier gelezen of het formulier is mij voorgelezen en ik stem in met deelname aan het onderzoek.

Plaats:

Datum: Dylan Besten

_ _

(Volledige naam, in blokletters) _

_ _

(Handtekening geïnterviewde)

☐ Ik heb toelichting gegeven op het onderzoek en ik verklaar mij bereid nog opkomende vragen over het onderzoek naar vermogen te beantwoorden.''

Appendix 6: CESAR model strategies and descriptions

Dimension	Group	Strategy	Description
Environmental	Climate	Increase green space	Increase the amount of grass, trees, or other vegetation set apart for recreational or aesthetic purposes, but also green roof tops
		Improve air quality and micro climate	Improve the area's heritage context's microclimate: vegetation, soil, latitude, elevation, and moisture, temperature, and winds air quality of the atmosphere close to the ground
		Improve biodiversity	Contribution to the preservation and enhancement of biodiversity, including measures to stop and reverse the loss of biodiversity
		Reduce GHG emissions	Reducing green house gas emissions, including building and site embodied energy reutilization
		Reduce air emissions (CO_2, NO_x, SO_x)	Reductions to air emissions including carbon dioxide ($CO_{2)}$), nitrogen oxides, (NO_x), sulphur oxides (SO_x), and particulate matter
		Create habitats	Increase the number of locations or habitats for animal, plant, or other organisms
		Limit disturbance of trees, soils, and habitats	Minimize habitat, soil, and tree disturbance throughout the process
	Design	Design for future adaptation	Implement design interventions with future adaptation and function change in mind
		Design for disassembly	Design for construction and building elements to be taken apart
		Design for multi tasking	Design for multiple use of spaces
		Design for better energy label and green building certification	Design for improved energy label or building certification (BREEAM, LEED, DGNB)
		Design for flexible heating and cooling	Design for energy efficiency including passive methods
		Design for maximal land use efficiency	Increase or maximize land use efficiency (square meter reductions to space requirements of new purpose)
	Material	Salvage / reuse materials	Salvage building materials and reuse within project or elsewhere
		Substitute new with used materials	Reuse materials from other projects or elsewhere
		Use circular building	Use materials that are, and are able to be, recovered from their initial or previous usage

		materials and isolation	phase, such as those composed of plastics, natural fibres, metals, etc.
		Reduce, collect, and separate C&D waste	Reduce the amount of excessive construction and demolition waste, collect the emitted waste and separate the waste for recycling
		Implement material passports	Implement material Passports that offer the data about materials, items, and parts required for reversible design and cyclical reuse of building materials
		Reduced exploitation of raw/virgin materials	Minimize the exploitation of raw and virgin resources
		Use bio based materials	Use of products that are primarily made of a substance (or substances) generated from living materials (biomass)
		Improved material maintainability and sustainability	Use of materials with improved maintainability effectiveness and efficiency
		Use local and culturally significant materials	Use of locally sourced and used materials like timber, stone, and sand
		Use materials for energy recovery	Use materials for energy recovery if there is no other option but landfill.
	Energy	Use renewable energy	Utilize renewable energy, which comes from natural resources that are supplied more quickly than they are used up, like sunlight and wind
		Reduce energy use	Reduce the amount of energy used, by for example improving insulation, and sealing seams and cracks.
		Reutilize embodied energy	Use as much of the existing structure, to maximize use of embodied energy (the total energy required to make a material or good, including that needed in mining, manufacturing, and transportation)
		Implement energy efficiency strategy	Create strategy to improve the structure energy efficiency, by reducing energy use but also maximize energy use by using heat and cold recovery
		Measure energy efficiency	Monitor structure energy efficiency during operation
	Water and soil	Maximize fresh and grey water efficiency	Water capture, filtration, and reuse systems that enable self-generation of water resources. Capture, filter and utilize grey water for toilets, washing machines, garden watering and such.
		Improve water quality	Improvement of water quality in both urban and rural settings, by for example using natural water banks.
		Improve soil quality	Clean up brownfields, toxic soil, and recover land recovery

		Reduce soil consumption	Reduce amount of fresh organic and fertile soil
Economic	Circular supply chains	Local material sourcing	Use locally available materials
		Collaborate with circular demolition contractor	Collaborate with circular demolition contractors or urban miners to dismantle and reuse building components and materials released from demolition
		Local sourcing for reduced transports	Reduce transport costs and emissions by sourcing locally
		Lease materials	Renting a product rather than purchasing it. The supplier retains ownership of the item and is in charge of maintaining it, replacing it when it breaks, and retrieving it when the lease period is up
		Take back programs	A manufacturer or merchant can create a "Take Back Program" to collect discarded goods or materials from customers and return them to the original processing and manufacturing process
	Financial	Financial self sustainability	Establish self-generation of financial resources required for cultural protection and ongoing maintenance through a variety of revenue flows from reuse activities
		Local circular economy	Circular reuse of revenues in the community for new adaptive reuse projects, circular entrepreneurial activities, and social and solidarity economy initiatives; Local resources like food, crafts, and materials are valued within the project, which can also encourages local investments and nearby economic activity
		Positive economic spill over	The project's indirect and increased economic effects extend over a variety of industries, such as building construction, cultural and creative actions, education and training, tourism, sustainable technology, innovation and research entrepreneurship, etc.
	Regional	Attractiveness for residents	the project area's increased attractiveness can result in an increased amount of permanent or transient occupants.
		Job creation	Creation of long-term employment growth connected both directly and indirectly to adaptive reuse project
		Attract CCI enterprises	Attract more sustainable, creative, and cultural ventures, R&D projects, and innovative entrepreneurs
		Contribute to regional development (3S)	Contribute to regional development by implementing local Smart Specialisation Strategies (a framework that seeks to foster regional enterprise innovation, promoting growth and wealth by assisting and enabling regions to concentrate on their strong points.)
		Circular tourism	By increasing the project's attractiveness circular cultural tourism and hospitality can

			become more prevalent locally
Social	Provision	Provide facilities for collecting recyclables and compost	Establish recycling and composting facilities for locals and visitors
		Provide shared space arrangement	Provide shared spaces for residents such as shared office, laundry, conference spaces
		Provide access to green space	Proved resident and user access to green space for recreation
		Provide low carbon mobility options	Provide low carbon mobility options such as shared bikes, public transport, electric cars etc.
	Health and safety	Improve public safety	Improve the public spaces' accessibility and safety
		Improve landscape and atmosphere quality	Improve the landscape's attractiveness, create desirable places for people to live, work, play, and study
		Quality of life for residents	Improve objective aspects of people's quality of life, such as the availability of nearby stores, while also avoiding the negative impacts of gentrification, and preventing the "touristification", of heritage
		Health & wellbeing	Contributions to health include healthy construction materials, environmentally friendly fixtures, indoor air quality, natural lighting, noise reduction, mental health, healthy outputs (such as nutritious food), both after and during the construction. All-round improvement of users' and citizens' self-perceived welfare.
		Cleanliness of public places	Improvements to maintaining the health and cleanliness public places
		Measure health impacts	Measure health impacts like, indoor air quality, humidity, temperature
	Community	Create heritage community	Encourage residents to organize and create a community that is cohesive and proactive in protecting, valuing, and reusing their history
		Improve local community	Improvement of local community's learning, education, and skill possibilities, by for example promoting volunteering
		Social cohesion	Greater understanding of the needs and rights of current and future generations by eliminating discrimination, social exclusion, and inequality, creating networks of relationships, trust, and identification across and within various societal groups, and promoting upward social mobility
		Civic pride	Improvement of common values and ties within the community, openness within the community, belonging, and responsibility

		Participation in decision making	Include a wide range of stakeholders and citizens in the project decision-making process
		Encourage user recycling and reuse	Implement high rates of product reuse and recycling, provide incentives for doing so, and motivate citizens to do so.
		Promote and incorporate local and regional agriculture	Promote and include regional and local agriculture to generate jobs, improve health, improve economy, and lessen the impact on the environment.
Cultural	Value	Regeneration of cultural capital and local identity	Revive heritage values through adaptive reuse and share it with the local residents and visitors to improve and promote the distinctive qualities of a place and its inhabitants, with the goal of restoring and increasing the quality of urban life.
		Mutual cooperation	Collaborate, share resources, information, and assets; participation of sharing economy or third sector actors in adaptive reuse; utilize agreements/cooperation pacts between the governmental, private, and individual sectors
		Cultural vibrancy	Improve access to culture and cultural heritage; improvement of cultural events and activities
	Knowledge	Cultural knowledge production	Stimulate the generation of knowledge and culture, exchange stories, celebrate traditional holidays, festivals, and food
		Tradition skills	Use and improve traditional skills throughout the project, like masonry and wood working, training programmes to spread knowledge on traditional skills
		Traditional materials	Use traditional and period correct materials like stone, wood, etc.