EXPLORING THE APPLICABILITY AND EFFECTIVENESS OF CIRCULAR BUILDING ADAPTABILITY STRATEGIES IN ADAPTIVE REUSE

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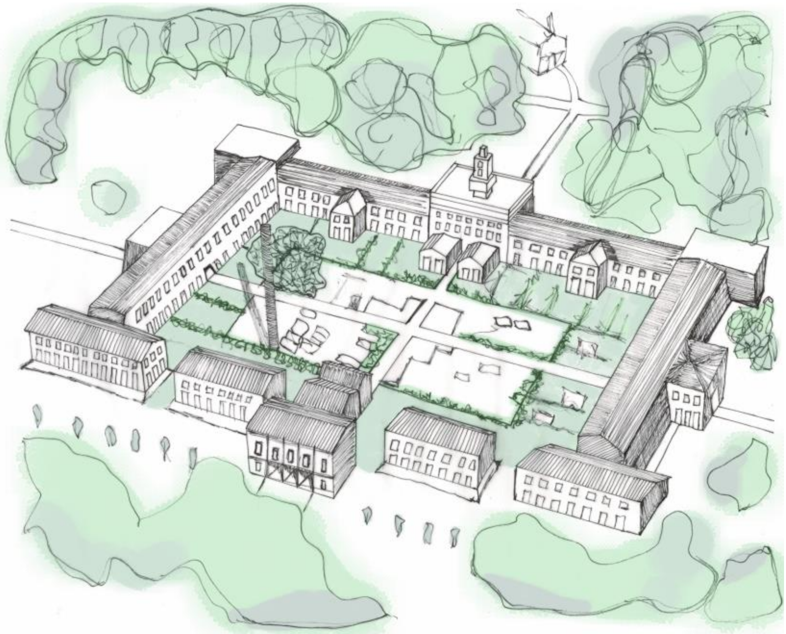
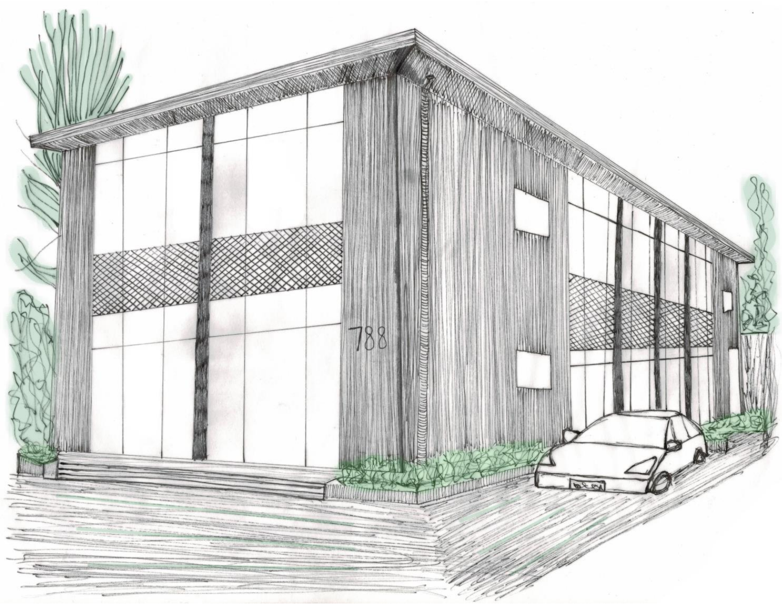
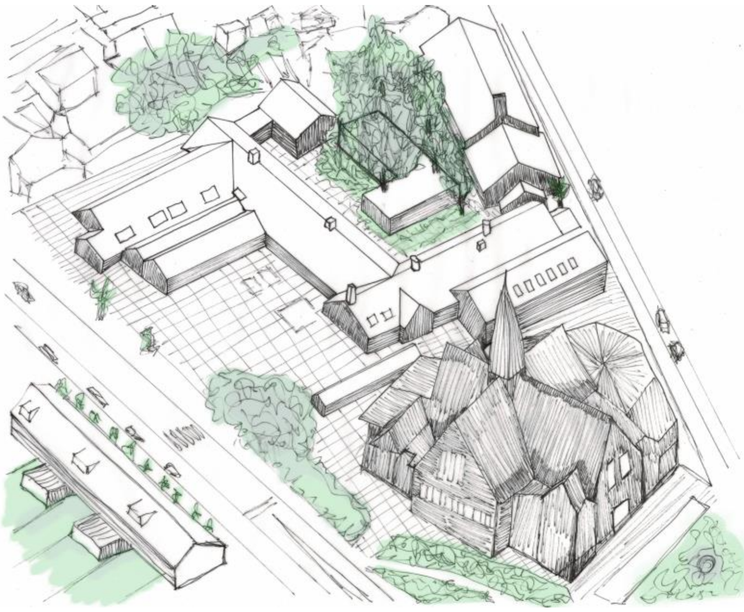
Delft University of Technology







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Şimdiye kadar elde ettiğim tüm başarılar, her zaman bana inanan, güvenen ve iyi-kötü günlerimde yanımda olan sevgili annem ve babam sayesindedir. En baştaki hedefim, sizlere hayırlı bir evlat, kardeşlerime ise iyi bir örnek olabilmekti. Annemin duaları ve babamın gölgesi, kanatlarımı çırpmama ve en yüksekteki hedeflere ulaşmama vesile oldu. Bugüne kadar başardığım ve bundan sonra başaracağım her şey daima sizin içindir.

ABSTRACT

Circular building adaptability (CBA) offers substantial benefits to the built environment, including reducing building costs through material efficiency and waste reduction, while enhancing the long-term value of structures through improved flexibility (Hamida et al., 2023). Next to this, CBA contributes to long-term sustainability in the built environment by making it possible to generate new business opportunities within the circular economy (CE). However, the Dutch building industry faces significant challenges in adopting CBA principles, particularly in the context of adaptive reuse (AR) projects. These challenges hinder the industry's transition towards a sustainable and circular built environment.

This research primarily concentrated on testing part of a relatively new framework that links determinants, strategies and the enabling and inhibiting factors of CBA in adaptive reuse projects to support the shift towards a circular economy. Accordingly, this study aimed to answer the following research question: ***"How can the applicability and effectiveness of design-oriented circular building adaptability strategies (CBASs) be promoted in adaptive reuse projects?"***. A stepwise research design of two approaches was followed, namely case studies and Research-through-Design (RtD). The methods include archival research, field observations, semi-structured interviews with key informants, questionnaires, and workshops focused on practical design solutions.

The results indicate that the CBA-AR framework is a useful tool that integrates CBA-determinants, strategies, and associated enabling or inhibiting factors, and can be useful during early-stage planning and collaboration in adaptive reuse projects. Second, based on the findings of the case study, three strategies have been identified as the most applicable and effective, namely: opening the floor plan, providing multi-purpose spaces, and aligning the interconnection between floor plans. In contrast, the less applicable and effective strategies for the cases examined in this study are designing for mixed-use, modularizing spatial configuration, and designing for surplus capacity. Finally, the successful implementation of CBASs requires raising awareness among professionals, as the lack of knowledge often leads to missed opportunities for integrating adaptable and sustainable design strategies.

The scope of the research has been limited to the design-oriented (passive) CBASs, and therefore, directions for future research have been put forward in the conclusion. Moreover, the findings of this study are not generalizable because they are case-specific; however, they provide valuable lessons for future research, policy-making, and practitioners seeking to promote resource efficiency and future-proofing in adaptive reuse projects.

Keywords: *Circular Economy (CE), Adaptive Reuse (AR), Circular Building Adaptability Strategies (CBASs), Applicability, Effectiveness*

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GLOSSARY

Term	Explanation
Circular Economy (CE)	"Circular Economy is a production and consumption process that requires the minimum overall natural resource extraction and environmental impact by extending the use of materials and reducing the consumption and waste of materials and energy'' (Foster & Kreinin, 2020).
Adaptive Reuse (AR)	"Conversion of a facility or part of a facility to a use significantly different from that for which it was originally designed'' (Iselin & Lemer, 1993).
Circular Building Adaptability (CBA)	''Circular building adaptability (CBA) is the capacity to contextually and physically alter the built environment and sustain its usefulness, while keeping the building asset in a closed-reversible value chain'' (Hamida et al., 2022).
Circular Building Adaptability Strategies (CBASs)	Circular Building Adaptability Strategies (CBASs) are strategies designed to enhance the adaptability and circularity of buildings, particularly in the context of adaptive reuse projects. These strategies aim to ensure that buildings can be easily adapted or repurposed, reducing waste and environmental impact while contributing to the sustainability of the built environment.

Chapter 1

Introduction

1. INTRODUCTION

1.1. BACKGROUND

The traditional linear model of building design and construction, characterized by resource extraction, production, construction, and waste disposal, stands as a significant environmental and resource-related challenge (Husain et al., 2021). These challenges grapple the European building sector by contributing to 42% of energy consumption, over 50% of extracted materials, 30% of water usage, and waste generation, as well as 35% of greenhouse gas emissions in the region (Mrad & Ribeiro, 2022). Additionally, the building industry in the Netherlands is confronted with a pivotal crossroad, where economic development converges with the looming environmental challenges of our era, highlighting the need for a comprehensive approach to assess the life cycle of buildings and components (de Graaf et al., 2022). The urgency to shift towards a circular model becomes increasingly apparent (Munaro et al., 2020).

Adopting circular economy principles in the built environment is crucial to mitigate its substantial contribution to global greenhouse gas emissions and raw material extraction (Joensuu et al., 2020). Acknowledging the importance of adaptive reuse as a strategic approach for proactively or reactively addressing changes in buildings, it is essential to incorporate circularity and adaptability into the design of these projects. This integration facilitates resource loops, preserves enduring functionality, and enables an effective response to contextual changes (Hamida et al., 2022). Circular building adaptability (CBA) emerges as a promising concept with the potential to enable the construction sector to be resource-efficient and adaptable in its building- and adaptation-related practices (Hamida et al., 2023).

CBA is defined as *''the capacity to contextually and physically alter the built environment and sustain its usefulness, while keeping the building asset in a closed-reversible value chain''* (Hamida et al., 2023). It involves ten determinants, namely *"configuration flexibility"*, *"product dismantlability"*, *"asset multi-usability"*, *"design regularity"*, *"functional convertibility"*, *"material reversibility"*, *"building maintainability"*, *"resource recovery"*, *"volume scalability"*, and *"asset refit-ability"* (Hamida et al., 2022). These determinants can be incorporated into buildings and adaptive reuse projects through passive, active and operational strategies. The differences among the aforementioned types of CBA-strategies can be briefly described as follow:

1. **Passive strategies** are those that do not require any active intervention or control, but rather rely on the characteristics of the building design and the organization of components.
2. **Active strategies** are those that require some level of active intervention or control by people, but do not involve major changes to the building design.
3. **Operational strategies** are those that are process-oriented solutions that require managerial intervention.

Hamida et al. (2023) developed a guiding framework for CBA in adaptive reuse through literature reviews, case studies, and a co-creation workshop with practitioners. The framework brings together the CBA determinants and strategies alongside their factors that facilitate or impede the implementation of those strategies. The framework includes a total of 33 strategies, including 15 passive, 7 active, and 11 operational strategies, respectively. All the 33 strategies are mapped against their enablers, inhibitors and determinants to provide a comprehensive understanding of what CBA could look like in adaptive reuse. Figure 1.1 depicts this guiding framework for CBA in adaptive reuse.

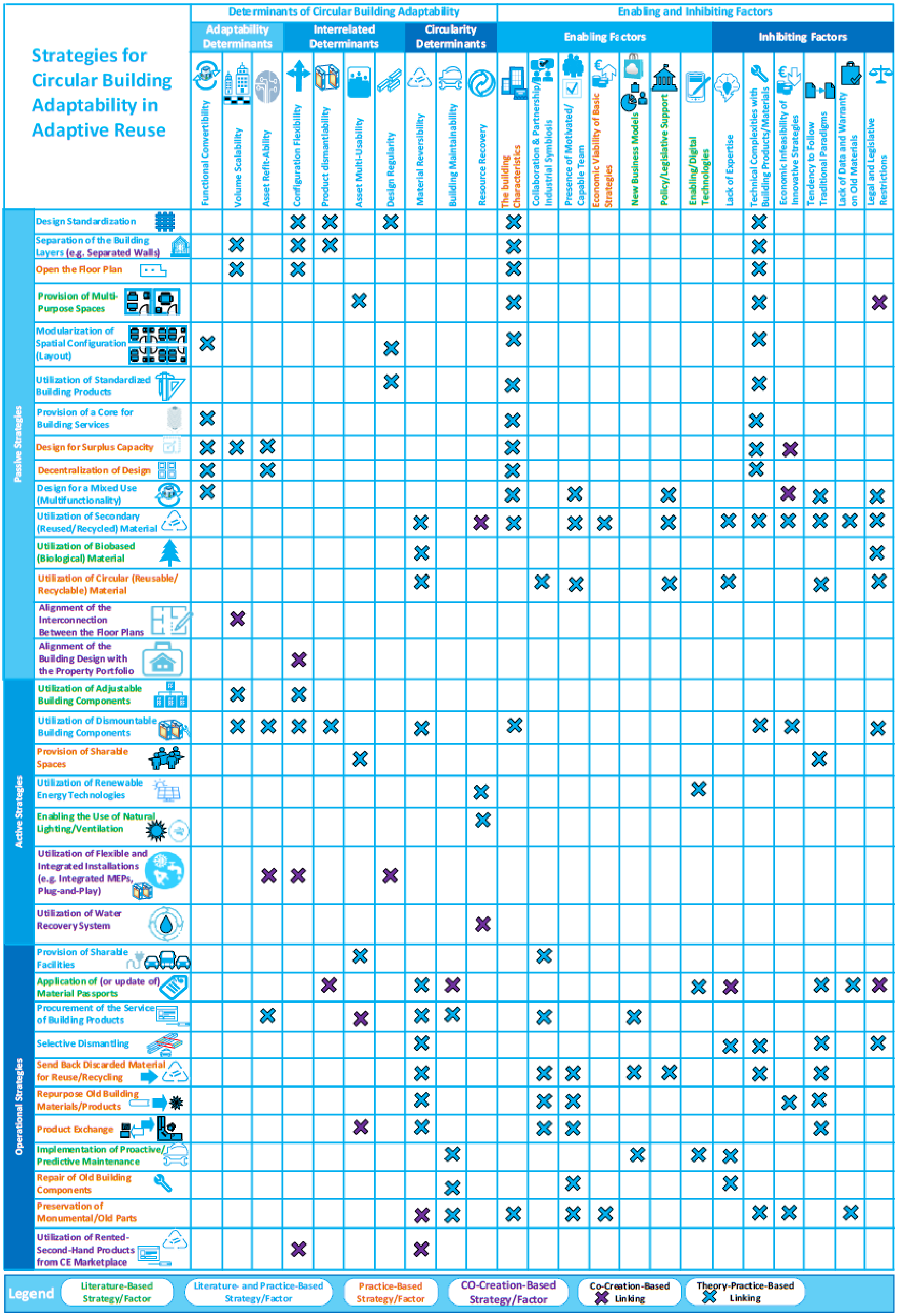


Figure 1.1: CBA-AR framework (Hamida et al., 2023)

1.2. PROBLEM STATEMENT

Despite the acknowledged potential benefits of circular building adaptability strategies (CBASs) in adaptive reuse in terms of reducing waste and promoting sustainability, their practical implementation in practice remains constrained (Kaya et al., 2021a, 2021b). This limitation impede addressing global environmental issues and unsustainable resource consumption in the built environment. Moreover, the real-world applicability and effectiveness of these strategies have neither been tested nor ranked based on evidence from the real world. The term "applicability" pertains to the ability to apply the design-oriented CBASs in adaptive reuse projects, while "effectiveness" refers to the extent to which CBASs foster the CBA determinates.

1.3. RESEARCH AIM

This research aimed to respond to this gap by exploring the applicability and effectiveness of circular building adaptability strategies (CBASs) in adaptive reuse projects within the Dutch context.

1.4. RESEARCH QUESTIONS

This research aimed to answer the following research question: **''How can the applicability and effectiveness of design-oriented circular building adaptability strategies (CBASs) be promoted in adaptive reuse projects?''**

To answer the aforementioned main research question, the following sub-questions were addressed:

- A) What are the effective ways to use the CBA-AR framework in the design & decision-making processes of adaptive reuse projects?
- B) What are the most applicable and effective design-oriented CBASs for circular and adaptable adaptive reuse projects?
- C) How can the applicable and effective design-oriented CBASs be implemented in adaptive reuse design?

1.5. SCOPE AND LIMITATIONS

Following are the scope and limitations of this study:

- It is important to note that the examination of CBASs in this research excluded all economic feasibility-related aspects, in order to focus on the practical dimensions pertinent to applicability. In exploring these dimensions, the soft and hard aspects of the contextual factors were comprehensively explored.
- This research only considered the design-oriented strategies, specifically the passive design strategies outlined in the framework proposed by Hamida et al. (2023).
- The empirical work of this research was limited to the context of the Dutch building industry.

1.6. SOCIETAL AND SCIENTIFIC RELEVANCE

1.6.1. Societal

This research offered evidence-based guidance to practitioners in the building industry by testing and validating circular building adaptability strategies (CBASs) in real-world settings, providing insights into how to effectively promote them in practical applications. Developers, architects, contractors, policymakers, and sustainability experts can benefit from the findings, as they will gain insights into the most applicable and effective CBASs. These practitioners can also utilize the research findings as a tool to inform and prioritize their decision-making processes. In addition, this research project aligned with CE- and sustainability-oriented initiatives in Europe and around the globe such as the sustainability development goals (SDGs).

1.6.2. Scientific

Scholars can gain insights into the practical application of CBASs in the real-world context of the Dutch building industry, therefore expanding and revising existing conceptual models or decision-making tools for circular and adaptable building transformation. This research bridged the gap between theory and practice in the context of circular building adaptability (CBA) in adaptive reuse by providing knowledge on the applicability and effectiveness of design-oriented CBASs, thereby providing a prioritized list which offers a practical tool for practitioners.

1.7. CONCEPTUAL MODEL

The conceptual model, depicted in Figure 1.2, shows how the key ideas in this study are interconnected. A conceptual framework is a visual or written product which clarifies the primary ideas to be studied and shows the presumed relationships among them (Hecker & Kalpokas, 2023a). It functions as a structure built on concepts that collectively connect and explain a certain method, phenomena, or philosophy using information gained from empirical research and discipline-specific theories (Jabareen, 2009).

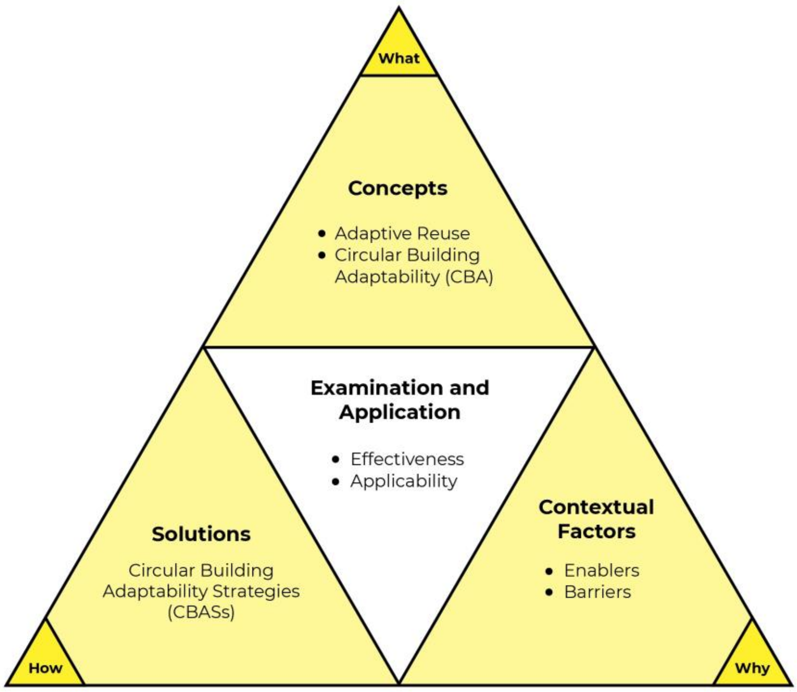


Figure 1.2: Connections between key concepts within the conceptual model (own work, 2023)

As shown in Figure 1.2, this research was positioned and centred between the relevant concepts, solutions and contextual factors. Concepts theoretically guided the empirical and experimental work, while the strategies were the variables tested. The contextual factors, namely enablers and inhibitors, provided causal interpretations of observations on the effectiveness and applicability of the strategies.

1.8. DELIVERABLES

Throughout this research, various deliverables were created to document and convey progress and findings. These deliverables, derived from both literature reviews and practical experiences, provided a clear structure to guide the research process and produced tangible outcomes. The insights gained offered a deep understanding of how to effectively integrate circular building adaptation strategies (CBASs) within typical design and decision-making processes. Additionally, semi-structured interviews and questionnaires captured practitioners' perspectives, highlighting the overall effectiveness and applicability of CBASs in adaptive reuse projects and making prioritization possible.

The thesis was divided into phases, referred to as "P moments". Figure 1.3 depicts the timeline, highlighting milestones and tasks, with yellow boxes indicating when specific sub-questions were addressed.

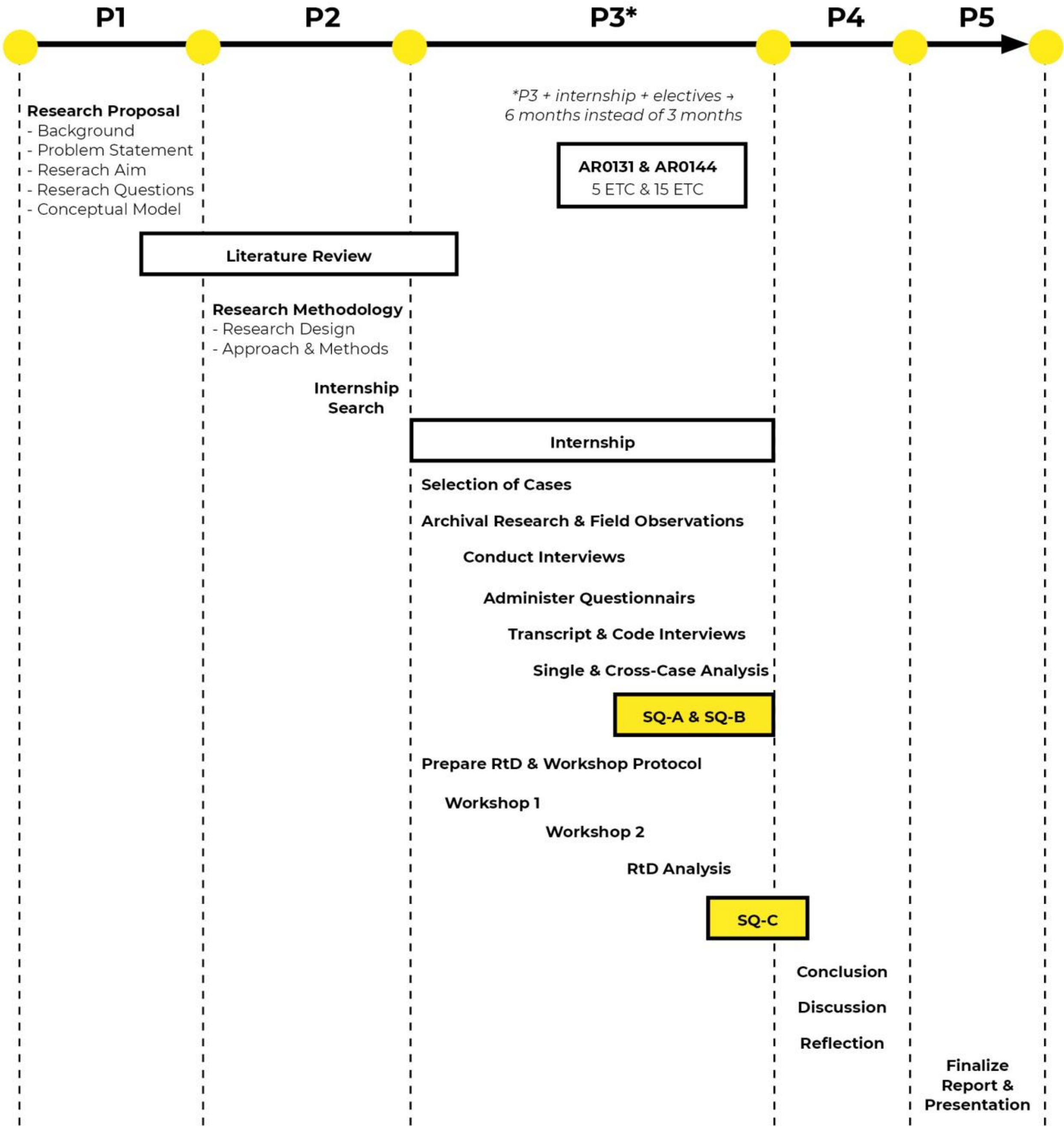


Figure 1.3: Research timeline (own work, 2023)

Chapter 2

Research Methodology

2. RESEARCH METHODOLOGY

2.1. RESEARCH DESIGN

This chapter presents the research methodology, which includes an in-depth explanation of the research design including the research approaches and data collection methods. The study incorporated a research design comprising two essential components: theoretical and empirical research. This design ensured a comprehensive answer to the research sub-questions, emphasizing different research approaches, such as an exploratory approach, case studies and Research-through-Design (RtD). These approaches employed different methods that integrated theoretical insights, empirical perspectives, and practical applications. This study established a direct connection between theory and practice by bringing a theoretical framework and empirical evidence together. Figure 2.1 visually illustrates the research design.

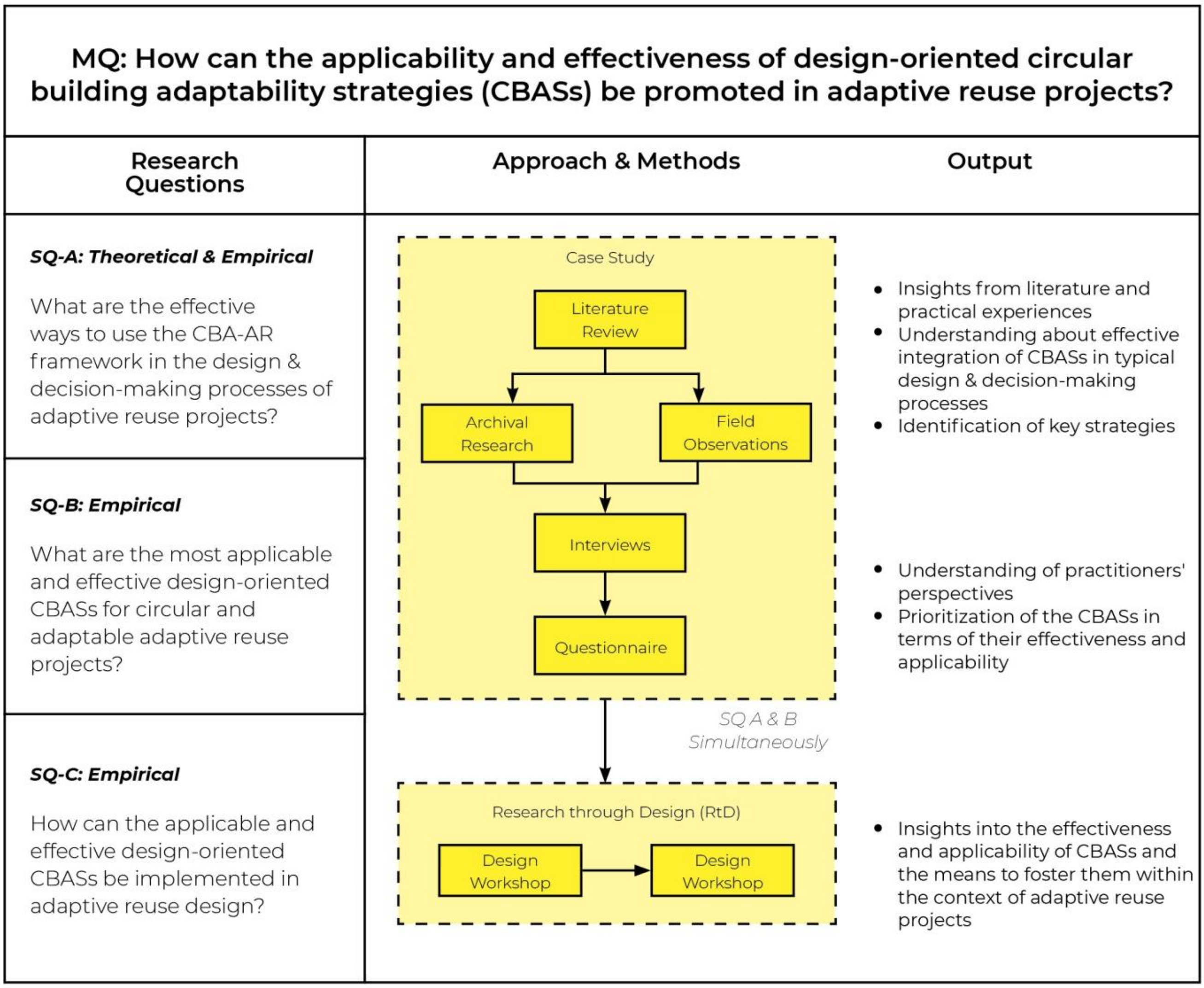


Figure 2.1: Research design (own work, 2023)

2.1.1. ANSWERING SQ-A: INSIGHTS INTO EXISTING KNOWLEDGE AND PRACTICAL EXPERIENCES

The theoretical and empirical parts of this research followed a case study approach with exploratory and descriptive purposes to better understand the effective integration of design-oriented CBASs in the design and decision-making processes of adaptive reuse projects. Exploratory studies are particularly aimed at gaining insight into relatively unexplored areas or phenomena, reinforcing the exploratory nature of the research (Swedberg, 2020). This part of the study was led by a literature review to consolidate existing knowledge by extracting lessons and identify contributions from previous research. For this reason appropriate keywords such as adaptive reuse (AR), circular economy (CE) and circular building adaptability (CBA), were incorporated in a search procedure for secondary data. The data sources used were journals, books, and reports gathered through academic search engines like Google Scholar, Scopus and TU Delft Library's digital platform. From these search results, publications were selected based on the study area, title, abstract, and introduction. Reading the references of previously downloaded publications also led to the discovery of other works.

After the literature review phase, the empirical part of the study was related partly to SQ-A and entirely to SQ-B. A case study approach was followed in this regard. The methods in this approach collectively provided a rich set of primary data, capturing real-world perspectives and experiences related to the implementation and effectiveness of design-oriented CBASs. The interviews with developers, project managers, consultants, architects, and contractors gathered practical insights of professionals actively involved in circular adaptive reuse projects. Given the nature of this study, a semi-structured interview format was used to extract lessons learned from professionals involved in the phenomenon of interest. This kind of interview provides a balance between flexibility and standardized questions. Together with a set of predetermined questions the researcher was able to delve deeper into specific aspects of the interviewee's responses, gaining richer insights into their experiences, opinions and perspectives (Leavy, 2014). The interview protocol, which includes pre-determined questions to consistently examine important areas of interest, is included in Appendix A.

The next phase of this empirical part involved the deductive analysis of collected interview data. The theoretical framework developed by Hamida et al. (2023), which was explored in the literature review, served as a coding scheme to guide and interpret the gathered data. The interviews were transcribed from audios or videos to text to carry out the analysis. To protect privacy, names of individuals were anonymized during transcription. The analysis followed a pre-established coding scheme, showed in Table 2.1, focusing only on the passive strategies and their enablers and barriers within the framework. This facilitated validating theoretical propositions and uncover patterns clarifying the applicability and effectiveness of CBASs in adaptive reuse projects. Atlas.ti software was used to assist the coding in which the transcripts were coded according various categories. With this program, large amounts of data could be qualitatively analysed (Hecker & Kalpokas, 2023b).

Table 2.1: Coding scheme for deductive analysis (adopted from Hamida et al,. 2023)

Code Group	Codes			
1. Adaptability Determinants	1.1. Functional Convertibility	1.2. Volume Scaleability	1.3. Asset Refit-Ability	
2. Interrelated Determinants	2.1. Configuration Flexibility	2.2. Product Dismantlability	2.3. Asset Multi-Usability	2.4. Design Regularity
3. Circularity Determinants	3.1. Material Reversibility	3.2. Building Reversebility	3.3. Resource Recovery	
4. Design-Oriented CBASs	4.1. Design Standardization	4.2. Separation of Building Layers	4.3. Open Floor Plans	4.4. Multi-Purpose Spaces
	4.5. Modular Spatial Configuration	4.6. Standardized Building Products	4.7. Core for Building Services	4.8. Design for Surplus Capacity
	4.9. Decentralization of Design	4.10. Mixed-Use Design	4.11. Utilization of Secondary Material	4.12. Utilization of Biobased Material
	4.13. Utilization of Circular Material	4.14. Alignment of the Interconnection Between the Floor Plans	4.15. Alignment of the Building Design with the Property Portfolio	
5. Enabling Factors	5.1. The Building Characteristics	5.2. Presence of Motivated/ Capable Team	5.3. Economic Viability of Basic Strategies	5.4. New Business Models
	5.5. Policy/ Legislative Support	5.6. Enabling/ Digital Technologies	5.7. Collaboration & Partnerships	
6. Inhibiting Factors	6.1. Technical Complexities with Building Products/ Materials	6.2. Lack of Expertise	6.3. Economic Infeasibility of Innovative Strategies	6.4. Tendency to Follow Traditional Paradigms
	6.5. Legal and Legislative Restrictions	6.6. Lack of Data and Warranty on Old Materials		

2.1.2. ANSWERING SQ-B: COMPREHENSIVE UNDERSTANDING AND PRIORITIZATION

According to Groat and Wand (2013), a case study is an empirical inquiry that investigates a phenomenon or settings within a context. To assess the implementation of CBASs (the phenomenon) within the transformation process, this study examined a range of adaptive reuse projects (the context). The purpose of the case studies was to investigate which CBASs were actively utilized and which were not. During the selection process, a distinction was made between single and multiple case studies. In a multiple case study, two or more cases are examined, typically to compare and contrast different instances of the phenomenon under investigation (Gustafsson, 2017). In this research, case studies were employed as a tool to understand how CBASs are applied in circular adaptive reuse projects, with a focus on their applicability and effectiveness.

Table 2.2: Multiple case study protocol (own work, 2024)

Component	Value
Research Question	SQA - What are the effective ways to use the CBA-AR framework in the design & decision-making processes of adaptive reuse projects? SQB - What are the most applicable and effective design-oriented CBASs for circular and adaptable adaptive reuse projects?
Definition of the Research Case	The applicability and effectiveness of circular building adaptability strategies (CBASs) in adaptive reuse projects within the Dutch built environment.
Case Unit/ Unit of Analysis	Adaptive reuse projects as the primary unit of analysis, including buildings, sites, or developments undergoing adaptation for new purposes.
Contextual boundaries	- Enablers and Inhibitors. - Buildings, sites, or developments undergoing adaptation for new purposes.
Theoretical prepositions	The conceptual framework will be guided by the principles of circular economy (CE), adaptive reuse (AR), and circular building adaptability (CBA).
Criteria for case selection	Adaptive reuse projects that have implemented design-oriented circular building adaptability strategies (CBASs) and have available data for analysis. Selection of cases representing a variety of building types, locations, key informants and project scales to ensure comprehensive insights.
Data collection methods	Mixed Methods: A combination of qualitative and quantitative data collection methods will be employed. - Qualitative: Archival research and semi-structured interviews with professionals involved in adaptive reuse projects. - Quantitative: Questionnaires with the interviewees
Logic of linking data to theory	Expanding Theory: Data collected from interviews and project documentation will be analyzed to expand the conceptual framework by providing a ranking of the CBASs in terms of their effectiveness and applicability
Criteria for interpreting the findings	Deductive Coding: Findings will be analyzed using deductive coding approach to guide the analysis. The CBA framework will guide the analysis by itself. The components of the framework – the CBASs and their enablers and inhibitors – will be used as a coding scheme.

These case studies formed the part of the empirical research, where data collection methods included interviews with key professionals, distribution of questionnaires, field observations, and archival research. The documents reviewed included images, videos, drawings, and other types of media. This mixed-methods approach, commonly employed in exploratory research, enabled a comprehensive examination of the phenomenon (CBASs) through multiple sources of evidence. The combination of semi-structured interviews and questionnaires were particularly effective, as each method complements the other by leveraging their respective strengths (Harris & Brown, 2010). The multiple case study protocol is outlined in Table 2.2, detailing the case (phenomenon of interest), unit of analysis, theoretical prepositions, selection criteria, data collection methods, and the logic of linking the data with the underlying theory.

A key aspect of the case study approach adopted in this research involved employing various methods to ensure the validity of exploring the effectiveness and applicability of CBASs in adaptive reuse projects. This approach utilized a combination of mixed research methods, specifically semi-structured interviews and questionnaires. In the semi-structured interviews, questions related to SQ-A and SQ-B were explored simultaneously. Semi-structured interviews are particularly valuable for gaining in-depth insights from interviewees, as they allow participants to express their thoughts from their own perspectives (Leavy, 2014). Moreover, interviews are more than just a data collection tool; they are a natural form of interaction that can occur in various contexts. The presence of the interviewer facilitates mutual understanding by enabling the interviewer to ask clarifying or rephrased questions if the interviewee misunderstands something, leading to more accurate and suitable responses (Hennink et al., 2011). Depending on the interviewee's availability, location, and preference, interviews were conducted either in English or Dutch, and either in-person or via Microsoft Teams as an online meeting tool.

After each interview, the interviewees were asked to complete a questionnaire to quantify the applicability and effectiveness of the CBASs from their perspectives. Appendix B includes this questionnaire, which lists the passive CBASs. The questionnaire utilized two 5-point Likert scale rating schemes to evaluate both qualities: the applicability and effectiveness of the strategies. The 5-point Likert scale provided a quantitative measure, allowing respondents to indicate the extent to which they agree or disagree with the applicability and effectiveness of the 15 passive CBASs under consideration. For assessing applicability, the 5-point scale ranged from "Extremely Applicable" to "Not Applicable". For evaluating effectiveness, the scale ranged from "Extremely Effective" to "Not Effective". This structured format helped ensure consistency and facilitated the ranking of results based on the calculated weighted average (Sullivan & Artino, 2013). To further analyse the data, the Relative Importance Index (RII) (Holt, 2014) was employed to determine the applicability index and effectiveness index for each strategy.

$$\textbf{Relative Importance Index (RII)} = \frac{5\,n5+4\,n4+3\,n3+2\,n2+1\,n1}{A*N}$$

- n5 = Number of respondents for Extremely Important
- n4 = Number of respondents for Very Important
- n3 = Number of respondents for Important
- n2 = Number of respondents for Somewhat Important
- n1 = Number of respondents for Not Important
- A (Highest Weight) = 5
- N (Total number of respondents) = x

The researcher adapted the RII formula to two equations in order to determine the applicability and effectiveness of each CBAS. The two equations below were used to determine the Relative Applicability Index (RAI) and Relative Effectiveness Index (REI), respectively:

Relative Applicability Index (RAI) =

$$\frac{4\,n4+3\,n3+2\,n2+1\,n1+0\,n0}{A*N}$$

- n4 = Number of respondents for Extremely Applicable
- n3 = Number of respondents for Very Applicable
- n2 = Number of respondents for Applicable
- n1 = Number of respondents for Somewhat Applicable
- n0 = Number of respondents for Not Applicable
- A (Highest Weight) = 4
- N (Total number of respondents) = x

Relative Effectiveness Index (REI) =

$$\frac{4\,n4+3\,n3+2\,n2+1\,n1+0\,n0}{A*N}$$

- n4 = Number of respondents for Extremely Effective
- n3 = Number of respondents for Very Effective
- n2 = Number of respondents for Effective
- n1 = Number of respondents for Somewhat Effective
- n0 = Number of respondents for Not Effective
- A (Highest Weight) = 4
- N (Total number of respondents) = x

To ensure the validity and reliability of the quantitative questionnaire data, it was crucial to interpret the Relative Applicability Index (RAI) and Relative Effectiveness Index (REI) results alongside the qualitative interview outcomes. This integrated analysis enabled the assignment of a definitive ranking to the strategies, as presented in subsection 5.4 (Table 5.5). The following formula was used to calculate the Relative Applicability-Effectiveness Index (RAEI).

Relative Applicability-Effectiveness Index (RAEI) =

$$\frac{(RAI*REI)}{100}$$

- RAI = Relative Applicability Index
- RAI = Relative Effectiveness Index

2.1.3. ANSWERING SQ-C: PRACTICAL INSIGHTS AND SOLUTIONS

In addressing SQ-C, collaborative workshops were organized to reflect on the outcomes of answering SQ-A and SQ-B; therefore designing an adaptive reuse project accordingly.

The first workshop was facilitated by the researcher to engage participants in discussions based on the empirical data. In this workshop, the participants had the opportunity to share their perspectives on the applicability and effectiveness of the CBASs for an adaptive reuse project. The workshop's primary objective was to develop an initial design strategy, highlighting CBASs with potential for integration into the project. Further details are provided in Appendix D.

The second workshop was a design-focused session that served as a Research-through-Design (RtD) technique. RtD is a research methodology that employs design activities as a means of generating new knowledge and understanding based on design (Zimmerman et al., 2010). In this study, RtD was used to apply the insights and recommendations, the design strategy, generated from the first workshop to the ongoing project. The workshop enabled the practical implementation of design-oriented CBASs in the design of a circular adaptive reuse project, in order to test the applicability and effectiveness of the strategies.

Participants were engaged to collaborate and brainstorm, thereby reacting to design proposals and generating an action plan. Participatory research bridges the gap between research and practice, by actively including specific participants in the research process, which promotes knowledge sharing. (Bergold & Thomas, 2012). More details about the content of this workshop are available in Appendix E.

The findings from both workshops underwent theory-driven analysis, a method that employs a conceptual model or theory to direct the data analysis (Saunders et al., 2019). After each workshop, the outcomes were reported and sent to the participants.

2.2. DATA MANAGEMENT PLAN

Before each interaction with interviewees or participants, a form of consent was reviewed and signed by the professionals involved. This form of consent is included in Appendix F. Furthermore, a comprehensive data management plan, detailed in Appendix G, was developed to ensure proper handling of participant data throughout the project. This plan details the procedures for data collection, organization, secure storage, and publishing. The report outlines the data analysis methods, which included collecting data through transcripts and applying codes using Atlas.ti software. Data was securely preserved on a project drive with cloud backup, while the anonymized raw data was stored in a private, secure location. Upon publication, the study results included in the research report were made publicly accessible through a designated repository.

2.3. ETHICAL CONSIDERATIONS

Maintaining integrity was crucial not only in interactions with participants but also in upholding the standards of the scientific community. This study aimed to bridge the gap between theoretical concepts and the practical application of CBASs in adaptive reuse by exploring their applicability and effectiveness in real-world settings. To achieve this objective, various validation points were incorporated into the research methodology.

The literature review identified a framework with a list of CBASs, which were then validated through case studies involving practical projects. These case studies employed methods such as interviews and questionnaires to gather information on the implementation of CBASs. While the emphasis in case studies is on factual information, potential misinterpretation, especially in interview analysis, was acknowledged. To address this, the second validation point involved confirming findings with the interviewees during a design-workshop session. This served to validate case study results and initiate broader discussions with the participants. To safeguard participants and maintain transparency, the study objectives, methods, and data collection and processing procedures were clearly communicated. Participants were requested to provide consent, and they retained the option to withdraw their participation at any point during the ongoing research, prioritizing ethical considerations throughout the study such as reporting their data anonymously.

Chapter 3

Literature Review

3. LITERATURE REVIEW

3.1. OVERVIEW

The structure followed in creating the theoretical research framework was based on the key concepts that play a crucial role in exploring the applicability and effectiveness of circular building adaptability strategies (CBASs). With this objective in mind, the literature review centred its attention primarily on the circular economy (CE), adaptive reuse (AR), and circular building adaptability (CBA) along with its corresponding strategies. Figure 3.1 illustrates the interrelationships between the key concepts. The yellow marked box in the theoretical research model shows that this research mainly focused on the design-oriented, passive strategies.

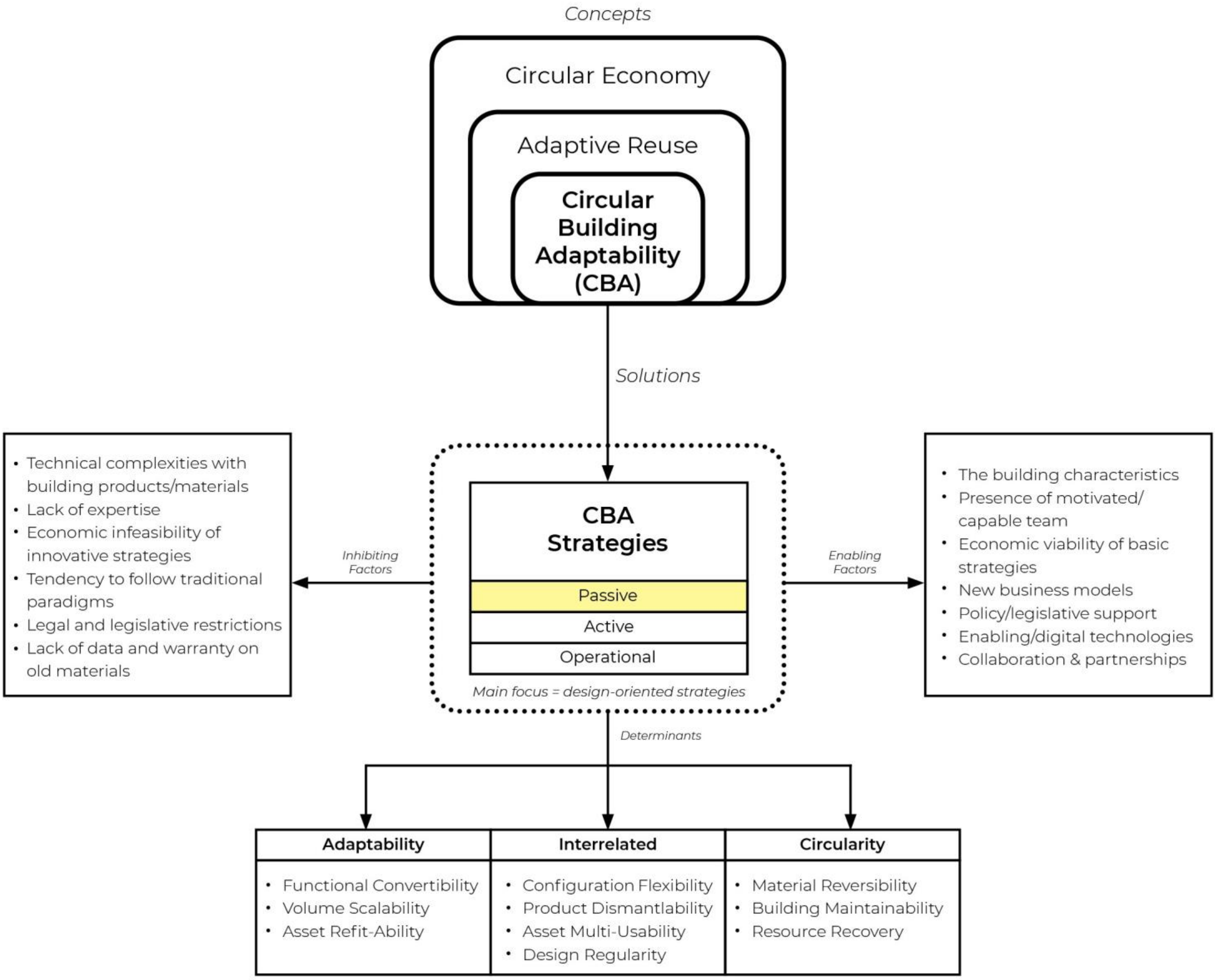


Figure 3.1: Theoretical research framework (adapted from Hamida et al., 2023)

3.2. DEFINING CIRCULAR ECONOMY (CE) AND ADAPTIVE REUSE (AR)

3.2.1. CIRCULAR ECONOMY (CE)

The pursuit of transitioning to a circular economy, serves as an example of fostering sustainability. It is a result of the realization that human activities have had a negative impact on the environment, causing ecosystem changes and habitat destruction that endangers human health. Within the context of the modern economic system, a linear product supply chain prevails, wherein natural resources are transformed into goods that consumers utilize and subsequently discard as waste (Foster, 2020). This linear model contrasts sharply with the CE supply chain, which is depicted in Figure 3.2.

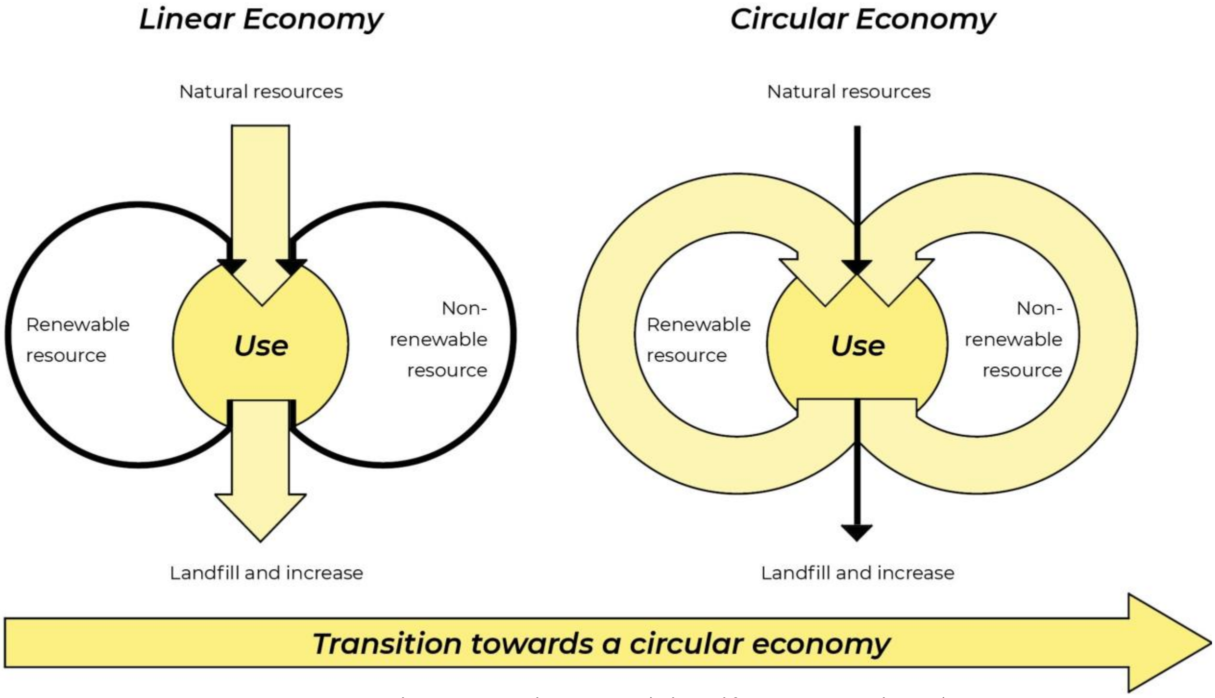


Figure 3.2: From a linear to a circular economy (adapted from Potting et al., 2017)

The CE seeks to address these challenges, with various schools of thought contributing to its conceptualization. However, better resource management and closed loops stand out as fundamental principles (Ellen Macarthur Foundation, z.d.). Given its significant environmental implications, the built environment plays a pivotal role in the CE, offering substantial opportunities to reduce energy consumption, greenhouse gas emissions, and waste generation (Pomponi & Moncaster, 2017).

The umbrella term CE encompasses a variety of tactics, strategies, and descriptions that play a role in shaping the relationship between humans and nature; however, a precise definition for this term remains difficult to find (Kirchherr et al., 2017). Even while closed-loop production and material consumption patterns are well understood, a more thorough explanation of the CE is necessary since depending just on these concepts is insufficient. This is why this research framed CE according to Foster (2020) who came up with the following definition:

"Circular Economy is a production and consumption process that requires the minimum overall natural resource extraction and environmental impact by extending the use of materials and reducing the consumption and waste of materials and energy'' (Foster & Kreinin, 2020).

The integration of the CE is essential within the building and construction sector, given its significant utilization of raw materials and its representation of human necessities for housing, communal interactions, and workplaces. Additionally, the built environment embodies fundamental aspirations for social inclusivity, community, and organizational structures. A CE promotes the use of renewable, non-toxic, and biodegradable materials that minimize life-cycle impacts. As a concept rooted in sustainability, embedding a CE within social structures is essential to enhance human well-being within the Earth's biophysical limits (Foster & Kreinin, 2020).

Foster (2020) highlights the environmental advantages of the CE, particularly in maximizing the use of embodied energy of materials in existing buildings, which refers to the total energy used during construction and operation (Hammond & Jones, 2008). To achieve the goal of maximizing embodied energy, the existing building stock, must undergo refurbishment and potential repurposing (Foster & Kreinin, 2020).

In the past, developers favoured demolishing buildings over reusing them, primarily due to the belief that demolition provided the optimal opportunity to maximize plot ratios. The common reason for demolition is the belief that the buildings needed to be replaced, especially if they were old or ineffective. However, there are signs of a changing perspective as evidenced by an increasing allocation of funds towards renovating and repurposing existing buildings, surpassing expenditures on new constructions. This shift indicates a growing popularity of the adaptive reuse concept (Bullen & Love, 2011b).

3.2.2. ADAPTIVE REUSE (AR)

Most buildings are initially constructed for specific purposes, but they frequently outlive these intended uses. This is where adaptive reuse becomes crucial, as it aims to repurpose buildings for new functions, embodying the essence of "change in use". This process is also known as conversion, across-use adaptation, or building transformation (Shahi et al., 2020; Wilkinson et al., 2014). Consequently, various definitions of AR revolved around the core idea of "performance change" or the transformation of a structure to serve a purpose different from its original design (Austin et al., 1988). This concept has historical origins with various definitions. One of the oldest definitions was formulated by Iselin & Lemer (1993), which defined adaptive reuse as *"Conversion of a facility or part of a facility to a use significantly different from that for which it was originally designed"*.

The new uses for which an old structure could be used is not something that could be determined with certainty. Old buildings had been adapted for a variety of mixed purposes, including residential, office, retail, market, cultural, and leisure (Mohamed et al., 2017). Given the appropriate circumstances, nearly any structurally sound building could be utilized as an adaptive reuse project, often involving significant modifications to its structural components (Conejos et al., 2011).

Finding a balance between incorporating environmentally friendly design principles and maintaining the building's historical character is an inherent challenge in adaptive reuse. Old buildings presented special difficulties because of the various construction techniques and materials that were used throughout the historical period and location of their production (Besten, 2023). Even while significant building renovations were expensive and resource-intensive, they were still more environmentally friendly than constructing new buildings. A variety of strategies could be used to balance the needs of limiting long-term environmental effects, energy efficiency, and early expenditures in order to successfully navigate this dilemma. Adopting a life-cycle approach to adaptive reuse lowered expenses and waste while improving the overall functionality of the structure (Bullen & Love, 2011a).

Additionally, the wasteful demolition and building process is avoided with adaptive reuse. This focus on reuse is in line with the principals of sustainable development, offering environmental advantages through reduced carbon emissions, energy savings, and the preservation of important old structures. Adaptive reuse has social and economic benefits in addition to environmental ones, which highlights its critical position in sustainable practices (Yung & Chan, 2012).

3.3. DESIGN AND DECISION-MAKING PROCESSES IN ADAPTIVE REUSE PROJECTS

There is an array of stakeholders engaged in the decision-making process of adaptive reuse projects. These stakeholders usually encompass, but are not limited to, investors, producers, marketeers, regulators, users, and developers (Wilkinson et al., 2014). Table 3.1 illustrates an overview of the diverse stakeholders integral to adaptive reuse projects, each wielding a distinct influence on the implementation process (Kurul, 2007).

Table 3.1: Brief description of the stakeholders involved in adaptive reuse (adapted from Wilkinson et al., 2014)

Stakeholder	Brief Description
Investor	Investors are those parties who supply the project with the financial resources, independent investors for example.
Producer	Producers are those professional parties who design, implement and manage the adaptive reuse projects, including architects, contractors and facility managers.
Marketer	Marketers are those who work to find a user for the adaptively reused buildings, such as sales managers in a real estate organization.
Regulator	Regulators are the local authorities which states the rules.
Policymaker	Policymakers are the government, whether local or state government.
Developer	Developers are organizations that merge all sectors in a partial manner or in an integrated one body, including the investment, production and marketing.
Users/ occupant	Users or occupants are the end user of the building, whether large organizations or individuals.

The process of adaptive reuse for buildings is influenced by variety of factors, including drivers, advantages, obstacles, and challenges that significantly influence the decision-making processes involved (Lardner et al., 2013). Relevant research to this study focused on modelling the information for these decision-making and design processes. A selection of these process-wise models regarding adaptive reuse projects are briefly discussed below.

3.3.1. A FRAMEWORK MODEL FOR AEC/FM KNOWLEDGE IN ADAPTIVE REUSE PROJECTS

Informing the involved AEC/FM practitioners in adaptive reuse projects about the project lifecycle and its functions is important for a successful project implementation. In this regard, Hamida and Hassanain (2021) developed a framework model for AEC/FM knowledge in adaptive reuse projects, which aimed to standardize the processes involved in adaptive reuse projects. The framework comprises four sequential processes, namely: *''assess the feasibility of the adaptive reuse project'', ''design the adaptive reuse project'', ''construct the adaptive reuse project'', and ''operate and maintain the adaptive reuse project''.* Hamida and Hassanain (2021) employed the $IDEF_0$ methodology to create the framework, in which processes were represented as nodes and interactions between them were illustrated with arrows to identify inputs, outputs, controls, and mechanisms of action. In Figure 3.3, the researcher of this study simplified each $IDEF_0$ model of the processes described in the paper and combined them to illustrate these process nodes and their activities.

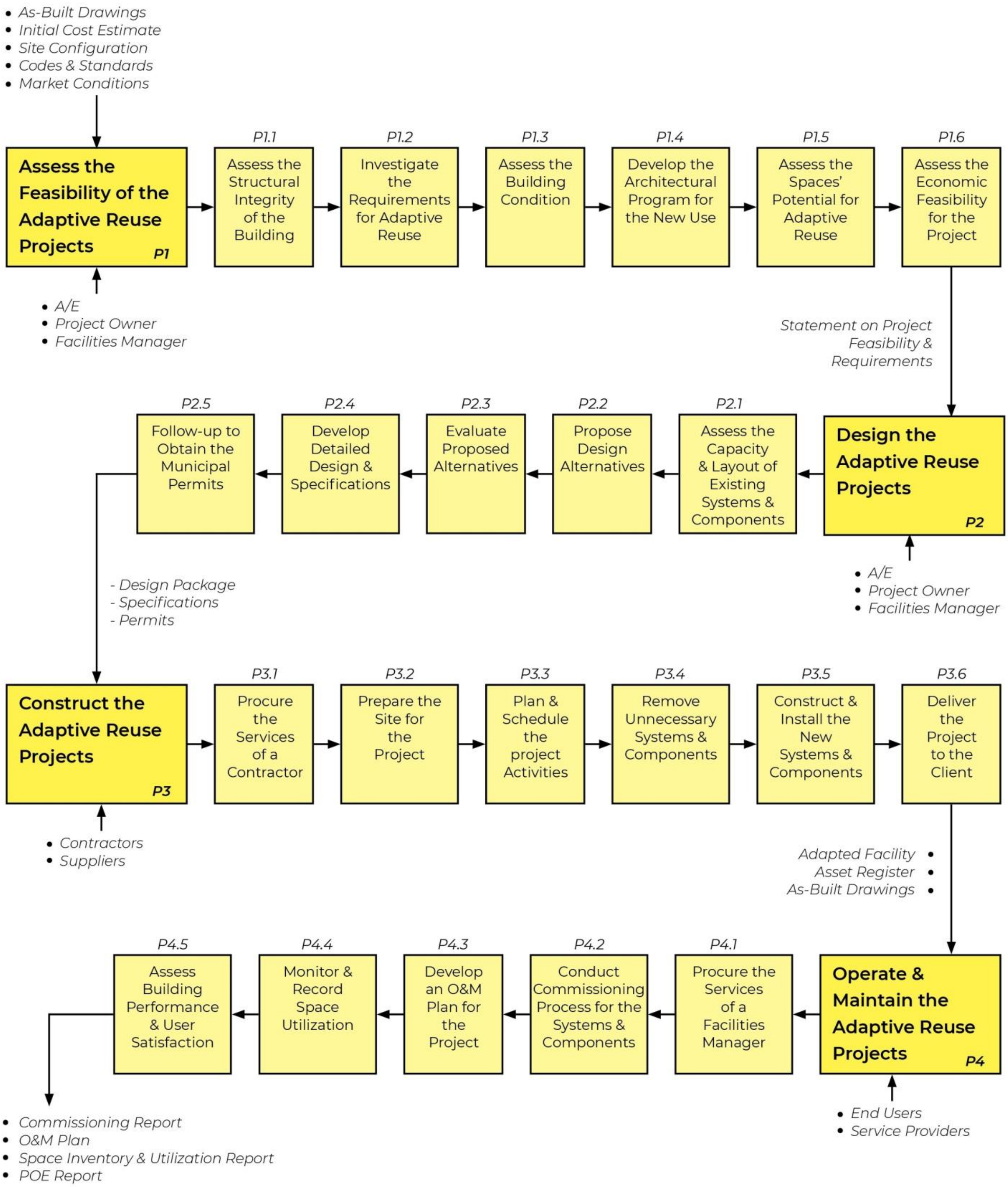


Figure 3.3: Framework model for AEC/FM knowledge in adaptive reuse projects (adapted from Hamida & Hassanain, 2021)

3.3.2. A DESIGN PROCESS MODEL BUILT FOR REUSE OF MONUMENTAL BUILDINGS

According to the process model of Yaldız & Gül (2013) for adaptive reuse projects, the process involves reprogramming and redesigning of the building spatial capacity in order to meet new function requirements. The authors developed a design process model which involves four stages of design process for adaptive reuse, namely: *''problem identification'','' synthesis'', ''decision (evaluation)''* and *''restoration project (final product)'' (*see Figure 3.4).

The first stage, *"problem identification"*, consists of two kinds of analysis. The first analysis in this stage is the information collection which involves researching the building and its environment. The second analysis in this stage is the goal setting which focuses on choosing an appropriate function, considering environmental, spatial, technical, and social factors. The second stage, *"synthesis"*, involves combining research findings to generate options for suitable functions for the building. The *"decision-making"* stage focuses on evaluating these options based on sustainability-related principles, originality preservation, and environmental impact; thereby leading to the selection of the most appropriate function. This decision-making process may involve feedback loops to refine options. Finally, the *"restoration project"* stage involves preparations based on the selected function, ensuring compatibility with the environment and conservation criteria (Yaldız & Gül, 2013).

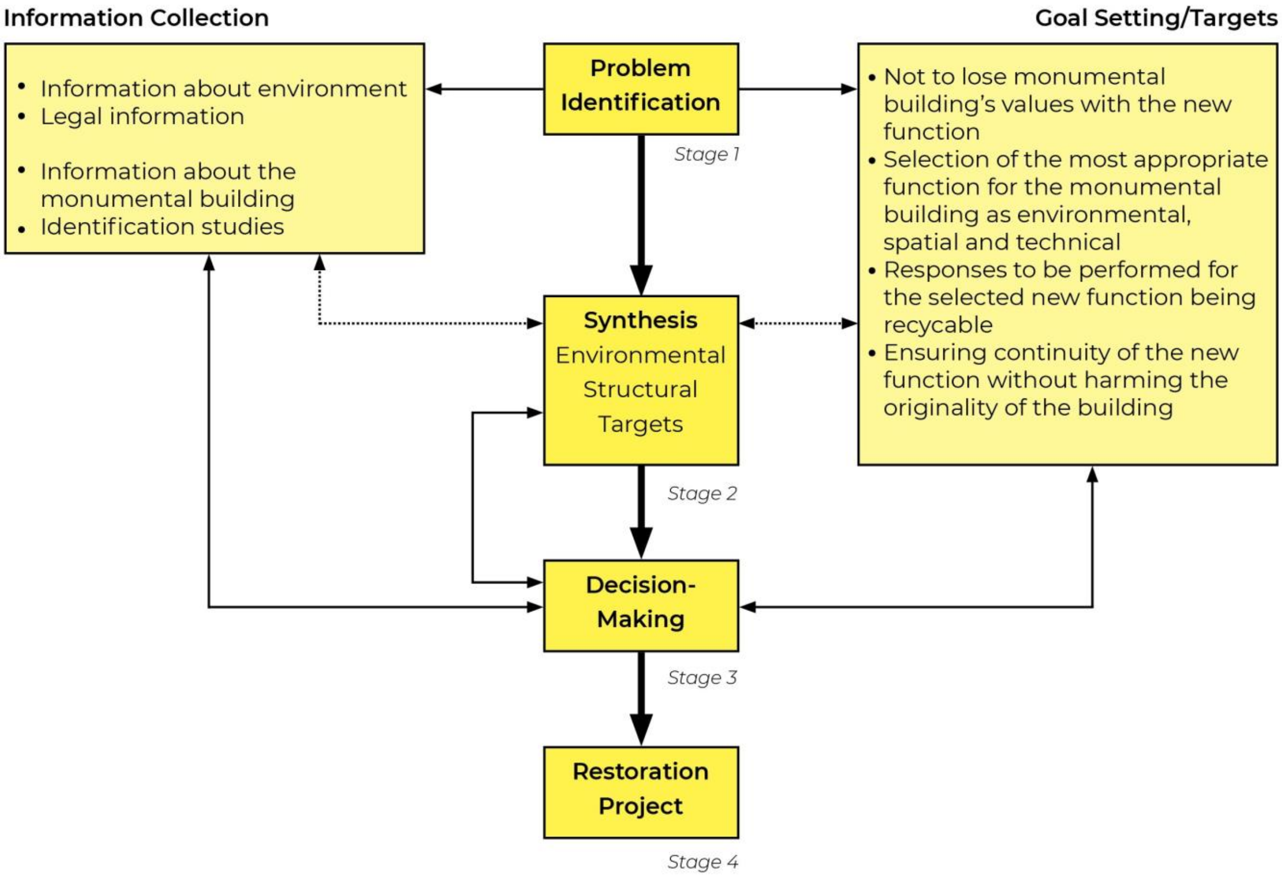


Figure 3.4: Design process model built for reuse of monumental buildings (adapted from Yaldız en Gül, 2013)

3.3.3. A MODEL FOR ADAPTIVE REUSE PROCESS OF HERITAGE BUILDINGS

Figure 3.6 depicts a developed model by Arfa et al. (2022) for the adaptive reuse process of heritage buildings. The model was developed as a means to preserve and enhance the values of these structures while adapting them for a change in use. As illustrated in Figure 3.5, the model systematically brings together ten steps, namely: *''initiative'', ''analysis'', ''value assessment'', ''mapping level of significance'', ''defining adaptive reuse potential'', ''defining design strategy'', ''final decision-making'', ''execution'', ''maintenance'',* and *''evaluation after years''.* These steps span across four main phases: *"pre-project"*, *"preparation"*, *"implementation"*, and *"post-completion"*.

In the initial pre-project phase, stakeholders are engaged, and the project's direction is established, often influenced by various interests that may either support adaptive reuse or propose demolition for profit. The preparation phase involves in-depth analysis, value assessment, and identifying the building's potential for reuse, setting the groundwork for an effective adaptive strategy. During this phase the goal is to identify an appropriate function for the heritage building and define design strategies, considering cultural-heritage values and other factors. These steps lead to final decision-making where stakeholders are convincing each other during negotiations. The post-completion phase, which includes maintenance and evaluation after years, is crucial for ensuring the longevity of the heritage building (Arfa et al., 2022).

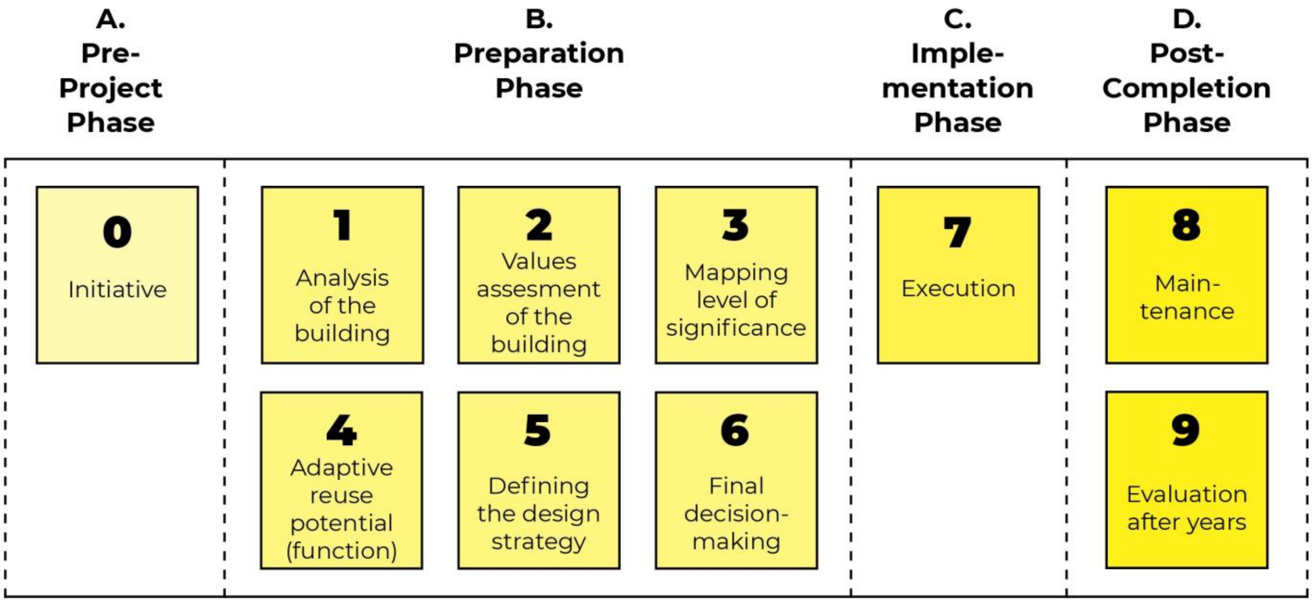


Figure 3.5: The 10-steps of the adaptive reuse process of heritage buildings (adapted from Arfa et al., 2022)

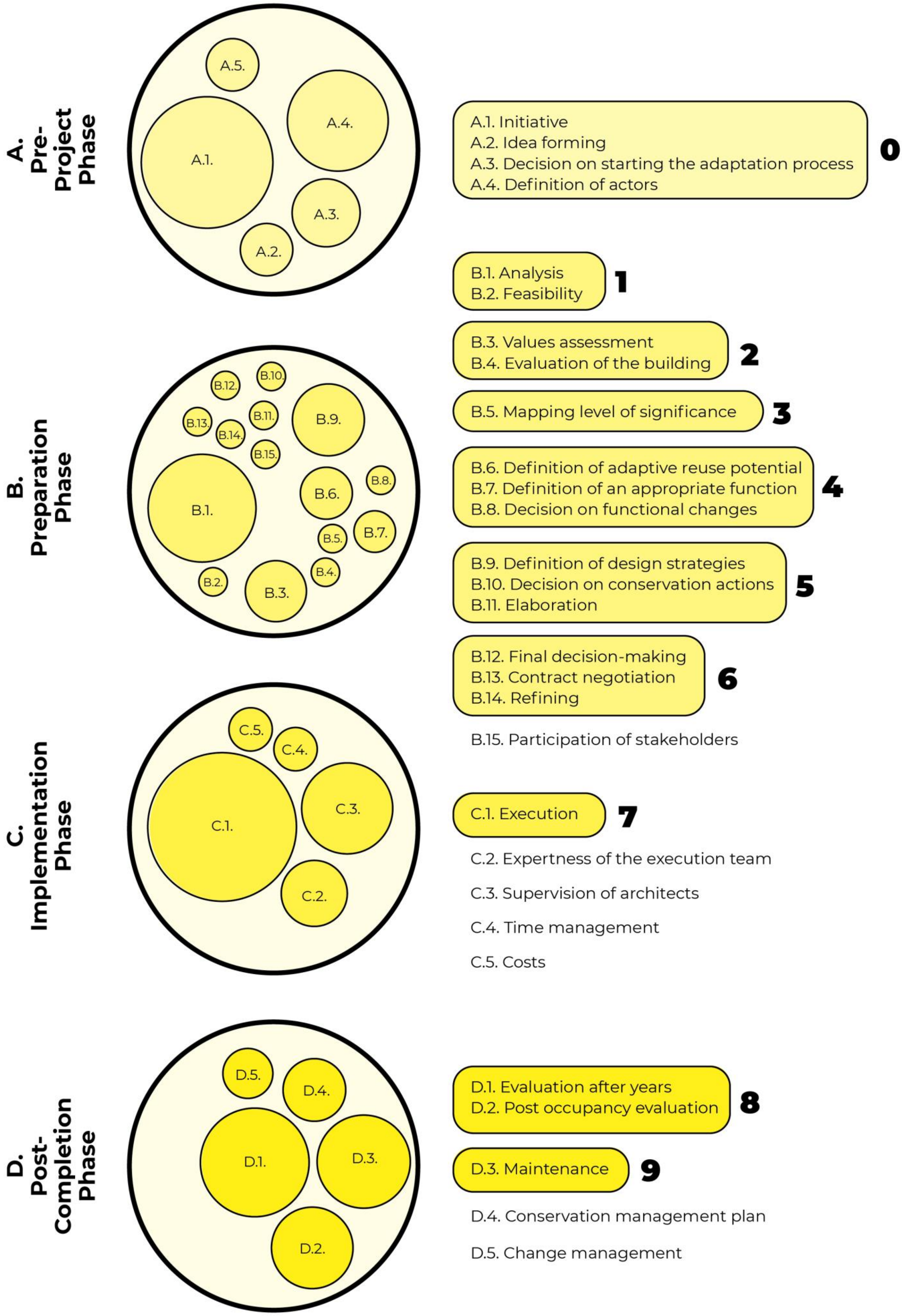


Figure 3.6: The model for an adaptive reuse process of a heritage building (adapted from Arfa et al., 2022)

Although buildings are usually thought of as static structures, they need to change in response to a variety of triggers, whether they be internal, external, or connected to the building itself (Kamara et al., 2020). This implies a continual need for adaptability to effectively address these changes (Slaughter, 2001). In order to fulfil future needs, it is projected that most current buildings will need to either proactively or reactively integrate adaptability in the following decades (Bullen, 2007). This means that both existing and new buildings ought to be designed to seamlessly accommodate future changes (Langston et al., 2014).

Building adaptability and adaptation align with the principles of the circular economy (CE) and a circular built environment (Ness & Xing, 2017). However Girard (2020) notes that placing adaptability solely within CE-oriented frameworks may overlook essential contextual dimensions. For this reason, it is necessary to bring circularity and adaptability together in a single framework, as shown in Figure 3.7 created by Hamida et al. (2022). Both concepts take into account the capacity to deal with the dynamics of the built environment and have the same goal of preserving the usefulness of buildings. While circularity analyses resource efficiency and reversibility within a closed-reversible value chain, adaptability involves developing changeability and functionality in light of contextual dynamics. Adaptability determinants involve design solutions that help with the physical and spatial changes in buildings. To make buildings more circular, half of these adaptability determinants are used along with interventions that control how resources are supplied, used, and reversed (Hamida et al., 2022).

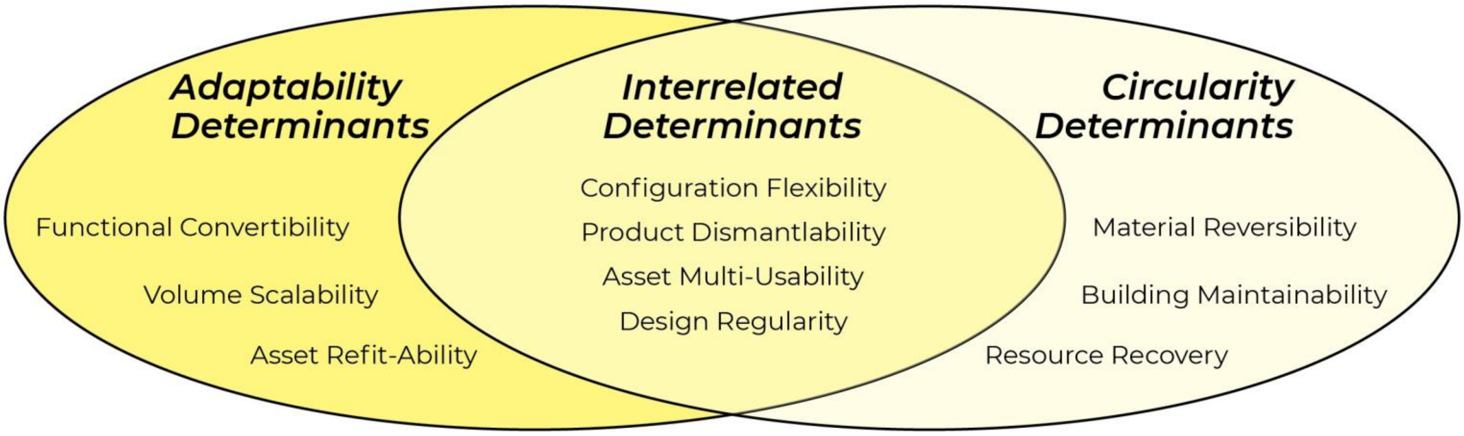


Figure 3.7: Circularity–adaptability interrelationship in buildings (Hamida et al., 2022)

Based on this analysis Hamida et al. (2022) defined a new emerging concept called circular building adaptability (CBA) in the following way:

''Circular building adaptability (CBA) is the capacity to contextually and physically alter the built environment and sustain its usefulness, while keeping the building asset in a closed-reversible value chain''.

The ten design and operation determinants that they found in their research were used to define this CBA concept. These ten determinants, depicted in Table 3.2, are pivotal to the incorporation and alignment of circularity and adaptability in building design and operation. These determinants are: ''configuration flexibility'', ''*product dismantlability*'', ''*asset multi-usability*'', ''*design regularity*'', ''*functional convertibility*'', ''*material reversibility*'', ''*building maintainability*'', ''*resource recovery*'', ''*volume scalability*'', and ''*asset refit-ability*'' (Hamida et al., 2022).

Table 3.2: Determinants of circular building adaptability (adapted from Hamida et al., 2023)

	Determinant	Brief Description
Adaptability	**1. Functional convertibility**	The capacity to repurpose the function of a building or part of it, so that promoting its longevity while keeping its value.
	2. Volume scalability	The capacity to increase and decrease the size of a building and its spaces in a response to the demands of user or organisation, so that alleviating the shortage and redundancy in the spatial use of the building.
	3. Asset refit-ability	The capacity to efficiently provide state-of-the-art building assets and technologies, while avoiding waste generation or over-invested solutions.
Interrelated	**4. Configuration flexibility**	The capacity to reconfigure the layout of spaces without using external resources and producing waste.
	5. Product dismantlability	The capacity to dismantle components and products in a building without inflicting damage and producing waste, so that they can be reused in the building or another building.
	6. Asset multi-usability	The capacity to offer a multiplicity of the use of building assets, so that maximising the efficiency of their utilisation.
	7. Design regularity	The capacity to provide a regular pattern in the spatial layout and composition of the physical assets in the building, so that facilitating the reuse and remanufacturing of the building components and products afterwards.
Circularity	**8. Material reversibility**	The capacity to efficiently provide, use and reuse the materials in the building within a reversible value chain.
	9. Building maintainability	The capacity to prolong the utility of the building assets and sustain their performance.
	10. Resource recovery	The capacity to regenerate the building resources in a manner that reduces the use of new materials and energy consumption.

3.5. CIRCULAR BUILDING ADAPTABILITY STRATEGIES (CBASs) AND ITS FRAMEWORK

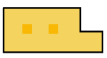
The identified ten determinants of CBA by Hamida et al. (2023) were based on an extensive review of the literature, case studies and a participatory study. Hence, there was a need to formulate a practical and evidence-based framework for circular building adaptability (CBA) to offer a methodological tool validated through empirical evidence. Such a framework would be beneficial for practitioners, enabling them to actively or reactively implement CBA in order to transform vacant and obsolete properties in a circular and adaptable manner (Hamida et al., 2022).

3.4.1. THE DESIGN-ORIENTED (PASSIVE) STRATEGIES

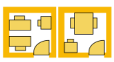
Nevertheless, the framework had some practical limitations since it hadn't been applied nor tested in real-world settings. Moreover, the circular building adaptability strategies (CBASs) that were found were associated with certain enabling and inhibiting factors without any prioritizing or ranking based on aspects like their applicability or effectiveness. For this reason, operational research became essential to assess the practical implementation of CBASs in real-world settings. This is why exploring the effectiveness and applicability of design-oriented CBASs served as a foundational step toward the development of buildings that embody circularity and adaptability. The fifteen design-oriented (passive) strategies are depicted in Table 3.3 and explained further in detail.

1. **Design Standardization:** This strategy involves creating uniformity in design elements across different parts of the building. By standardizing design aspects such as layout, materials, and architectural features, it becomes easier to implement future changes or renovations consistently and efficiently (Circubuild, 2021).

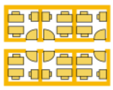
2. **Separation of the Building Layers (e.g. Separated Walls):** This strategy involves designing building components, such as walls, floors, and ceilings, in a way that allows them to be easily separated or disassembled without causing damage. By designing these layers to function independently, it allows for easier modification, replacement, or reconfiguration of specific building elements without affecting the entire structure (Bertino et al., 2021).



3. **Open the Floor Plan:** This strategy involves providing open floor plans that minimize the use of permanent parts or walls. This approach maximizes spatial adaptability, enabling users to adjust the arrangement of rooms or divide building layout according to changing needs over time (Vinke & Van Der Lubbe, 2014).

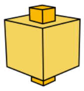


4. **Provision of Multi-Purpose Spaces:** This strategy involves designing spaces that can serve multiple functions or accommodate different activities. By providing areas that can be used for various purposes, the building becomes more adaptable to evolving user requirements without requiring significant structural modifications (Davison et al., 2006).



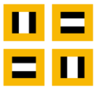
5. **Modularization of Spatial Configuration (Layout):** Modularization involves dividing the building into distinct and unitized modules. Modular design allows for scalability, customization, and efficient construction processes (Almashaqbeh & El-Rayes, 2021).

6. **Utilization of Standardized Building Products:** Involves selecting construction materials and components that adhere to common standards and specifications. This approach simplifies planning, procurement, and construction processes by ensuring compatibility and consistency across different projects. It essentially means using building elements that are produced according to established industry norms, making them easier to integrate and work with during construction (Aedes, 2023).



7. **Provision of a Core for Building Services:** Consolidating essential building systems, such as plumbing, electrical, and HVAC (heating, ventilation, and air conditioning), into a centralized core area within the building. This centralization simplifies maintenance, servicing, and access to these vital systems (Bhatia, z.d.).

8. **Design for Surplus Capacity:** Intentionally designing building systems and components to have additional capacity beyond current requirements. This surplus capacity allows for future expansion, upgrades, or modifications without the need for extensive renovations or replacements. Essentially, it's about building in extra room or capability to accommodate future needs and changes (Slaughter, 2001).



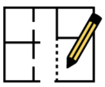
9. **Decentralization of the Design:** This strategy involves compartmentalizing various elements of a building's design to ensure that different areas or modules can operate independently. By organizing the building into distinct, self-contained units, each can be tailored and adjusted without affecting the functionality of others. This compartmentalization enables greater flexibility and adaptability in the building's usage, allowing it to respond more effectively to the diverse and changing needs of its occupants (Isaac et al., 2014).

10. **Design for Mixed-Use (Multifunctionality):** Designing for mixed-use involves incorporating diverse functions or activities within the same building or space. By accommodating multiple uses, such as residential, commercial, and recreational, the building remains adaptable to changing market demands and user preferences (Hamida et al., 2022; Szarejko & Trocka-Leszczynska, 2007).

11. **Utilization of Secondary (Reused/Recycled) Material:** Employing materials that have been previously used in other projects. This strategy emphasizes repurposing materials to give them a second life, thereby reducing waste and conserving resources. It aligns with principles of sustainability and environmental responsibility by minimizing the demand for new materials (Hobbs & Adams, 2017).

12. **Utilization of Biobased (Biological) Material:** This strategy focuses on utilizing renewable, biodegradable materials derived from natural sources, such as wood, bamboo, or straw. Biobased materials offer sustainable alternatives to traditional construction materials, contributing to the process of capturing and storing atmospheric carbon dioxide (WUR, 2023).

13. **Utilization of Circular (Reusable/Recyclable) Material:** Circular materials are those that can be reused, recycled, or repurposed at the end of their life cycle. By prioritizing the use of circular materials, the building contributes to a closed-loop system, where waste is minimized, and resources are kept in circulation (De Graaf et al., 2022).



14. **Alignment of the Interconnection Between the Floor Plans:** organizing the layout of a building to ensure a smooth and a spatially coordinated connections between different floors. This strategy aims to create seamless transitions between spaces, optimizing usability and functionality throughout the building (R Architecture, z.d.).

15. **Alignment of the Building Design with the Property Portfolio:** Designing a new building in a manner that complements and fits well with other existing buildings or properties owned by the same entity. This strategy ensures a cohesive and harmonious overall appearance across the property portfolio, facilitating efficient management and maintenance practices (Van Der Voordt et al., 2022).

Table 3.3: Fifteen design-oriented (passive) CBASs (adapted from Hamida et al., 2023)

Design-Oriented (passive) CBASs	Brief Description
1. Design Standardization	Make design elements consistent across buildings for easier future modifications.
2. Separation of Building Layers (e.g. Seperated Walls)	Design components like walls to be easily disassembled without damage.
3. Open Floor Plans	Create flexible layouts with minimal permanent structures.
4. Provision of Multi-Purpose Spaces	Design areas to serve multiple functions.
5. Modularization of Spatial Configuration (Layout)	Divide the building into units for easy assembly and rearrangement.
6. Utilization of Standardized Building Products	Use materials meeting common industry standards for compatibility and ease of use.
7. Provision of a Core for Building Services	Centralize essential systems like plumbing and HVAC for easier maintenance.
8. Design for Surplus Capacity	Design systems with extra capacity for future expansion.
9. Decentralization of the Design	Design self-contained units, allowing each to function independently.
10. Design for Mixed-Use (Multifunctionality)	Incorporate diverse functions within the building.
11. Utilization of Secondary (Reused/ Recycled) Material	Reuse/recycle materials from previous projects to reduce waste.
12. Utilization of Biobased (Biological) Material	Use renewable materials like wood for sustainability.
13. Utilization of Circular (Reuseable/ Recyclable) Material	Prioritize materials that can be reused/recycled to minimize waste.
14. Alignment of the Interconnection Between the Floor Plans	Ensure smooth transitions between different areas of the building.
15. Alignment of the Building Design with the Property Portfolio	Design new buildings to fit well with existing properties for a cohesive look and efficient management.

3.4.2. SIMPLIFIED FRAMEWORK

The framework developed by Hamida et al. (2023), depicted in Figure 1.1, brings together a practical set of strategies that promote CBA qualities together with factors that either facilitate or hinder them. It was created using the results of multiple case studies, earlier literature study and a participatory research approach. Within the framework, passive design strategies focus on promoting CBA through the building design, while active strategies involve solutions that enhance CBA through both building configuration and user intervention. Additionally, operational strategies embody process-oriented solutions that promote CBA (Hamida et al., 2023). Table 3.4 depicts a simplified version of the whole framework focusing only on the passive strategies described in Table 3.3.

Table 3.4: Simplified version of the whole framework (adapted from Hamida et al., 2023)

			15 Design-Oriented (passive) CBASs														
			1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.
Determinants of Circular Building Adaptability	*Adaptability*	Functional Convertibility					x		x	x	x	x					
		Volume Scaleability		x	x					x						x	
		Asset Refit-Ability								x	x						
	Interrelated	Configuration Flexibility	x	x	x												x
		Product Dismantlability	x	x													
		Asset Multi-Usability				x											
		Design Regularity	x				x	x									
	Circularity	Material Reversibility											x	x	x		
		Building Maintainability															
		Resource Recovery											x				
Enabling & Inhibiting Factors	*Enablers*	The Building Characteristics	x	x	x	x	x	x	x	x	x	x	x				
		Presence of Motivated/Capable Team										x	x		x		
		Economic Viability of Basic Strategies											x				
		New Business Models															
		Policy/Legislative Support										x	x		x		
		Enabling/Digital Technologies															
		Collaboration & Partnerships													x		
	Inhibitors	Technical Complexities with Building Products/Materials	x	x	x	x	x	x	x	x	x		x				
		Lack of Expertise											x		x		
		Economic Infeasibility of Innovative Strategies								x		x	x				
		Tendency to Follow Traditional Paradigms										x	x		x		
		Legal and Legislative Restrictions				x						x	x	x	x		
		Lack of Data and Warranty on Old Materials											x				

3.6. SUMMARY

The circular economy was recognized as a transformative approach for the built environment, aiming for a shift from traditional linear consumption patterns towards a more sustainable model. Adaptive reuse is in line with CE as it facilitates repurposing existing buildings to meet new uses. Circular building adaptability (CBA) refers to:

"The capacity to contextually and physically alter the built environment and sustain its usefulness, whilst keeping the building asset in a closed-reversible value chain" (Hamida et al., 2023).

In other words, CBA is a way to promote the circularity of the built environment through adaptive reuse. By promoting CBA in adaptive reuse, buildings could be designed and operated in a way that maximizes their lifespan, reduces waste and emissions, and enhances their flexibility and adaptability. This can contribute to the transition to a circular economy, where resources are used more efficiently and waste is minimized. Therefore, promoting CBA in adaptive reuse can provide different benefits to the built environment, including long-lasting functionality and material reversibility (Hamida et al., 2023).

The determinants, on the other hand, are the underlying principles and values that guide the development and implementation of the strategies and are crucial in ensuring that buildings can be effectively adapted or repurposed within the CE context. Central to these concepts are the circular building adaptability strategies (CBASs), which are the specific actions that can be taken to promote CBA, while the inhibiting and enabling factors are aspects that can either hinder or facilitate the implementation of these strategies. Through the implementation of design-oriented (passive), active, and operational strategies, the CBASs play a crucial role in operationalizing these determinants, emphasizing the significance of thoughtful design in enhancing building adaptability.

Subsection 3.3 highlighted the design and decision-making processes in adaptive reuse projects, emphasizing the importance of a systematic method to integrate circular economy principles. The design-oriented part of the CBA-AR framework can be applied effectively in various planning- and design-related phases of adaptive reuse projects. Specifically, it can be utilized during the pre-project phase of assessing the feasibility of the adaptive reuse project, where the framework can help evaluate the project's potential and sustainability. Additionally, during the preparation phase, the framework aids in integrating circular principles into the design process, ensuring the reuse and conservation of materials and resources.

Chapter 4

Overview of the Case Studies and their Informants

4. OVERVIEW OF THE CASE STUDIES AND THEIR INFORMANTS

4.1. SELECTION CRITERIA

The phenomenon of interest in this research was the applicability and effectiveness of CBASs in adaptive reuse projects within the Dutch built environment. When defining a phenomenon of interest in case study research, it is important to consider the context and boundaries of the research case (Meyer, 2001). Contexts are the factors that interact with the phenomenon of interest, which cannot be completely controlled by researchers (Yin, 2009). Different contexts were considered in this study, by including different building typologies such as medical, commercial, educational and residential. Furthermore, different triggers for adaptive reuse were considered, namely vacancy, obsolescence and change of user. Other criteria that were considered when choosing the cases were the stage of completion, location, monumentality and scale. A list of the cases with brief descriptions and the selection criteria is shown in Table 4.1.

Table 4.1: Case study projects and selection criteria (own work, 2024)

Case	Brief Description	Criteria
C1	*Bloemendaal - realised* The first psychiatric hospital in the Netherlands transformed into a residential community for the higher segment.	**Scale:** Total of 14.600 m^2. **Monumentality:** yes **Trigger:** vacancy, obsolescence and change of owner
C2	*Amsterdam - realised* An educational building transformed into offices. During the transformation, a possible change of function to residential was also taken into account.	**Scale:** Total of 470 m^2 **Monumentality:** no **Trigger:** vacancy and change of owner
C3	*Alkmaar - realised* A former commercial building transformed into a mixed-use complex with commercial and residential functions.	**Scale:** Total of 520 m^2 **Monumentality:** only front façade **Trigger:** change of owner
C4	*Westland - ongoing* Transformation of an educational building into a residential complex intended for housing seniors and young people with care needs.	**Scale:** Total of 4210 m^2 **Monumentality:** yes **Trigger:** vacancy and change of owner

4.2. DESCRIPTION OF THE EXPLORED CASE STUDIES

4.2.1. CASE 1 (C1)

Figure 4.1: Old situation C1 (C.V. C van Bloemendaal et al., 2017)

Figure 4.2: Aerial photo after completion (Heilijgers, 2024)

C1 was constructed in 1844 and is located at the edge of the Bloemendaal dunes, connected to National Park Zuid-Kennemerland. Figure 4.1 depicts the building designed by J.D. Zocher Jr., which housed the first Dutch psychiatric hospital (MOOI Noord-Holland, 2020). The hospital was originally based on a central courtyard and surrounded by four masses, but it has since been expanded to include a catholic chapel, a theatre, and a bell tower, all while remaining true to Zocher's architectural vision (C.V. C van Bloemendaal et al., 2017).

The building became vacant in 1996, and consequently, it was transformed into a residential complex while preserving its historical essence. Figure 4.2 illustrates the redevelopment plan with a total area of 14,600 m², which includes thirty-eight homes and five flats. The original façade and corridors have been maintained. Modern elements, such as metal conservatories are provided to enhance the building functionality and its aesthetics (C.V. C van Bloemendaal et al., 2016).

4.2.2. CASE 2 (C2)

C2, shown in Figure 4.3, is located in Amsterdam. It was adaptively reused from an educational facility to a modern commercial building. The building was constructed in 1961. The total floor area of the building is 471 m², while the plot area is 886 m². The building was designed by L.J.G.M. van Steenhardt Carré and J.M. van Daal to serve educational purposes. The building was used as an educational facility until 1986 (Tholens & Van Steenhardt Carré, 2002).

Figure 4.3: Old situation C2 (Stadsarchief Amsterdam, 1953–1955)

The school was relocated in 1986, and therefore, the building turned to be vacant. A security company acquired the vacant building and transformed it to commercial use in 1995 (Komijn, 2014). Figure 4.4 shows the current situation. The current owner of the building adopted resource-efficiency measures such as using recycled materials, energy-efficient systems, open floor plans, and sustainable waste management (Mulderblauw Architecten, 2010). The new user also promoted future adaptability by incorporating features for potential residential conversion.

Figure 4.4: Current situation after redevelopment (own photo, 2024)

4.2.3. CASE 3 (C3)

C3, depicted in Figure 4.5, is located in Alkmaar. It had been used for commercial purposes, including retail spaces on the ground floor and other stores and offices on the upper floors. In 2021 the building was transformed into a mixed-use building. The current functional use of C3 consists of residential and commercial spaces. In the 17th and 18th century, the building underwent renovations (Regionaal Archief Alkmaar, z.d.).

Figure 4.5: Front (left), continuing to the back (right) (Regionaal Archief Alkmaar, z.d.)

In the 1960s, significant renovations were carried out, preserving only the structural walls and part of the front façade, which led to the loss of most of the building's original monumental interior elements. The backside of C3 includes a shared entry leading to an internal courtyard, which provides access to seven apartments and shared outdoor spaces (Up Architecture, z.d.). The commercial use of C3 incorprates shops into the building as an experiential activity, with integrated dining options that complement the retail environment. Figure 4.6 shows the current redevelopment of C3, covering a total area of 520 m².

Figure 4.6: Current redevelopment of C3 (own photos, 2024)

4.2.4. CASE 4 (C4)

C4, depicted in Figure 4.7, is an educational building located in Westland. Designed by architect P.N. de Bruijn and built in 1955, the building is recognized as a monumental structure from the post-World War II era. The building was constructed using durable materials such as wood and brick, featured an L-shaped layout, internal yards, and large windows for natural light (Bouwer, 2017). To meet changing educational needs, the building underwent four expansions in 1983, 1987, 1994, and 2002, respectively. These expansions introduced new facilities while preserving the building's original architectural style.

Figure 4.7: Current situation of C4 (Omgevingsloket, 2023)

After nearly 65 years, the school closed due to its relocation. In 2019, a redevelopment plan was introduced, which largely preserves the original identity of the building. The building's new purpose will be residential, providing housing for vulnerable groups, including individuals with disabilities and the elderly (Omgevingsloket, 2023). The current redevelopment of C3 spans a total area of 4.120 m². It is worth noting that C4 is used in this research as an experimental case.

4.3. KEY INFORMANTS

The selection of interviewees was guided by the involvement of key informants who had implemented circularity and adaptability in the case study projects, ensuring both the availability and reliability of the data collected. During the archival research, documents such as construction meetings, project descriptions, and contracts were reviewed to identify the professionals who influenced the development of the case study projects. Consequently, circular building adaptability strategies (CBASs) were identified through the lens of professionals who integrated circularity and adaptability in the adaptive reuse projects. Table 4.2 provides an overview of the interviewees and their professional background. The next chapter, presents a within- and a cross-case analysis of the aforementioned cases.

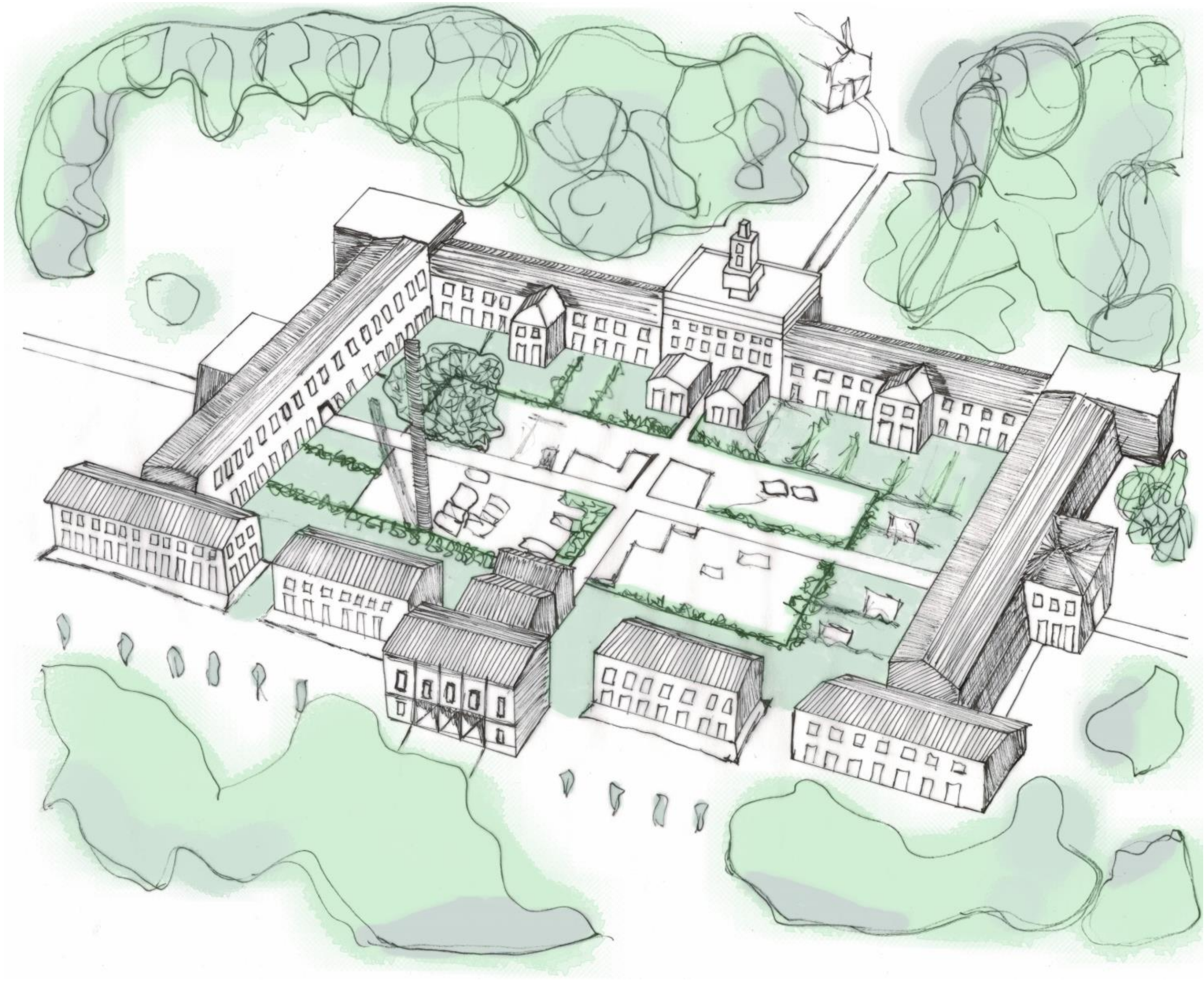
Table 4.2: Key informants of each case study (own work, 2024)

Case 1	Case 2	Case 3
1. FH - Contractor	**6.** AB - Architect	**11.** HH - Circularity Expert
2. HvM - Sub-contractor	**7.** DD - Technical Architect	**12.** NJ - Contractor
3. PS - Architect	**8.** EB - Project Manager	**13.** RJR - Architect
4. RT - Construction Engineer	**9.** RvD - Developer	**14c.** MS - Owner Developer
5. RB - Landscape Architect	**10.** WK - Architect	
14a. MS - Owner Developer	**14b.** MS - Owner Developer	

Chapter 5

Results of Empirical Research

C1



5. RESULTS OF EMPIRICAL RESEARCH

This chapter discusses the results of the explored case studies, including a within-case analysis as well as a cross-case analysis. Subsections 5.1 to 5.3 correspond to the tables in Appendix C, which present the survey findings for each case. These tables provide Likert scale ratings from the key informants listed in Table 4.2, covering all 15 circular building adaptability strategies (CBASs). Subsequently, the subsections elaborate on the implementation of the 15 design-oriented CBASs in each case study, including an analysis of the factors that enabled or hindered their implementation, followed by an evaluation based on the survey findings. Subsection 5.4 presents a cross-case analysis, comparing the three different cases with each other.

5.1. WITHIN CASE ANALYSIS OF C1

5.1.1. DESIGN STANDARDIZATION

The original layout of C1 with dormitories, dining halls, and treatment rooms, along with the corresponding window structure, was standardized for the new residential design. Interviewee 3 stated: *''Design was approached as a non-standard process but with standard dimensions to ensure flexibility within the homes"*. To enhance comfort in the homes, new windows were installed fitting the existing structure, as seen in Figure 5.1. Aluminium frames with a profile covering the reveals were designed. Interviewee 3 noted: *''This detail could be developed because it was replicated 150 times, creating a kind of standard that could also be used in future projects"*.

Additionally, standard sketches and floor plans were provided at the sale for buyers to customize the basic design, allowing adjustments to floors, stairs, and layouts. Interviewee 3 stated: *''The 6.5-meter high ceilings allowed flexible room configurations, giving residents the freedom to personalize their living spaces''*.

Figure 5.1: Façade view of the main building (C.V. C van Bloemendaal et al., 2016)

This strategy was facilitated by the building characteristics, specifically because interviewee 3 explained that existing structures like corridors and bathrooms could be reused for new purposes. According to interviewee 1, the economic viability of basic strategies was another factor, where the choice to standardize the window structure not only saved costs but also shortened construction time and increased efficiency.

Based on the findings, the technical complexities with building products and materials was an inhibiting factor. Interviewee 4 stated: *''Standardizing elements in [name of C1] was challenging due to the building's non-uniformity, requiring a customized approach tailored to its specific conditions''*. Interviewee 4 explained further that structural elements like poles and reinforcements were handcrafted and adjusted on-site. Concrete was delivered by truck and poured, while wall openings were manually created.

Two interviewees from this case rated the applicability of this strategy as "extremely applicable", while one rated it as "very applicable", one ''applicable'' and two ''somewhat applicable''. Regarding the effectiveness, four interviewees rated this strategy as ''extremely effective'', while one interviewee rated it as ''effective'' and one rated ''somewhat effective''.

5.1.2. SEPERATION OF BUILDING LAYERS

In C1, the partition walls were prefabricated elements that divided long corridors into apartments, allowing for vertical splitting. Interviewee 1 stated: *''This was done by gluing prefabricated ceramic blocks into walls, which were then placed in slots cut into the roof and floors and then stacked''*. Although the prefabricated walls were lifted through the roof using cranes, they can potentially be removed if needed.

Furthermore, the use of demountable structures in the newly built part, as shown in Figure 5.2, illustrates another method of construction where the new elements were separately added to the existing building using dry connections with the original structure. Interviewee 2 stated: *''When adding to monumental buildings, it is essential to consider the possibility of later removal of these additions without damaging the original monument''*.

Additionally, another construction method employed in C1 was the box-in-box construction, where the exterior of the building was retained while a new structure was placed inside. Interviewee 2 mentioned: *''This method protects the historical value of the original building and allows for flexibility in future modifications''*.

Figure 5.2: Newly built part (right) and existing part (left) (own photo, 2024)

This strategy was facilitated by its economic viability and collaboration between different project stakeholders. Diverse actors, including an architect, landscape architect, developer, contractor, and municipal representatives, initiated their collaboration at an early stage. Initially, the plan was to build the walls on-site. However, it was concluded that prefabricated walls are more cost-effective and faster in delivery. Interviewee 3 stated: *''The focus was less on the reversibility of the construction and more on cost-efficiency and practical feasibility''*.

Interviewee 3 indicated that the technical complexities with building products and materials was an inhibiting factor, specifically in removing prefabricated walls as they are glued together and require sawing for separation, complicating future modifications. Similarly, interviewee 4 stated: *''Dismantling existing masonry walls and old wooden floors is challenging, with removal only possible through cutting''*.

One interviewee from C1 rated the applicability of this strategy as "very applicable", while four rated it as "applicable" and one ''somewhat applicable''. Regarding the effectiveness, four interviewees rated this strategy as ''very effective'', while two interviewees rated it as ''effective''.

5.1.3. OPEN THE FLOOR PLAN

The spatial configuration, shown in Figure 5.3, featured three floors with high ceilings, including only the partition walls and stairs. Interviewee 3 stated: *''The floor plans were entirely open and flexible, providing an investor with the possibility to arrange the spaces as they wish''*. Buyers could add light partition walls themselves, allowing flexibility in determining the number of bedrooms and other layouts.

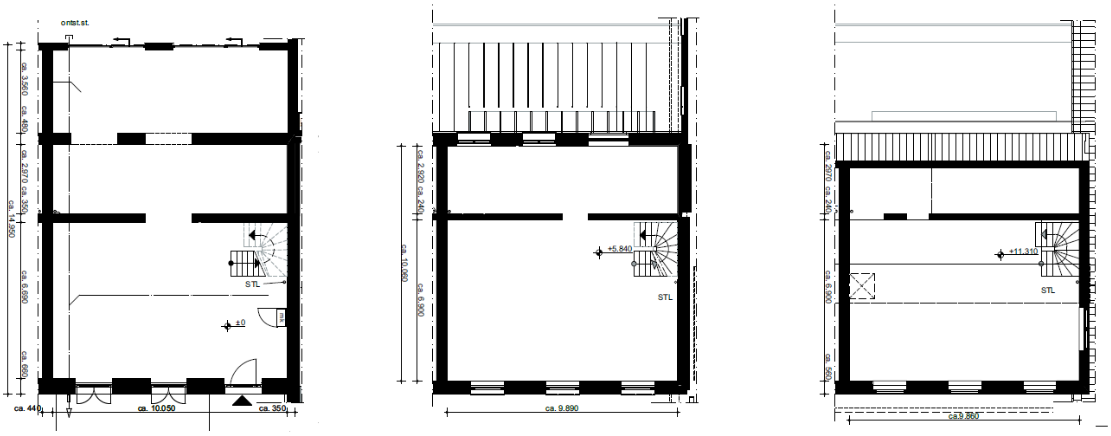


Figure 5.3: Floor plans of a house (Heiko Hulskar Architecten, 2016)

Interviewee 3 stated: *''It is crucial to design floor plans early by mapping out the existing structure and then puzzle over how to transform them into new, well-functioning layouts''*. Interviewee 3 further explained that digital technologies offer an alternative to manual measurements. Interviewee 3 stated: *''By scanning the entire building during a walkthrough, detailed 3D models are created, which can then be utilized in design software''*.

Implementing this strategy in C1 was challenging due to legal, legislative and physical restrictions involving agencies, such as the Cultural Heritage Agency. Interviewee 3 stated: *''The process of creating the open floor plans was complex due to the monumental corridor that couldn't be demolished in the existing structure''*.

According to interviewee 4, another common issue was the technical complexities with building materials, specifically accounting for downward forces. Interviewee 4 stated: *''Structural adjustments might be necessary when using a column-based design to ensure that the overhead structure remains safe and stable''*. These adjustments are essential to prevent any risk to the building's structural integrity, while also allowing the space below to remain open and adaptable for different purposes.

In C1, one interviewee rated the applicability of this strategy as "extremely applicable", four as "very applicable", and one as "applicable". In regards to its effectiveness, two interviewees rated the strategy as "extremely effective", three "very effective", and one "effective".

5.1.4. PROVISION OF MULTI-PURPOSE SPACES

After purchasing C1, the focus was on restoring the façade, waterproofing the building, and strengthening the walls. The design was then updated as new requirements and users emerged. Interviewee 1 stated: *''Because of the structural delivery, the buyers basically received a large empty space, which was ideal for interior designers to create something unique''*. This structural delivery is depicted in Figure 5.4. Residents could also arrange their own backyards as they wished, while the outer edge facing the public landscape remained multifunctional and open without property boundaries.

The building's characteristics facilitated this strategy, as the old brick walls spaced approximately 7 meters apart in one direction and 8 meters in the other, totalling an area of 50-60 m^2. Interviewee 4 stated: *''This gave buyers a lot of freedom to arrange the spaces according to their wishes''*.

Another enabling factor was the economic viability of basic strategies, illustrated by the marketability of the building. Interviewee 3 stated: *''Rather than aiming for maximum density, the developer chose to create luxury homes that better suited the market, which resulted in increasing the attractiveness of the building''*.

The technical complexity of building materials was a challenge faced during the implementation of this strategy. The functional change has influenced the building's physical properties and indoor environmental quality (IEQ) performance. More specifically, this alteration led to a high humidity ratio inside the buildings. Interviewee 2 stated: *''When modifying a building's function or designing multi-purpose spaces, it is essential to carefully assess the impact on the structure and indoor environmental quality (IEQ). Proper adjustments must be made to prevent potential issues and ensure the space remains functional, safe, and comfortable''*.

Figure 5.4: Cross section of a house (Heiko Hulskar Architecten, 2016)

In C1, two interviewees rated the strategy as "extremely applicable", two as "very applicable", and two as "somewhat applicable". Regarding its effectiveness, two interviewees rated the strategy as "extremely effective", three as "very effective", and one as "effective".

5.1.5. MODULARIZATION OF SPATIAL CONFIGURATION

In C1, the modularization of spatial configuration was manifested by how the individual homes are configured, as shown in Figure 5.5. Interviewee 1 stated: *''Each home is a module and in theory, you could empty an entire home and replace it with a new one''*.

The findings did not identify a specific enabling factor connected to this strategy. However, interviewee 4 indicated that in new construction projects, modularization can be effectively applied by stacking elements such as sanitary blocks. Interviewee 4 stated: *"[name of C1] is an existing building with a solid structure, making modularization more difficult''*.

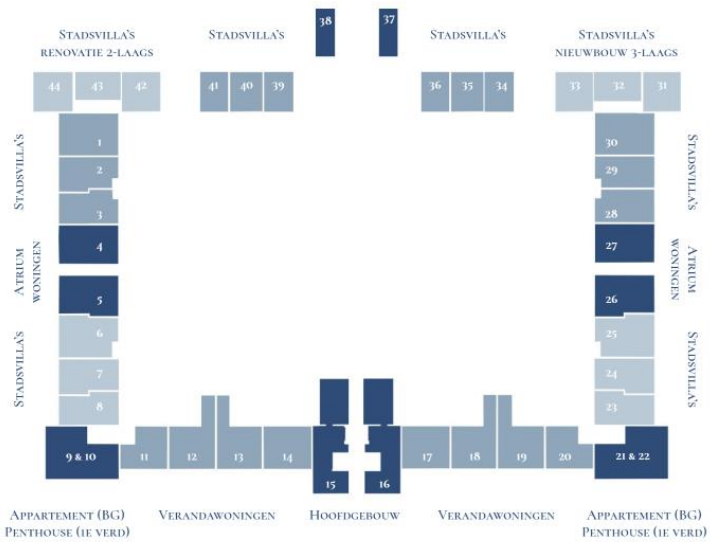


Figure 5.5: The quantity and type of housing (C.V. C van Bloemendaal et al., 2016)

Inhibiting factors related to this strategy include technical complexities with building products and materials due to the need for customization and structural constraints in existing buildings. Interviewee 4 stated: *’’Modularizing elements in existing buildings is limited and often requires modifications such as removing load-bearing walls and installing steel portals for structural support and create space for new functions’’*.

One interviewee rated the applicability of this strategy as "very applicable", two as "applicable", two as "somewhat applicable", and one as "not applicable". Regarding its effectiveness, three interviewees rated the strategy as "very effective", one as "effective", and two as "not effective".

5.1.6. UTILIZATION OF STANDARDIZED BUILDING PRODUCTS

In C1, the installed roof panels, steel columns, HE profiles, and prefab walls are standardized products. The walls are compatible with the building dimensions and they meet the requirements of acoustics and fire safety.

The building's characteristics significantly influenced the choice of prefabricated walls. Interviewee 1 stated: *"In this existing building, stacking the blocks on-site with a crane was difficult, so using prefabricated walls was a practical solution’’*. Additionally, the presence of a motivated and capable team facilitated this strategy, as the developer proposed using high-quality, heavy, stone-like partition walls.

Technical complexities with building products and materials is considered as an inhibiting factor related to this strategy. Interviewee 4 stated: *‘’Using standardized building products in an older structure like [name of C1] can be challenging due to physical constraints in the original design’’*.

One interviewee rated the applicability of this strategy as "extremely applicable", another as "very applicable", and four as "applicable". Regarding its effectiveness, one interviewee rated this strategy as "extremely effective", three as "very effective", one as "somewhat effective", and one as "not effective".

5.1.7. PROVISION OF A CORE FOR BUILDING SERVICES

In C1, the building layout was designed with centrally placed bathrooms and ventilation grilles to create a vertical stack with shafts running from bottom to top. Additionally, meter boxes and a sewer connection point were provided on the ground floor. Interviewee 3 stated: *"The installations were centrally arranged, but residents had the freedom to add extras, like solar panels"*.

This strategy was enabled by its economic viability. Interviewee 4 mentioned that placing toilets centrally requires parallel pipe installation; otherwise, detouring the pipes would require additional structural openings and increase the risk of clogging.

A hindrance to this strategy was the lack of data and warranty on old materials, as rapid aging of installations complicates repurposing. Interviewee 2 stated: *"Innovations in installation and energy technology can quickly become outdated, limiting the sustainability and relevance of solutions"*.

One interviewee rated the applicability of this strategy as "very applicable", three as "applicable", one as "somewhat applicable", and two as "not applicable". Regarding its effectiveness, three interviewees rated the strategy as "effective", one as "somewhat effective", and two as "not effective".

5.1.8. DESIGN FOR SURPLUS CAPACITY

There was a plan to provide an underground parking in the building. However, this plan was cancelled due to the low structural capacity of the foundation. Instead, the foundations were reinforced to enable the addition of multiple layers to the building in the future. This solution aligns with the strategy of designing for surplus capacity. Interviewee 1 stated: *"Although the building was not specifically designed for additional loads, the new foundation provides a certain safety margin"*.

This strategy was enabled by the presence of a motivated and capable team, as a thorough investigation of the technical condition determined the necessary restoration measures. Another enabling factor was the economic viability of basic strategies, such as cost-saving measures like avoiding an underground parking garage.

Technical complexities with building products and material were a significant inhibiting factor, as the foundation on dune sand led to subsidence and cracks, necessitating structural intervention with approximately five hundred steel piles filled with concrete. Figure 5.6. shows the situation during reinforcement works. Additionally, adding stories requires the entire structure, including existing walls, columns, and wooden beams, to bear the additional load and transfer the forces to the foundation.

The economic infeasibility of innovative strategies also impacted the addition of more layers due to the high costs associated with reinforcing the entire structure. Interviewee 3 stated: *"Circular choices may be more expensive initially, but the return on investment can be attractive in the long term"*.

Furthermore, legal and regulatory constraints prevented the approval of adding extra layers.

Two interviewees rated the applicability of this strategy as "very applicable", one as "somewhat applicable", and three as "not applicable". Regarding its effectiveness, one interviewee rated the strategy as "extremely effective", one as "very effective", one as "effective", two as "somewhat effective", and one as "not effective".

Figure 5.6: Before situation of the foundation (Res & Smit BV, 2016)

5.1.9. DECENTRALIZATION OF DESIGN

C1 originally operated as one compartment, but the building has now been decentralized into individual homes. Interviewee 3 stated: *''The building configuration was created by us, but further adjustments regarding interior layouts could be determined by the buyers''*.

The original spatial design of the building eased running pipes and ducts above and below the high ceilings, which has increased the flexibility of installing systems. Figure 5.7 depicts the considerable ceiling height in C1. Interviewee 1 stated: *''For the homeowner sector, it is necessary for each home to have its own installation''*.

Interviewee 4 indicated that decentralizing the design in existing buildings is complicated due to shared walls essential for the structural integrity of neighbouring homes. Interviewee 4 stated: *"Prefab concrete systems in new construction offer double walls, theoretically allowing entire homes to be removed without affecting the surrounding structure, making the design decentralized"*. Since this is not the case in C1, technical complexities with building products and materials can be perceived as an inhibiting factor.

Figure 5.7: High ceilings in the before situation (Res & Smit BV, 2016)

One interviewee rated the applicability of this strategy as "extremely applicable", three as "very applicable", one as "applicable", and one as "somewhat applicable". Regarding its effectiveness, three interviewees rated the strategy as "extremely effective", two as "effective", and one as "somewhat effective".

5.1.10. DESIGN FOR MIXED-USE

This strategy was not implemented in C1 because the building is limited to residential use. Interviewee 3 stated: *''Real changes to other functions, such as converting an office building into a shop or restaurant, were not applicable here''*.

Based on the findings, there was not a specific enabling factor that was faced in this project.

Legal and legislative restrictions were considered as an inhibiting factor, as the zoning policies for this monofunctional area do not support the implementation of this strategy.

Four interviewees rated the applicability of this strategy as "somewhat applicable", while the other two rated it as "not applicable". Regarding its effectiveness, one interviewee rated the strategy as "very effective", two as "somewhat effective", and three as "not effective".

5.1.11. UTILIZATION OF SECONDARY MATERIAL

In C1, the roof required extensive work, including the removal of roof boarding and tiles, repairing rotten rafters, and installing insulated roof panels. Figure 5.8 shows that old roof tiles were reused and supplemented with second-hand tiles from other projects.

The economic viability of basic strategies was influenced by the willingness of developers and investors to allocate budgets. Interviewee 1 stated: *''The parent company of the main contractor actively promoted the utilization of secondary materials''*. Next to this, interviewee 1 explained that new business models such as construction marketplaces offer platforms, allowing materials from demolition projects to be reused.

Technical complexities with building products and materials was an inhibiting factor, according to interviewee 2 who stated: *‘’While bricks are relatively easy to find in second-hand marketplaces, specific elements such as windows, doors, and frames often require custom work‘’*.

Regarding the economic infeasibility of innovative strategies, interviewee 1 stated: ‘’*As long as reuse is more expensive, developers will prefer new materials’’*. Interviewee 4 added: *‘’Using secondary materials involves multiple steps, including harvesting, transportation, storage, preparation, and potentially subscription fees for an innovative building materials market’’*.

Figure 5.8: Secondary roof panels (Res & Smit BV, 2016)

Three interviewees from C1 rated the applicability of this strategy as "very applicable", two as "applicable", and one as "somewhat applicable". Regarding its effectiveness, three interviewees rated this strategy as "extremely effective", two as "very effective", and one as "effective".

5.1.12. UTILIZATION OF BIOBASED MATERIAL

In C1, damaged natural stone was repaired with lime mortar, which is a biobased mortar made from limestone mixed with sand. Additionally, timber and wooden construction materials were used as biobased materials in C1. Figure 5.9 illustrates that all additional floors and structural wooden beams are made of wood, rather than concrete. Many of the existing window frames, which were in poor condition, were replaced with new wooden frames. Interviewee 1 stated: *"Nowadays, all the wood we get from material suppliers is often FSC-certified, indicating that it comes from sustainably managed forests"*.

The implementation of this strategy was feasible due to the presence of a motivated and capable team, particularly the subcontractor's laboratory, which researched the reuse of lime mortar. Once cleaned, the lime mortar retained its reactive properties, making it suitable for circular construction.

Additionally, policy and legislative support from agencies such as the ‘’Netherlands Enterprise Agency’’ enabled the subcontractor to test this innovative approach to biobased mortar.


Figure 5.9: Wooden structure (Res & Smit BV, 2016)

Inhibiting factors for this strategy included the tendency to follow traditional paradigms and technical complexities with building products and materials. Interviewee 4 indicated that building with wood is more expensive than other construction materials due to the need for precise calculations and new methods, leading to higher costs and extended time requirements. Additionally, wooden floors have lower load-bearing capacity than concrete, making them less effective for sound insulation

Furthermore, it was found that the condition of components, such as wooden beams, was worse than expected, making reuse impossible because they were too rotten, as shown in Figure 5.10.


Figure 5.10: Rotten wooden beams (Res & Smit BV, 2016)

Four interviewees from C1 rated the applicability of this strategy as "very applicable", while two rated it as "applicable". Regarding the effectiveness, one interviewee rated this strategy as ‘’extremely effective’’, two as ‘’very effective’’, two as ‘’effective’’, and one rated ‘’somewhat effective’’.

5.1.13 UTILIZATION OF CIRCULAR MATERIAL

The steel columns are reusable because they are demountable, which makes it possible to close openings in the future by removing the steel columns and restoring the masonry. Interviewee 4 stated: *‘’Steel and concrete as materials are not very environmentally friendly due to the CO2 emissions during their production, but building them in a demountable way makes it a sustainable solution’’*.

In the long term, demountable elements could be used elsewhere, which reduces costs associated with purchasing new materials, enhancing the economic viability of basic strategies.

Based on the interviews, there were not any specific inhibiting factors to this strategy.

Two interviewees from C1 rated the applicability of this strategy as "very applicable", one as "applicable", two as "somewhat applicable", and one as "not applicable". Regarding its effectiveness, two interviewees rated the strategy as "very effective", one as "effective", two as "somewhat effective", and one as "not effective".

5.1.14. ALIGNMENT OF THE INTERCONNECTION BETWEEN THE FLOOR PLANS

In C1, the monumental corridors, such as the one in Figure 5.11, were preserved by dividing them into smaller sections with walls. The individual apartments are connected by the outdoor space, as stated by interviewee 3: *‘’The inner yard and the axes are accented with specific tiles and small trees along the axes, connecting the whole’’*.

The enabling factor of this strategy was the presence of a motivated and capable team, as interviewee 5 stated: *''You always have to design transitions between public and private spaces and come up with solutions for these boundaries''*. The landscape architect integrated the front gardens with the surrounding park by adding a height difference, known as an HH element. This solution maintains an open sightline for the homeowners, allowing visitors to see the building without the presence of visible barriers. In addition, hedges and trees have been used to provide privacy in the backyards, creating a garden-like atmosphere despite their small size.

An inhibiting factor to this strategy was the legal and legislative restrictions, due to the strict regulations for the preservation of cultural heritage. Interviewee 1 stated: *''No fences can be placed in the front yard, and garden furniture must be brought inside in the evening. From the park, you can essentially walk right into the residents' gardens''*.

Two interviewees from C1 rated the applicability of this strategy as "very applicable", while three rated it as "applicable" and one as ''somewhat applicable''. Regarding its effectiveness, four rated the strategy as ''very effective'', and two rated as ''effective''.

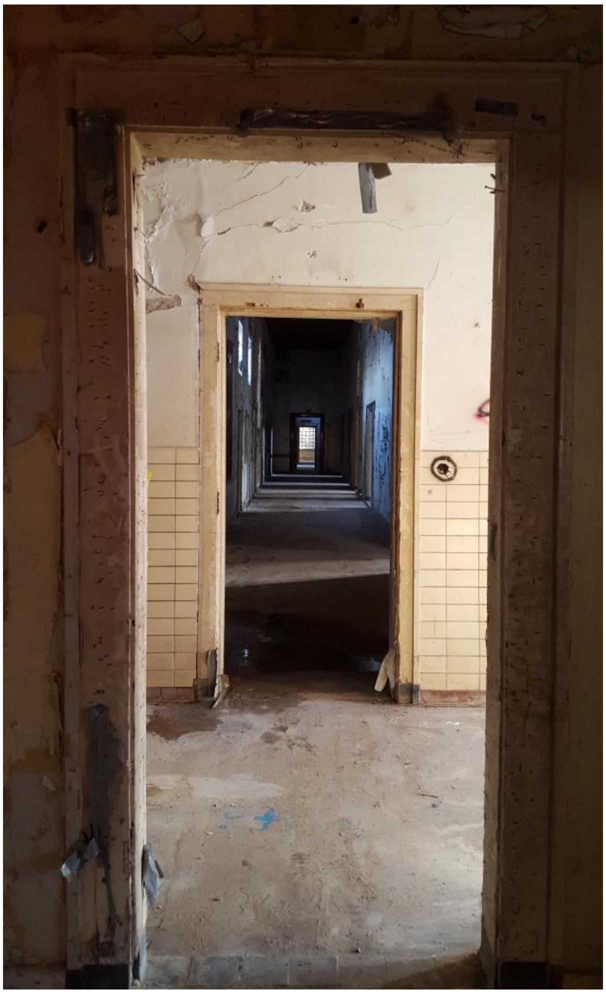


Figure 5.11: Monumental corridor (Res & Smit BV, 2016)

5.1.15. ALIGNMENT OF THE BUILDING DESIGN WITH THE PROPERTY PORTFOLIO

The specific implementation of this strategy in the design was the focus on increasing daylight and adding extra windows. A deliberate approach was chosen where new additions are distinctly recognizable as modern yet harmonize with the structure of the existing building. Interviewee 3 stated: *''This was achieved by using different materials and detailing that accentuate the contrast with the original design''*.

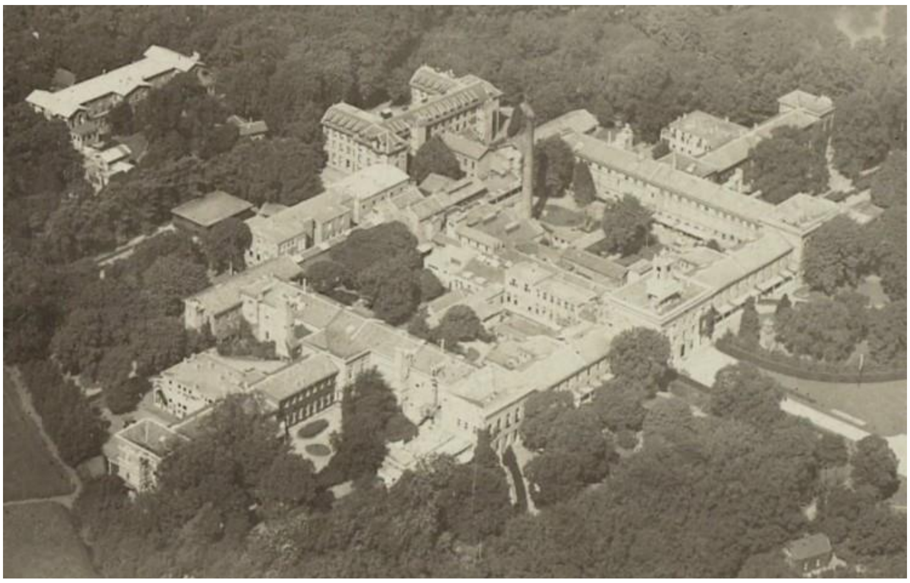


Figure 5.12: Old situation with all outbuildings (Res & Smit BV, 2016)

In close collaboration and partnership between the architect and the landscape architect, the C1 project began by demolishing less valuable building parts and incorporating axes and new constructions to restore the original square shape. Both situations are depicted in Figure 5.12 and 5.13. During repairs and renovations, interventions were kept minimal to preserve the character of the old and authentic psychiatric hospital. Interviewee 2 stated: *''New stones were chosen that match well with the existing structure to create a harmonious transition between old and new''*.

This strategy was specifically enabled by policy and legislative support, due to strict requirements from the municipality to preserve the heritage. Additionally, there were active local foundations collaborated with the Netherlands Cultural Heritage Agency to ensure that the new design respected the historical character of the building.

Based on the interviews, there were not any specific inhibiting factors to this strategy.

Three interviewees from C1 rated the applicability of this strategy as "very applicable", while two rated it as "applicable" and one as ''somewhat applicable''. Regarding its effectiveness, one rated this strategy as ''very effective'', three rated it as ''effective'', and two rated as ''somewhat effective''.

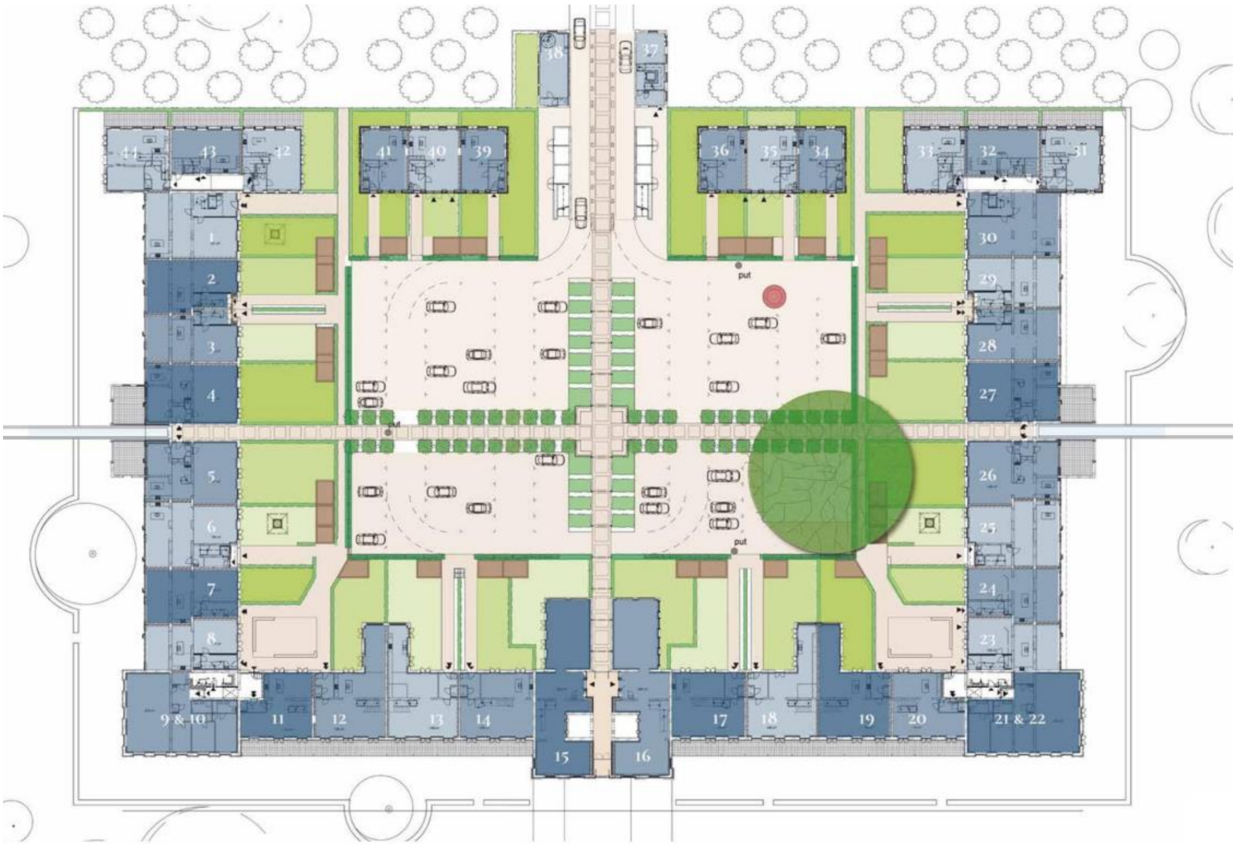
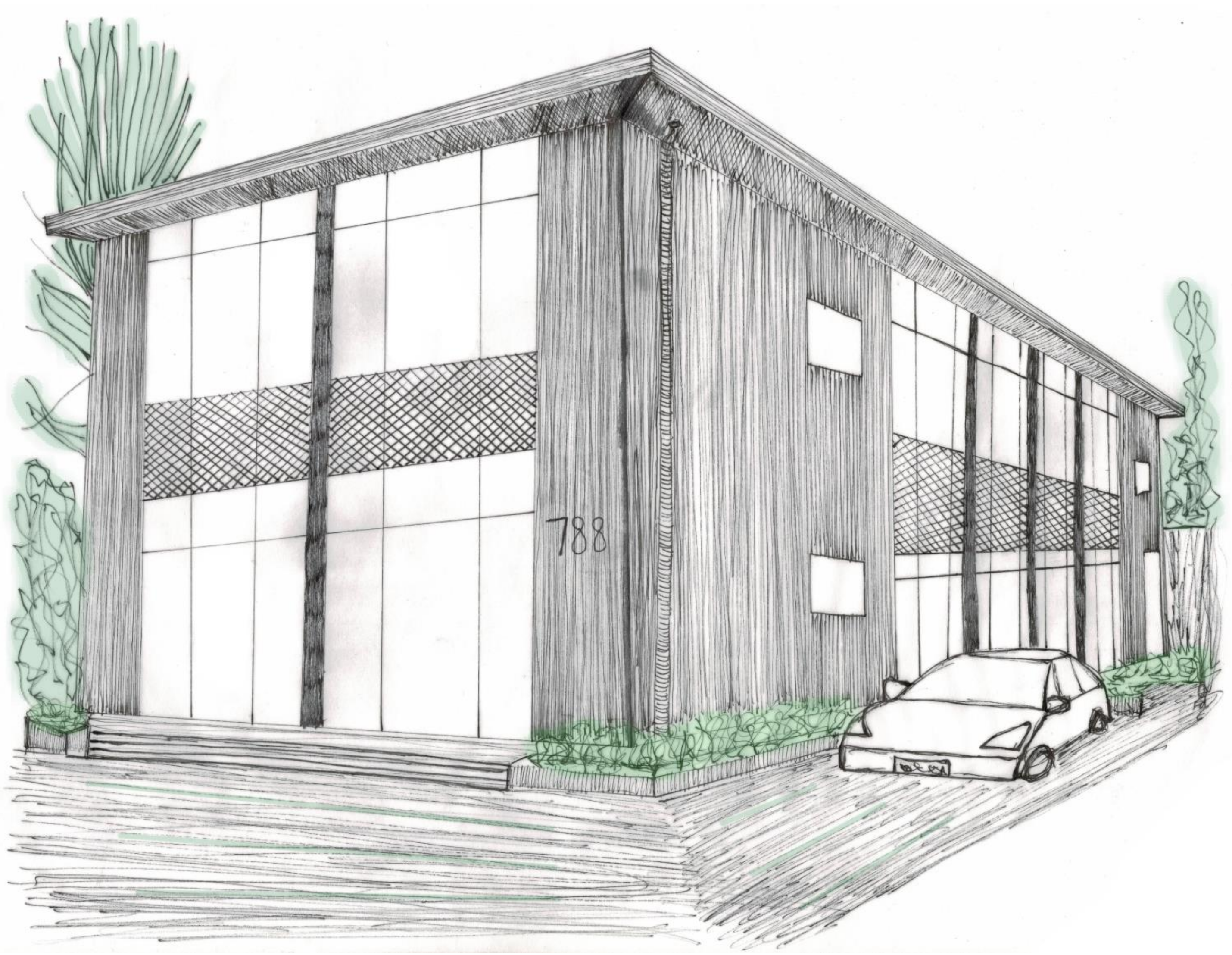


Figure 5.13: Outdoor interconnection (Res & Smit BV, 2016)

C2



5.2. WITHIN CASE ANALYSIS OF C2

5.2.1. DESIGN STANDARDIZATION

As seen in Figure 5.14, C2 was stripped down to its basic structure by retaining only the construction elements such as columns, walls, roof structure, and floors. Interviewee 6 stated: *"Thanks to the consistent design elements, changes could be easily implemented without major structural modifications"*. Interviewee 8 added: *"The basic structure of [name of C2] is standardized, allowing for specific adjustments based on the type of organization and their corporate identity"*. Interviewee 9 explained that standardized window frames were used during the renovation of C2, as shown in Figure 5.15, making it easy to add doors if the building is later converted into housing.

Figure 5.14: Structure C2 (Res & Smit BV, 2018)

The enabling factor for this strategy was the building's characteristics, as interviewees 7 and 10 pointed out that floor heights and beech sizes determine the potential for adaptive reuse. Interview 7 stated: *''In the case of old school buildings like [name of C2], the floor and window heights are greater than those in residential buildings''*. Interviewee 10 added: *''The building's characteristics not only meet current building code requirements, but also provide sufficient daylight and space for essential installations, such as air handling systems''*.

The tendency to follow traditional paradigms was an inhibiting factor for this strategy, as developers often prefer conventional methods due to lower costs and predictable results, even if it means overlooking innovative and sustainable alternatives. Interviewee 8 stated: *''The applicability of this strategy depends on the type of project: it works well for repetitive housing construction, but for specific structures like churches or museums, customization is required''*.

Five interviewees from C2 rated the applicability of this strategy as "very applicable" and one as "somewhat applicable". Regarding its effectiveness, four interviewees rated the strategy as "very effective", and two as "effective".

Figure 5.15: Standardized window frames (Res & Smit BV, 2018)

5.2.2. SEPERATION OF BUILDING LAYERS

Interviewee 7 explained that the feasibility of this strategy for existing buildings depends on the original construction method. Interviewee 7 stated: *"If a building is prefabricated, it is easier to dismantle than when concrete structures are fully cast on-site, with floors and walls often interconnected, as is the case with [name of C2]"*. Interviewee 9 added that timber frame construction elements were used that can be dismantled, allowing certain parts of the building to be disconnected and repurposed for various functional purposes. Figure 5.16 shows the construction of this system.

The building's characteristics were a key enabling factor for this strategy. Certain sections of the building utilize a box-in-a-box construction method, which allows for easier dismantling without causing damage.

Additionally, the economic viability of basic strategies served as another enabling factor, as the use of standard, dismountable products reduces costs through consistent quality and facilitates reuse, thereby preventing capital destruction by avoiding demolition.

However, there were also inhibiting factors for this strategy, due to the technical complexities with building products and materials in areas where load-bearing elements limited demountability, making these sections difficult to dismantle. Interviewee 7 stated: *"Buildings like [name of C2] are more suitable to be stripped down to the basic structure, and then reimagined from the existing structure for new purposes''*.

Figure 5.16: Detail of dismountable element (own photo, 2024)

Four interviewees from C2 rated the applicability of this strategy as "very applicable", one as "applicable", and one as ''somewhat applicable''. Regarding its effectiveness, one interviewee rated the strategy as ''extremely effective'', three as "very effective", one as ''effective'', and one as "somewhat effective".

5.2.3. OPEN THE FLOOR PLAN

Originally, the old school building had classrooms with non-load-bearing partition walls. During the transformation, these walls were removed, creating large open spaces with only a few columns in the middle, as shown in Figure 5.17. Interviewee 10 explained that open designs offer several advantages, including improved light, better air circulation, and greater versatility for future changes in the use of the space. Interviewee 8 added: *''As users of [name of C2], we wanted to collaborate in a common area without separate rooms, so we adapted the layout to our way of working, with open spaces for collaboration and meeting rooms for conversations"*.

The building characteristics were regarded as enabling factors, as interviewee 6 stated: *''The column structure serves as the load-bearing component, which makes [name of C2] flexible and facilitates reconfiguration''*. Interviewee 7 explained that in repurposing projects for old schools such as C2, it was crucial to follow the rhythm and dimensions of the existing column structure.

A lack of experience could be an inhibiting factor for the implementation of this strategy, as interviewee 8 stated: *''Overlooking the existing structure could lead to columns being positioned in the middle of living spaces, or result in misaligned shafts and meter cabinets''*.

Figure 5.17: Open workspace (own photo, 2024)

Three interviewees from C2 rated the applicability of this strategy as "extremely applicable", two as "very applicable", and one as ''applicable''. Regarding its effectiveness, three interviewees rated the strategy as ''extremely effective'', and three rated as "very effective".

5.2.4. PROVISION OF MULTI-PURPOSE SPACES

Interviewee 7 emphasized that this strategy is crucial for fostering interaction, both in the context of urban planning and within the building's layout and design. In C2, there is a shared space, depicted in Figure 5.18, where both the owner-user and tenants can use it to cook, work, relax, and meet, with options available both indoors and outdoors. Additionally, the office spaces include rooms designed for multiple purposes, accommodating individual work, meetings, and presentations for larger groups.

Figure 5.18: Multi-purpose space in C2 (own photo, 2024)

The enabling factor of building characteristics was crucial for this strategy, as it underscored the significance of the building's physical attributes, such as foundation strength, floor load capacities, ceiling heights, and overall structural flexibility. These characteristics could enable for minimal adjustments while accommodating multiple purposes within the existing architectural context.

Additionally, the presence of a motivated and capable team was crucial; the architect's expertise in both architecture and interior design enhanced the potential of the spaces.

Technical complexities related to building products and materials, such as installations, were regarded as inhibiting factors. Interviewee 6 stated: *‘’The size of the ducts determines the potential multifunctionality of a space, as maintaining good air quality is essential for both workspaces and gatherings involving multiple people’’*.

Two interviewees from C2 rated the applicability of this strategy as "extremely applicable", three as "very applicable", and one as ‘’somewhat applicable’’. Regarding its effectiveness, one interviewees rated the strategy as ‘’extremely effective’’, four as "very effective", and one as ‘’effective’’.

5.2.5. MODULARIZATION OF SPATIAL CONFIGURATION

The extension of C2 is an independent module that can be fully dismantled. According to interviewee 10, the consistent beech size of 7.5 meters in C2 allowed for a flexible arrangement of various spaces. In contrast, a 5-meter span would be insufficient for accommodating both a bedroom and a living room when converting the building into residential units. Additionally, due to the open floor plans and the preferred working methods within the offices, modules that are not connected to the main structure have been placed on both the ground floor and the upper floor, as illustrated in Figure 5.19.

The building characteristics, such as the modularity of the construction and the façade, made it possible in C2 to design specific solutions that enable the building to be reused repeatedly. Interviewee 6 stated: *"[name of C2] has exceeded the typical lifespan of a building, indicating its intrinsic quality and allowing it to be flexibly adapted for new functions, such as converting from a school to an office or residence"*.

Interviewee 10 stated: *‘’Modular construction is straightforward in new projects; however, a lack of expertise becomes an inhibiting factor when working with existing buildings’’*. The challenge of installing prefabricated sanitary modules is hindered by the need to open façades and is further restricted by the existing column structure.

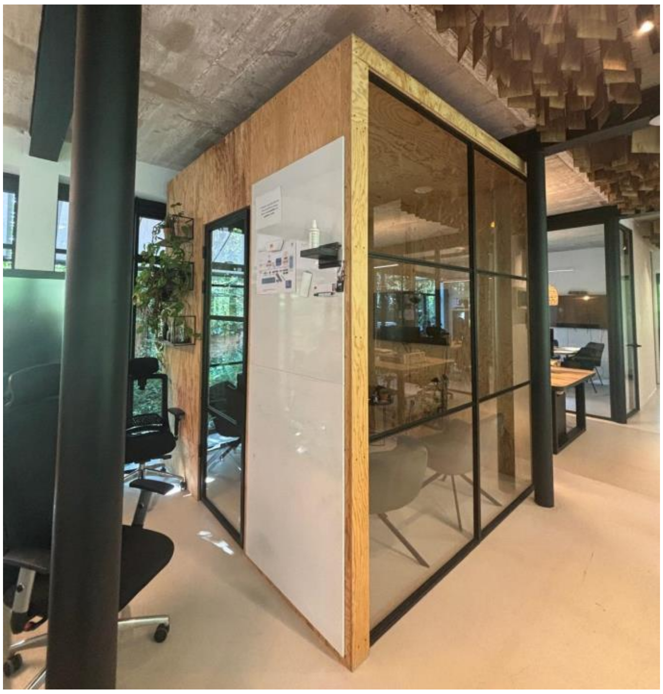


Figure 5.19: Modular unit in C2 (own photo, 2024)

One interviewee from C2 rated the applicability of this strategy as "extremely applicable", two as "very applicable", one as "applicable", one as "somewhat applicable", and one as "not applicable". Regarding its effectiveness, one interviewee rated this strategy as "extremely effective", two as "very effective", one as "effective", and two as "somewhat effective".

5.2.6. UTILIZATION OF STANDARDIZED BUILDING PRODUCTS

Interviewee 7 stated that increased standardization benefits the contractor by reducing complexity, shortening construction time, and ensuring consistent quality throughout the project. In C2, this approach was applied to products such as finishes, claddings, façades, and window systems.

This strategy was supported by the enabling factor of collaboration and partnerships. According to Interviewee 7, working closely with suppliers enables contractors to identify the most sustainable and efficient methods for product application, thereby reducing costs and minimizing leftover waste. Interviewee 8 further explained that while elements may vary in appearance, they still maintain the same underlying system, stating: *"Instead of starting each design from scratch, a solid base design can be customized with prefabricated elements such as different colours and finishes"*. Additionally, interviewee 10 stated: *‘’Effective material use prevents waste and ensures that, even after 10 years, the system's assembly remains clear, making replacements or adjustments easier’’*.

Based on the interviews, there were not any specific inhibiting factors connected to this strategy.

One interviewee from C2 rated the applicability of this strategy as "extremely applicable", one as "very applicable", one as "applicable", and three as "somewhat applicable". Regarding its effectiveness, two interviewees rated this strategy as "extremely effective", one as "effective" and three as "somewhat effective".

5.2.7. PROVISION OF A CORE FOR BUILDING SERVICES

C2 utilizes a passive ventilation system, reducing the building's reliance on technical installations. Interviewee 7 explained: *"This is achieved by optimizing positioning, sunlight exposure, overhangs, material use, and the building's heating and cooling processes, ensuring effective heat retention in winter and cooling in summer"*. Interviewee 6 added that in C2, a large skylight above the staircase, shown in Figure 5.20, remains open on warm days, facilitating effective night ventilation and cooling.

Economic viability of basic strategies was the enabling factor. Interviewee 8 stated: *‘’We have consciously chosen to apply as many natural means as possible to keep costs low and ensure sufficient comfort while maintaining a high standard of sustainability’’*. For areas of the building requiring mechanical ventilation, installations were centralized in the pantry zone to simplify maintenance, with main vertical and horizontal pipes branching out to specific rooms, as illustrated in Figure 5.21.

Figure 5.20: Passive system in C2 (own photo, 2024)

Technical complexities with building products and materials is considered an inhibiting factor, because installations have an impact on a building's interior design. Interviewee 6 stated: *''When selecting the type of installation—whether natural ventilation, mechanical supply and exhaust, or a balanced system—it is important to consider the positions of stairs, shafts, and meter cabinets, as well as the structural possibilities related to ceiling heights and necessary ductwork''*.

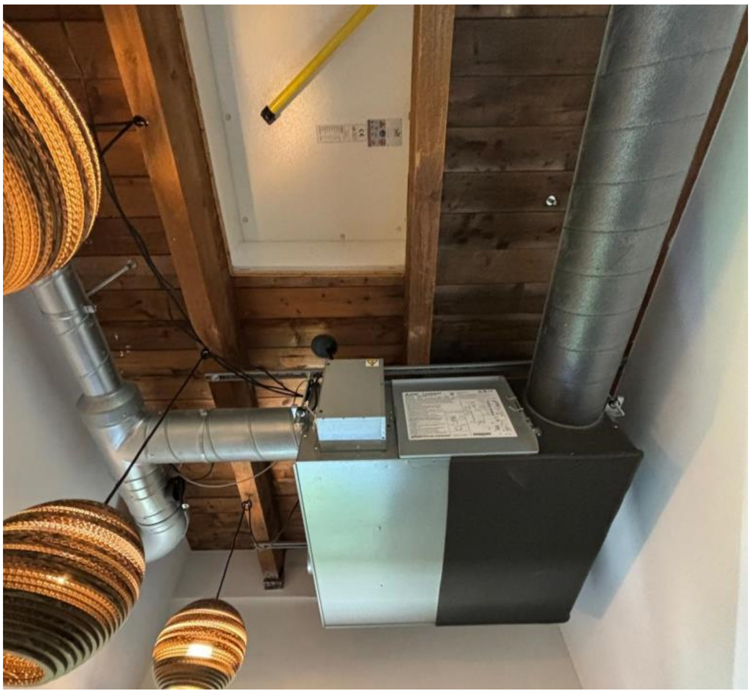


Figure 5.21: Centralized installations (own photo, 2024)

One interviewee from C2 rated the applicability of this strategy as "very applicable", three as "applicable", and two as "somewhat applicable". Regarding its effectiveness, two interviewees rated this strategy as "very effective", two as "effective" and two as "somewhat effective".

5.2.8. DESIGN FOR SURPLUS CAPACITY

Interviewee 6 highlighted that this strategy requires forward thinking to prevent future problems and offers flexibility for repurposing the space. Interviewee 9 added that the design of C2 enables for the easy installation of sewer systems on the ground floor, which facilitates its transformation into residences. Investments in the building's structure, such as floor height and structural stability, are crucial for accommodating overcapacity. Additionally, as shown in Figure 5.22, C2 was expanded horizontally with an extension to meet the tenant's growth needs.

Figure 5.22: Horizontal expansion (Res & Smit BV, 2018)

Building characteristics were considered as an enabling factor for the implementation of this strategy. According to Interviewee 7, many buildings from the 70s and 80s, including C2, have strong concrete skeletons with large margins, making them suitable for adding layers to the existing structure. Interviewee 8 stated: *"Instead of demolishing and rebuilding, we can give existing structures a second life by building vertically"*. Additionally, offices typically have higher floor load capacities than residences due to more occupants and furniture, meaning a change in function for C2 automatically can meet the requirements of residential buildings.

This strategy could be inhibited by two main factors: economic infeasibility of innovative strategies combined with legal and legislative restrictions. Interviewee 6 stated: *‘’Modern buildings are designed to be more slender by using less material, making them more cost-efficient but less suitable for vertical expansion without significant structural modifications’’*. Although C2 could technically support additional floors, environmental factors and regulations, like parking norms and zoning plans, limited expansion possibilities.

Two interviewees from C2 rated the applicability of this strategy as "very applicable", two as "applicable", and two as "somewhat applicable". Regarding its effectiveness, three interviewees rated this strategy as "very effective", and three as "effective".

5.2.9. DECENTRALIZATION OF THE DESIGN

In the current setup of C2, the two floors and a new addition are disconnected to allow for separate rentals. Each space has its own meter cabinet and heat pump, providing users with control over the indoor climate. Interviewee 9 stated: *‘’The floors are designed independently in the current situation, with separate kitchens, meeting rooms, and installations for the upper and lower floors, including separate restrooms"*.

The presence of a motivated and capable team was an enabling factor, as the building owner considered the differences between installation systems for residences and offices. Interviewee 10 explained that offices typically use a central system, while residences are managed with decentralized systems, leading the owner to reserve space for future installation shafts. Interviewee 9 stated: *‘’Water drainage can be easily installed by drilling pipes through the wooden beam layer, while electrical and data points are positioned according to the layout of potential future residential units’’*.

Office buildings like C2 typically operate with central systems, such as long ducts for air supply and exhaust or floor heating per floor. Interviewee 6 stated: *‘’Ventilation poses a challenge when converting to apartments, as the existing central system prevents individual regulation for separate units on the same floor’’*. This underscores the economic infeasibility of innovative strategies, given that separate systems are more costly. Interviewee 10 added that if the building is transformed into residences, each unit must have its own system to allow for independent control.

One interviewee from C2 rated the applicability of this strategy as "very applicable", three as "applicable", and two as "somewhat applicable". Regarding its effectiveness, one interviewee rated this strategy as "very effective", four as "effective", and one as "somewhat effective".

5.2.10. DESIGN FOR MIXED-USE

C2 is designed to accommodate different uses of space with minimal interventions, such as adding doors and partition walls. Interviewee 10 explained that future functional changes were considered by disconnecting the building from the gas supply and equipping it with solar panels and heat units. Interviewee 8 stated: *‘’A double permit application was submitted during the renovation and extension of [name of C2], allowing for the creation of residences within the existing structure’’*. Figure 5.23 shows the different floor plans drawn for both scenarios. Interviewee 6 stated: *"[name of C2] is well-suited for mixed-use, combining residences and offices, where offices are used during the day and residences in the evening, which is beneficial for parking occupancy and the liveliness of the neighbourhood"*.

Policy and legislative support, combined with economic viability of basic strategies, were the enabling factors for this strategy within the context of C2. Interviewee 9 stated: *''Regulations for existing buildings are less strict than for new constructions. To maximize housing units on [name of C2], we might create smaller units, as there is no requirement for outdoor spaces. In contrast, larger units would require the addition of costly balconies''*.

Additionally, interviewee 6 stated: *"When integrating residences into the existing structure of an adaptive reuse project, it is important to respond to the existing context"*, emphasizing that regulatory flexibility allows architects to be more creative with elements like staircases. In C2, the main staircase cutting through the building on both sides was a key consideration when planning potential residences.

Technical complexities related to building products and materials were an inhibiting factor for this strategy in existing buildings, as load-bearing structures and layouts dictate the feasibility of adjustments and new functions. Interviewee 6 stated: *"Mixed-use poses a challenge with noise: with residences on the ground floor and offices above, noise disturbances can occur"*. In C2, this added additional costs for insulating the intermediate floors to prevent noise disturbances between layers. Interviewee 10 explained that in new construction projects, it is crucial to design a flexible and adaptable structure to facilitate easy modifications to the load-bearing framework.

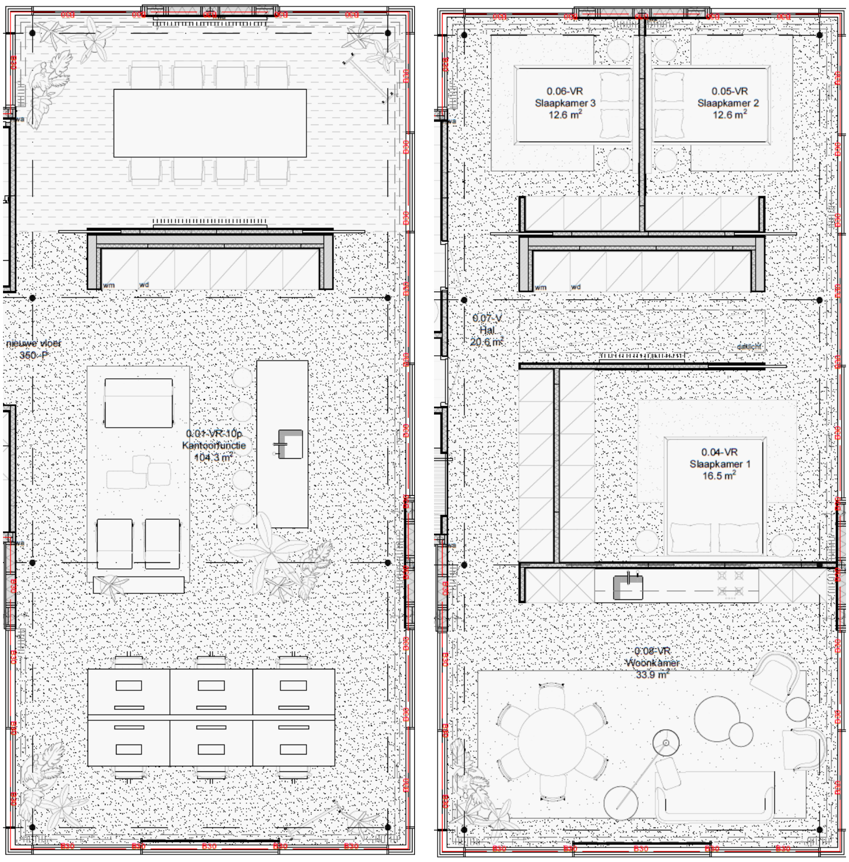


Figure 5.23: Floorplan for office (left) and house (right) (Res & Smit BV, 2018)

One interviewee from C2 rated the applicability of this strategy as "extremely applicable", four as "very applicable", and one as "applicable". Regarding its effectiveness, five interviewees rated this strategy as "very effective", and one as "effective".

5.2.11. UTILIZATION OF SECONDARY MATERIAL

Some second-hand construction products were used in C2. Interviewee 8 stated: *''[name of C2] was constructed using a mix of old and new materials, with secondary materials contributing to the building's identity and sense of history''*. Reused sinks were repurposed in the lower hall, while second-hand tiles, shown in Figure 5.24, were used for both the interior and exterior. Blue tiles from a material provider added a unique aesthetic to the kitchen, while 30x30 cm concrete tiles were used for planters, the parking lot boundary, and surrounding greenery. Interviewee 9 stated: *''The ceiling contains reused beams from a previous project''*. The outdated straw roof was replaced with these beams, and additional steel girders were installed to ensure stability and prevent collapse.

Figure 5.24: Second-hand tiles for interior (left) and exterior (right) (Res & Smit BV, 2018)

Collaboration and partnerships were an enabling factor for utilizing second-hand materials, as involving a demolition contractor in the renovation of an adaptive reuse project allows for the identification and selective dismantling of materials with reuse potential. Interviewee 7 stated: *"This is interesting because it allows materials to be given a second life"*. Interviewee 6 added that sourcing secondary materials is done within their own network or from completed projects, rather than through second-hand marketplaces. Figure 5.25 shows the secondary wood used in C2.

Additionally, policy and legislative support was an enabling factor due to the "Milieu Prestatie Gebouwen (MPG)" regulation, which requires a minimum score for the environmental performance of building materials. Interviewee 7 stated: *''This regulation will be tightened, forcing developers to innovate in construction methods and material usage, often resulting in higher costs''*.

The inhibiting factor for this strategy was the technical complexities associated with building products and materials. Interviewee 6 stated: *''The goal was to reuse more existing wood, but this was not possible due to bad condition of some parts, which affected their reliability and performance''*.

Additionally, the lack of data and warranties on old materials was another inhibiting factor. This inability to provide clients with assurance based on known product lifespans and factory data means the work may not meet certain quality standards. Interviewee 10 added: *''Clients must understand that minor signs of use and the absence of formal warranties do not necessarily diminish the functionality and value of the materials''*.

Figure 5.25: Secondary wood used in C2 (Res & Smit BV, 2018)

One interviewee from C2 rated the applicability of this strategy as "extremely applicable", three as "applicable", and two as "somewhat applicable". Regarding its effectiveness, two interviewees rated this strategy as "very effective", three as ''effective'', and one as "somewhat effective".

5.2.12. UTILIZATION OF BIOSBASED MATERIAL

Interviewee 6 aimed to create a connection between indoors and outdoors in C2 by using natural materials such as stone, wood, greenery, and bamboo, reflecting its green surroundings. Additionally, a green roof, depicted in Figure 5.26, was installed to slow down rainwater runoff, effectively managing the large amount of rainfall.

Figure 5.26: Green roof (own photo, 2024)

Since the owner of C2 is also the building's user, there was sufficient budget to invest in biobased materials, making the presence of a motivated team an enabling factor. Interviewee 8 stated: *"We aimed to create a cozy and functional building that positively influences the indoor climate and the well-being of our employees"*.

Another enabling factor was the building’s characteristics, particularly in the use of biobased materials, which do not release toxins when not reused. Interviewee 10 stated: *‘’Although wooden beams or frames may no longer meet updated requirements for their original function, these materials can often be repurposed for alternative uses, such as ceiling materials’’*.

A lack of expertise and a tendency to adhere to traditional paradigms were identified as inhibiting factors, as the widespread adoption of biobased materials in construction remains limited. Interviewee 7 stated: *"The adoption of innovative materials by contractors is progressing slowly, driven primarily by government regulations or market demands rather than by their own initiative"*. Interviewee 10 explained that traditional materials such as concrete, steel, and glass are familiar and financially predictable, leading the market to hesitate in investing in more expensive, sustainable alternatives.

One interviewee from C2 rated the applicability of this strategy as "very applicable", and five as "applicable". Regarding its effectiveness, two interviewees rated the strategy as "very effective", three as ‘’effective’’, and one as "somewhat effective".

5.2.13. UTILIZATION OF CIRCULAR MATERIAL

Interviewee 6 stated: *‘’Designing with built-in elements is avoided in [name of C2], as it restricts flexibility when the use of the space changes. Instead, the space utilizes built-on elements, such as furniture, which can be dismantled and reconfigured’’*. Interviewee 9 further stated: *"For the interior, we selected chairs that have been in use for 25 years but come with a 50-year warranty. After being cleaned, they are nearly indestructible"*. The circular furniture used in the interior is depicted in Figure 5.27.

The presence of a motivated team was an enabling factor, as interviewee 9 stated: *‘’True sustainability is realized through the production of durable, long-lasting products that minimize the need for frequent maintenance or replacement. Therefore, we choose to invest in high-quality items designed to last for decades, rather than products requiring annual refurbishing’’*.

In addition, the economic viability of basic strategies were regarded as an enabling factor, as interviewee 6 stated: *‘’The furniture we used is designed with timelessness in mind, ensuring they look good both now and in ten years. This approach allows them to be sold out to reuse and recycling agencies while avoiding waste generation’’*.

Technical complexities associated with building products and materials were considered an inhibiting factor for this strategy. Interviewee 8 stated: *" Some of the products we used, such as lighting and installations, may become outdated or inefficient in terms of energy use, making their reusability or recyclability uncertain or impractical"*.

Figure 5.27: Circular furniture (own photo, 2024)

One interviewee from C2 rated the applicability of this strategy as "extremely applicable", two as "very applicable", and three as ‘’applicable’’. Regarding its effectiveness, one interviewee rated this strategy as "extremely effective", three as ‘’very effective’’, and two as "effective".

5.2.14. ALIGNMENT OF THE INTERCONNECTION BETWEEN THE FLOOR PLANS

In C2, this strategy focuses on creating multifunctional and flexible spaces without the need for structural adjustments. Interviewee 6 stated: *"Through smart material choices and zoning, spaces blend seamlessly into each other, reducing the need for walls while still offering distinct qualities"*.

The presence of a motivated and capable team was an enabling factor for this strategy. Interviewee 9 explained that by recognizing the needs of different users, it becomes possible to efficiently manage and utilize the available space. Interviewee 9 stated: *"Sharing spaces ensures that everyone can make optimal use of amenities, creating a dynamic and flexible working environment"*. Interviewee 7 added: *‘’Shared kitchens and meeting rooms further promote interaction and collaboration’’*.

Based on the interviews, there were not any specific inhibiting factors connected to this strategy.

Three interviewees from C2 rated the applicability of this strategy as "very applicable", and three as "applicable". Regarding its effectiveness, one interviewee rated this strategy as "extremely effective", four as ‘’very effective’’, and one as "effective".

5.2.15. ALIGNMENT OF THE BUILDING DESIGN WITH THE PROPERTY PORTFOLIO

According to Interviewee 6, who worked on multiple projects with the developer of C2, there is a consistent focus on high quality and maintenance across the entire portfolio. Interviewee 6 stated: *"The projects offer added value, not only financially for the developer but also for the environment and the users"*. Additionally, the exterior appearance of C2 remained intact, and the horizontal extension was integrated with the original architectural context. Interviewee 8 added: *"In this way, we created a balance between the existing and the new, aligning with the broader real estate portfolio"*.

The economic viability of basic strategies served as the enabling factor for this strategy, as the developer is also the user and directly benefits from investments that ensure the high quality and value of the existing building. Interviewee 6 stated: *"These decisions, though not strictly necessary, prioritize quality over cost-saving measures"*.

In addition, collaboration and partnerships were also an enabling factor. Interviewee 7 stated: *"The preference is for long-term collaborations with returning, relatively small clients in a so-called 'bouwteam' setting, which allows for quick decision-making and direct communication"*.

On the other hand, the findings indicate that the economic infeasibility of innovative strategies was an inhibiting factor. Interviewee 10 stated: *"For investors, it is less attractive to transform offices into residences due to the lower square meter prices and associated rental income"*. As a result, investors often choose not to proceed with transformations, instead choosing to anticipate changing market demands. Additionally, Interviewee 7 explained that each client has unique issues and challenges, leading to specific designs that make every project distinct.

Four interviewees from C2 rated the applicability of this strategy as "very applicable", and two as "somewhat applicable". Regarding its effectiveness, three interviewees rated this strategy as "very effective", one as ‘’effective’’, one as ‘’somewhat effective’’, and one as "not effective".

C3

5.3. WITHIN CASE ANALYSIS OF C3

5.3.1. DESIGN STANDARDIZATION

This strategy maximized the available space for future residents by the strategic placement of shafts and the distribution of technical spaces. Interviewee 13 stated: *''Standardizing the design improved the functionality of the apartments''*. The façade was designed with standardized openings and unitized window frames. Additionally, bathrooms and kitchens were configured with standard sizes, creating designated wet zones where all technical elements were concentrated, as depicted in Figure 5.28.

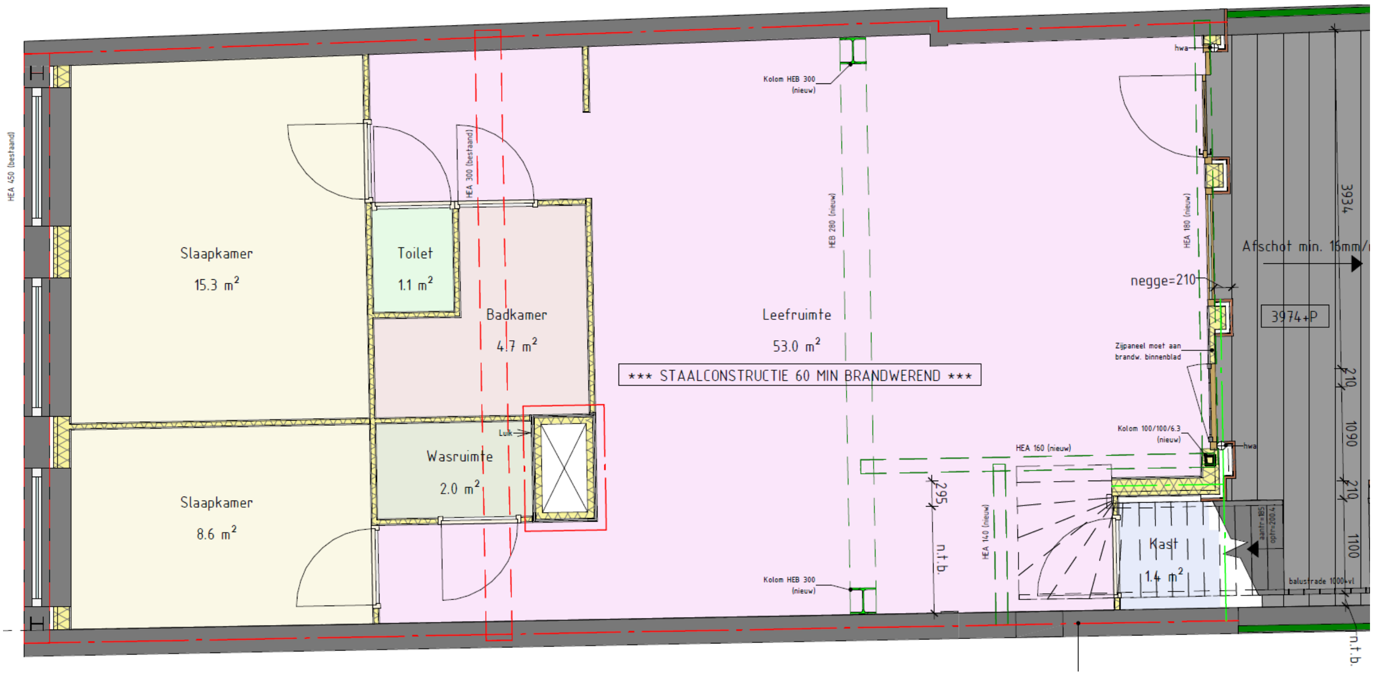


Figure 5.28: Layout with centrally placed wet zone (Res & Smit BV, 2021)

The capability of the team enabled for implementing this strategy, contributing to the predictability and manageability of the project. Interviewee 11 stated: *"When elements are standardized, I can anticipate what is required for construction or demolition, which facilitates efficient planning and execution"*.

Interviewee 13 indicated that standardizing the design in a transformation project represents greater challenges compared to new construction. The required adjustments resulted in varying façade heights on each floor and different window openings, which increased production time for custom frames and made the design process more labour-intensive. As illustrated in Figure 5.29, which shows a section drawing of the original condition, these complexities contribute to the economic infeasibility of innovative strategies, thereby acting as an inhibiting factor.

Furthermore, interviewee 13 emphasized that some aesthetically pleasing architectural details proved difficult to implement in practice, underscoring a lack of expertise as another inhibiting factor.

One interviewee from C3 rated the applicability of this strategy as "very applicable", two as "somewhat applicable", and one as ''not applicable''. Regarding its effectiveness, two interviewees rated this strategy as "extremely effective", one as ''somewhat effective'', and one as ''not effective''.

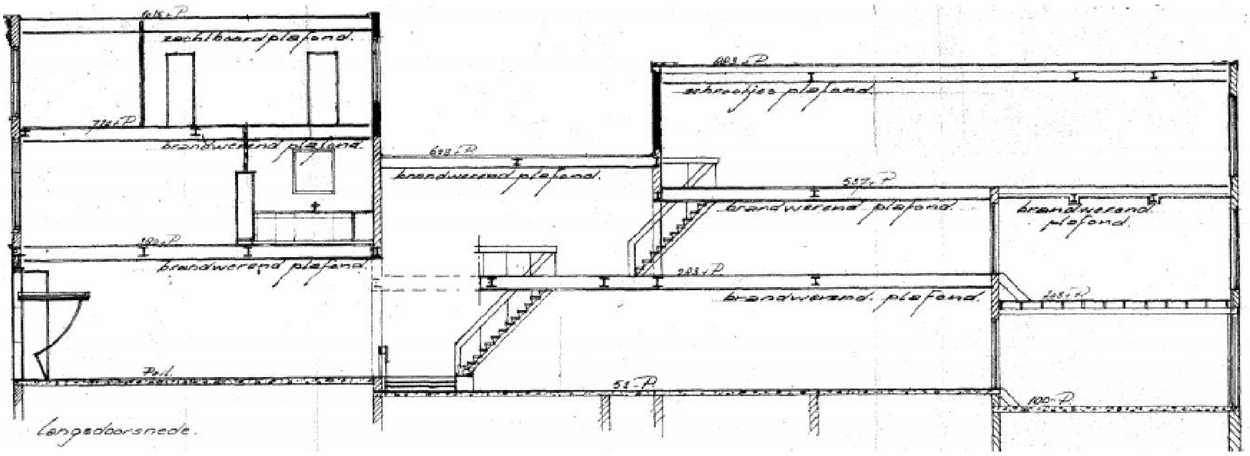


Figure 5.29: Section drawing of the old situation in 1966 (Van Dam & Moerman, 2021)

5.3.2. SEPERATION OF BUILDING LAYERS

In C3, it is possible to combine multiple apartments into larger units if the demand arises. Interviewee 12 stated: *''This can be achieved by demolishing walls and separating the wooden structure without causing any damage''*. Figure 5.30 illustrates two apartment layouts on the second floor where this modification is feasible.

The building characteristics in C3 were regarded as an enabling factor. Interviewee 13 stated: *"Most walls are non-load-bearing and removable, providing flexibility for various floor plans despite the project's small size"*.

Technical complexities related to building products and materials were considered an inhibiting factor. Interviewee 13 indicated that the fire separations between apartments involve walls constructed with metal studs and two layers of drywall on each side, finished with plaster. This construction method complicates dismantling and makes the removal of insulation more costly and challenging.

Three interviewees from C3 rated the applicability of this strategy as "applicable", and one as "somewhat applicable". Regarding its effectiveness, all four interviewees rated this strategy as "somewhat effective".

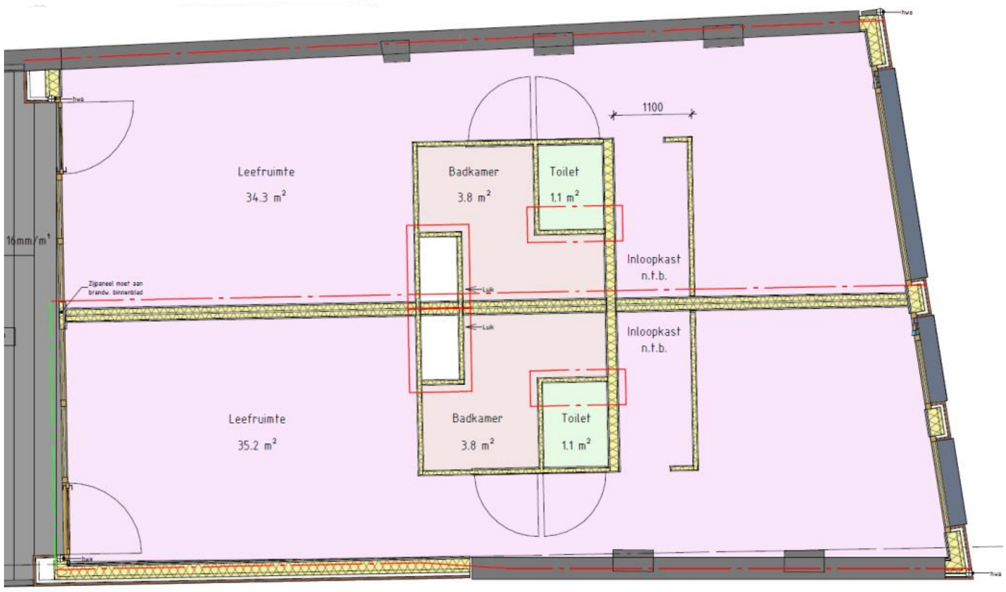


Figure 5.30: Layouts of smallest apartments on the second floor (Res & Smit BV, 2021)

5.3.3. OPEN THE FLOOR PLAN

In C3, this strategy was applied to both residential and commercial spaces. Interviewee 13 stated: *''The retail space on the ground floor was kept as a large, undivided area, allowing daylight from both sides, making the space appealing for various commercial uses. Similarly, the upper-floor apartments kept an open design, giving tenants flexibility to arrange their interior layout''*. Figure 5.31 illustrates the open floor plan of the ground floor, showing the commercial space and one of the apartments.

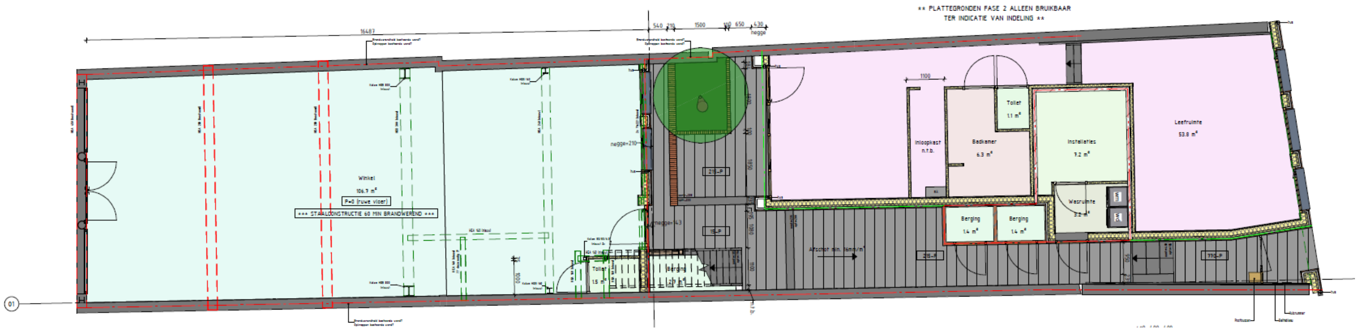


Figure 5.31 Layouts of the ground floor (Res & Smit BV, 2021)

The building characteristics were considered an enabling factor. As Interviewee 13 stated: *"The structure, originally designed as a commercial storage space with few internal walls and high ceilings, supported an open concept"*.

Technical complexity with building materials was viewed as an inhibiting factor. Interviewee 11 expressed a preference for structures that require demolition rather than open floor plans, stating: *"Demolition is a significant part of our work, and open floor plans reduce our workload since there are fewer interior walls and elements to remove"*.

One interviewee from C3 rated the applicability of this strategy as "extremely applicable", two as ''very applicable'', and one as "applicable". Regarding effectiveness, one rated this strategy as ''extremely effective'', one as ''very effective'', one as ''effective'', and one as ''somewhat effective''.

5.3.4. PROVISION OF MULTI-PURPOSE SPACES

The apartments in C3 are designed with flexible layouts, providing the capacity to accommodate changes between sleeping and living zones, while the kitchen remains fixed. Interviewee 13 explained that the larger units, each with two bedrooms, offer the possibility of setting up a home office. Additionally, interviewee 12 stated: *''The ground-floor retail space, was originally planned to be a shop, but later on, it was adapted to include a dining area''*.

Both interviewee 12 and interviewee 13 observed that an open floor plan significantly enhances the multifunctionality of a space, thereby making the building characteristics an enabling factor.

While the results did not explicitly identify an inhibiting factor for this strategy, interviewee 13 stated: *"Due to the limited space in some apartments, ranging from approximately 37 to 50 m^2, multifunctionality is restricted"*.

Three interviewees from C3 rated the applicability of this strategy as "very applicable", and one as ''applicable''. Regarding its effectiveness, three rated this strategy as ''very effective'', and one as ''effective''.

5.3.5. MODULARIZATION OF SPATIAL CONFIGURATION

Interviewee 12 explained that the space was reconfigured from a large warehouse into several apartments, with a modular layout as illustrated in Figure 5.32. Interviewee 13 added that the non-load-bearing interior walls provide some flexibility, as they can be easily removed if needed.

The findings did not identify any specific enabling factors for this strategy. However, interviewee 11 observed that, in terms of efficiency, modularization offers significant advantages for dismantling. During the demolition process, all elements were removed systematically, floor by floor, from top to bottom.

Technical complexities related to building products and materials were considered an inhibiting factor due to the strict requirements for sound transmission and fire safety in partition walls. Interviewee 13 stated: *''Modular construction does not adequately meet these requirements, necessitating the use of heavy, fixed materials in the apartments to minimize sound transmission and ensure a comfortable living environment''*.

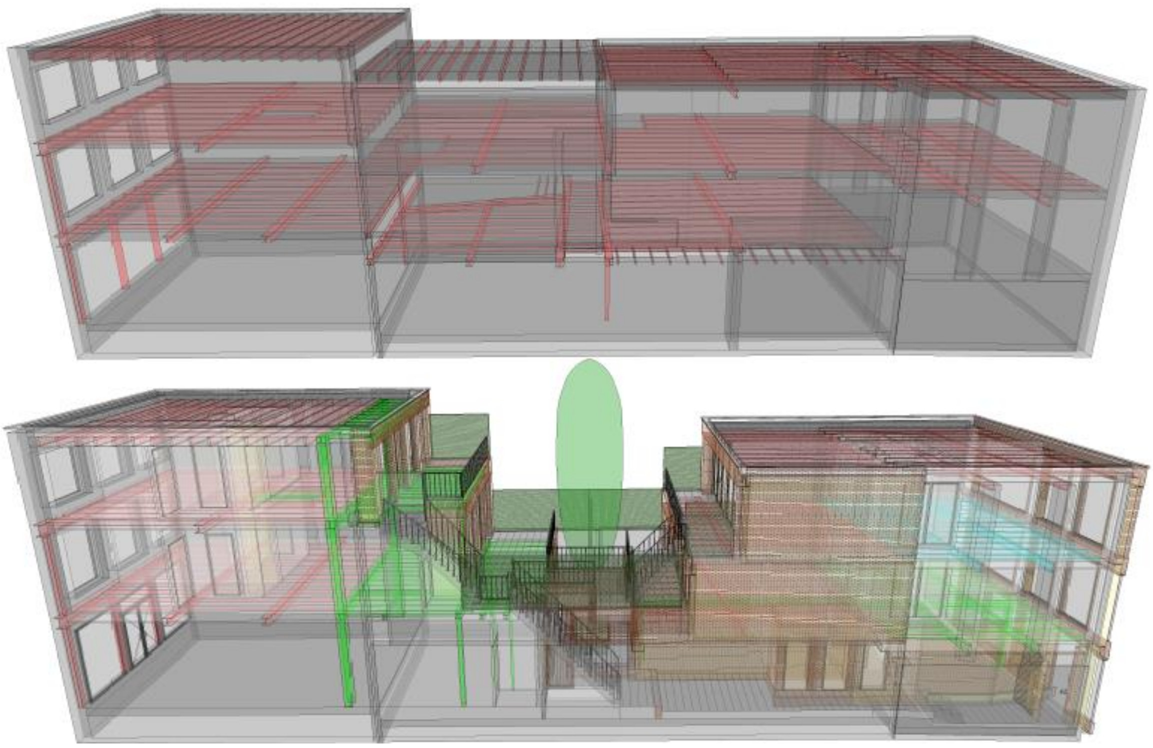


Figure 5.32: 3D drawing of before (up) and after (down) situation (Res & Smit BV, 2021)

One interviewee from C3 rated the applicability of this strategy as "very applicable", one as ''applicable'', one as "somewhat applicable", and one as ''not applicable''. Regarding its effectiveness, two rated this strategy as ''very effective'', one as ''somewhat effective'', and one as ''not effective''.

5.3.6. UTILIZATION OF STANDARDIZED BUILDING PRODUCTS

According to interviewee 12, most elements used in the project adhere to standard building dimensions and can be easily dismantled, including panels, wood, insulation materials, installations, and hatches for fire shafts. Interviewee 13 stated: *''A single type of standardized, modular window frame, available in various sizes, was used for both the interior and exterior of the building''*.

A key enabling factor for implementing this strategy was the presence of a motivated and capable team. Interviewee 13 stated: *‘’A crucial principle for the developer was ensuring that frames on both the interior and exterior façades could be easily removed for maintenance or replacement’’*. Interviewee 12 added that the decision to use standardized products was also driven by the need to comply with sound and fire safety regulations. The design was carefully reviewed in collaboration with the constructor, with a focus on utilizing common wood sizes and materials that were readily available.

Technical complexities related to building products and materials posed challenges for reusing standardized elements. Since all walls were plastered, any modifications required demolishing plasterboards along with their plaster layer, making it difficult to reuse these materials. Interviewee 12 explained: *"What is demolished cannot be easily reused because it does not remain intact"*.

Another inhibiting factor was the legal and legislative restrictions associated with the building. The front façade is a municipal monument, which prevents the use of standardized products. The contrast between the monumental façade and the modernized façade is depicted in Figure 5.33.

Figure 5.33: Monumental (left) and modernized (right) façade (Res & Smit BV, 2021)

One interviewee from C3 rated the applicability of this strategy as "extremely applicable", two as ‘’very applicable’’, and one as "applicable". Regarding its effectiveness, one rated this strategy as ‘’extremely effective’’, two as ‘’very effective’’, and one as ‘’effective’’.

5.3.7. PROVISION OF A CORE FOR BUILDING SERVICES

Interviewee 13 stated: *‘’Designing the apartments required careful planning of the shaft and wet cell placement, ensuring they were stacked vertically for efficiency’’*. The sanitary section was centrally located in each apartment, with outdoor installations strategically placed in a central location on the roof. Interviewee 12 explained that the central technical room on the ground floor is divided into two distinct areas, as depicted in Figure 5.34. The first area serves as a laundry room with housing meter cabinets and shared washing machines for tenants who do not have their own technical space within their apartments. Behind this area is a closed section containing complex installations, such as heat units, which are inaccessible to tenants for safety reasons.

The economic viability of basic strategies served as an enabling factor, particularly in centralizing building services, which was crucial for maximizing rental income given the space constraints in C3. Interviewee 13 stated: *"The limited space necessitated smart design, so by centralizing the installations, we avoided allocating extra space for technical equipment in each apartment".*

Figure 5.34: Centralized technical room (own photo, 2024)

The findings did not identify specific inhibiting factors for this strategy in C3. However, interviewee 11 pointed out that in office buildings, technical rooms are typically centrally located, with pipes transported vertically and then distributed horizontally. Interviewee 11 stated: *‘’During demolition, outdated installations are often exported abroad since they no longer meet Dutch standards but can still be used elsewhere’’*. This situation underscores an inhibiting factor: the lack of data and warranties on old materials, which complicates their reuse and limits their applicability within the Netherlands.

All interviewees from C3 rated the applicability of this strategy as "extremely applicable". Regarding its effectiveness, two rated this strategy as ‘’extremely effective’’, one as ‘’very effective’’, and one as ‘’effective’’.

5.3.8. DESIGN FOR SURPLUS CAPACITY

The practical solution for this strategy was the placement of technical installations outside the apartments. According to Interviewee 13, this approach simplifies maintenance and facilitates easy upgrades or improvements in the future. The modular system employed, allows each apartment to be upgraded or downgraded as needed, providing flexibility and adaptability over time.

The presence of a motivated and capable team enabled this strategy, as the developer aimed to implement a technical installation system specifically tailored for the target group of tenants, primarily starters. Interviewee 13 stated: *‘’Because household compositions in the apartments can vary, a modular installation system was designed to accommodate these changes effectively’’*.

Interviewee 13 emphasized that vertical expansion is not feasible due to the existing plot and foundation, which have undergone multiple extensions over the years, as shown in Figure 5.35. Adding extra load-bearing elements would surpass the foundation's capacity and require additional costs. Moreover, significant expenses would be required due to the need for archeological and extensive soil research if a certain depth was exceeded during excavation. Interviewee 12 indicated that the municipality would not permit additional layers in the city center. Consequently, the economic infeasibility of innovative strategies, coupled with legal and legislative restrictions, were key inhibiting factors for this strategy.

Figure 5.35: Cadastral maps for the years 1879, 1897, and 1898 (Van Dam & Moerman, 2021)

Two interviewees from C3 rated the applicability of this strategy as ‘’somewhat applicable", and two as ‘’not applicable’’. Regarding its effectiveness, two rated this strategy as ‘’somewhat effective’’, and two as ‘’not effective’’.

5.3.9. DECENTRALIZATION OF THE DESIGN

Interviewee 13 stated: *‘’All building sections in [name of C3] are decentralized and can function independently’’*. The building features two distinct sides with varying space sizes. The front façade, which includes larger apartments and commercial space, has sufficient square meters to accommodate its own technical room. In contrast, the apartments on the back façade do not have enough space for individual technical rooms.

The use of digital technologies were an enabling factor for this strategy, as interviewee 13 stated: *"Each apartment has its own thermostat, allowing for decentralized control of the indoor climate"*. This approach optimizes space usage while providing tenants with individual control over their living environment.

Based on the interviews, there were not any specific inhibiting factors connected to this strategy.

One interviewee from C3 rated the applicability of this strategy as "very applicable", one as ‘’applicable’’, and two as "somewhat applicable". Regarding its effectiveness, one rated this strategy as ‘’effective’’, and three as ‘’somewhat effective’’.

5.3.10. DESIGN FOR A MIXED-USE

Interviewee 12 stated: *"In [name of C3], residential and commercial functions come together"*. The commercial space on the ground floor is designed for mixed-use, with water and toilet facilities positioned in a corner to create an open floor plan. This flexible layout allows for the potential addition of a café on the yard side or the conversion of the commercial space into two housing units, as natural light is available from both sides. Figure 5.36 illustrates the commercial space currently occupied by a bookshop.

Collaboration and partnerships between the developer, architect, and contractor were key enabling factors for this strategy. Interviewee 13 stated: *"At [name of C3], maximizing flexibility is crucial, as the building's function is likely to change multiple times over a hundred years"*. Recognizing this potential for adaptive reuse, the developer and architect strategically implemented an open floor plan and a decentralized design, thereby facilitating the creation of a mixed-use project that can easily adapt to future needs.

Legal and legislative restrictions posed significant challenges, as the municipality did not grant a permit for a full catering function on the ground floor. Interviewee 12 stated: *"The municipality limited the square footage allocated for catering, mandating that the space primarily function as a store with only a small catering section"*. This restriction hinders the process of finding a suitable tenant.

Figure 5.36: Current use of the commercial space (own photo, 2024)

One interviewee from C3 rated the applicability of this strategy as "extremely applicable", two as ‘’very applicable’’, and one as "applicable". Regarding its effectiveness, one rated this strategy as ‘’extremely effective’’, and three as ‘’effective’’.

5.3.11. UTILIZATION OF SECONDARY MATERIAL

Regarding secondary materials, none were sourced from other projects. Instead, the inventory process identified various materials within C3 that had reuse potential. Interviewee 11 emphasized that existing fixtures, railings, and entire staircases could be dismantled and reused if removed intact. Additionally, many construction materials were repurposed, as illustrated in Figure 5.37. Interviewee 13 stated: *"We managed to reuse about eighty percent of the wooden beams and preserve the original steelwork, with new materials added as needed"*.

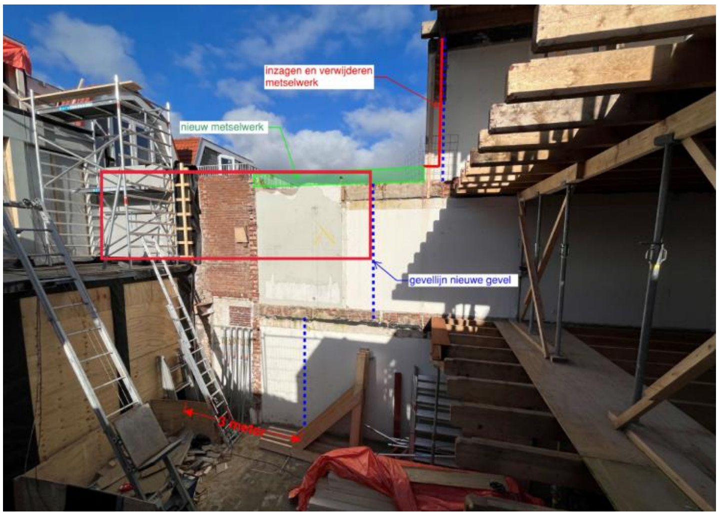


Figure 5.37: Situation during construction process (Res & Smit BV, 2021)

Collaboration and partnerships, along with the integration of digital technologies, were key enabling factors in this context. The early involvement of both the demolition contractor and the architect in C3's development demonstrates this approach. Interviewee 11 stated: *''We collaboratively created an inventory to identify reusable materials and used Xerax to produce detailed material passports, including dimensions, which were then provided to architects as valuable design and reuse resources''*.

Economic feasibility also played a crucial role as an enabler. Reusing materials such as steel, wood, and other building components significantly reduces the costs associated with purchasing new materials.

Additionally, interviewee 11 stated: *''The implementation of a CO_2 tax as a measure to discourage the purchase of new materials can facilitate reuse''*. Making the tendering process more financially attractive by offering discounts to construction companies that demonstrate circular practices could further enhance sustainability through policy and legislative support.

The inhibiting factors for this strategy included the technical complexities associated with building products and materials. Interviewee 11 explained that certain elements, such as MDF, laminated boards, and ceiling systems, were too deteriorated to be refurbished. Additionally, the mineral wool in the metal stud walls was damaged during dismantling, complicating efforts to reuse it. Interviewee 12 stated: *''Much of the wood was affected by rot and woodworm, significantly reducing its feasibility for reuse''*.

A lack of expertise was visible as interviewee 13 stated: *"There is also a lack of knowledge about where to find second-hand materials"*.

Additionally, the economic infeasibility of innovative strategies, along with a tendency to follow traditional paradigms, were regarded as significant inhibiting factors. Construction companies prefer new materials because the labour costs associated with preparing old materials are high. Interviewee 12 stated: *''When construction costs rise due to circular practices, these increased costs are typically passed on to real estate prices''*. Interviewee 11 added: *''The low demand for second-hand materials leads to surplus materials being discarded as waste''*.

Two interviewees from C3 rated the applicability of this strategy as "very applicable", and two as ''somewhat applicable''. Regarding its effectiveness, one rated this strategy as ''extremely effective'', one as ''very effective'', one as ''effective'', and one as ''somewhat effective''.

5.3.12. UTILIZATION OF BIOBASED MATERIAL

Initially, the plan for C3 involved constructing primarily with new concrete. However, after assessing the structure's reusability, wood was chosen as the primary material instead. Interviewee 13 stated: *''Much of the basic structure is made of wood, with the base floors composed of shredded wood used for levelling''*. The project also incorporates greenery on both the roof and terraces, as depicted in Figure 5.38.

Figure 5.38: Green roof (Res & Smit BV, 2021)

New business models were an enabling factor for this strategy. Interviewee 11 stated: *''Structural wooden elements, which lack potential for direct reuse, are* *mechanically removed from buildings and transported to a circular hub’’.* At the hub, these elements are cleaned and sawed into standard-sized beams, which are then repurposed for ceiling finishes.

The tendency to follow traditional paradigms were perceived as an inhibiting factor for this strategy. Interviewee 12 stated: *"We consciously chose materials that are widely used and whose effectiveness has been proven in the past"*. Interviewee 11 explained that producing biobased materials still requires significant energy and land, whereas reusing existing materials is more efficient as no additional energy is needed to create them. A lack of expertise further inhibits the adoption of this strategy, as interviewee 11 stated: *‘’Biobased materials are relatively new innovations, and their long-term durability remains uncertain’’*.

One interviewee from C3 rated the applicability of this strategy as "very applicable", two as ‘’applicable’’, and one as ‘’somewhat applicable’’. Regarding its effectiveness, one rated this strategy as ‘’extremely effective’’, two as ‘’very effective’’, and one as ‘’effective’’.

5.3.13. UTILIZATION OF CIRCULAR MATERIAL

In the C3, this strategy involved selecting new materials, such as aluminium window frames and bricks, for their long-term durability and low maintenance requirements. Interviewee 13 stated: *‘’Aluminium frames are particularly advantageous because they can be easily recycled and reused by melting them down. Similarly, bricks can be demolished, crushed, and repurposed into new products’’*.

New business models were considered an enabling factor for implementing this strategy. Interviewee 11, who specializes in circular material use, explained this approach: *"Redevelopment focuses on office buildings, residences, and factories, which are either transformed or completely demolished, involving three streams for reuse and high-grade recycling"*. Interviewee 11 explained these three streams as following:

1. First, directly reusable building materials, such as system walls, air conditioners, carpet tiles, and sanitary fixtures, are unscrewed, removed, and processed elsewhere.
2. Second, minor processes involve refurbishing or reprocessing, including sawing drywall into new panels, cutting construction steel to different sizes, and reusing wooden beams from demolitions.
3. Third, recycling converts materials into new products, such as concrete aggregate, mixed granulate, glass, and non-reusable wood. Mixed granulate is used for construction road foundations or as clean concrete for crane plate floors, ensuring high-grade recycling.

Technical complexities with building products and materials represented a significant inhibiting factor. Interviewee 12 stated: *‘’The primary challenge at [name of C3] is that materials are difficult to dismantle without causing damage during the deconstruction process’’*. Furthermore, older buildings often suffer from poor insulation and ventilation, which can result in moisture and leakage issues, leading to beams and other structural elements being damaged over time.

One interviewee from C3 rated the applicability of this strategy as "very applicable", one as ‘’applicable’’, and two as ‘’somewhat applicable’’. Regarding its effectiveness, two rated this strategy as ‘’very effective’’, one as ‘’somewhat effective’’, and one as ‘’not effective’’.

5.3.14. ALIGNMENT OF THE INTERCONNECTION BETWEEN THE FLOOR PLANS

The implementation of this strategy in the C3 lies in connecting the apartments within the long, narrow plot. The architect introduced the concept of a vertical courtyard by demolishing parts of the building, which ensured natural light and airflow throughout the structure, as depicted in Figure 5.39. Interviewee 13 stated: *"Outdoor spaces were integrated along the circulation route, effectively making the route part of the terrace"*. This innovative design reduced the need for separate stairwells and terraces, thus saving space and allowing for the inclusion of more apartments. Additionally, sightlines were carefully managed by incorporating different heights and split-levels between the apartments, enabling residents to see one another without directly looking into each other's spaces.

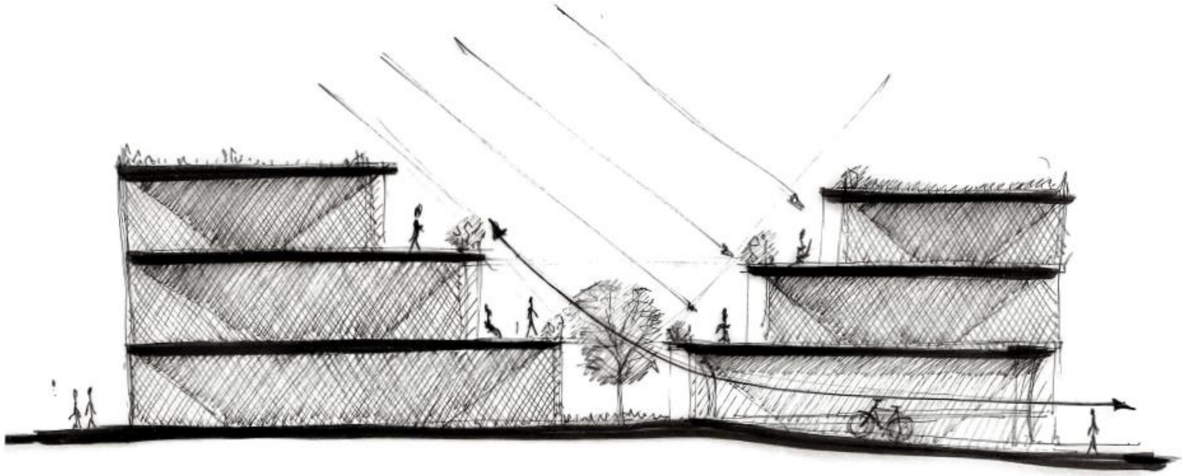


Figure 5.39: Section drawing of the ‘’new situation’’ (Up Architecture, z.d.)

The presence of a motivated and capable team was crucial in enabling this strategy, with the developer focusing on promoting social cohesion. Interviewee 13 explained: *‘’Apartment kitchens were strategically placed along the yards, except for one ground-floor unit with a front kitchen, to encourage resident interaction and foster a sense of community’’*. Interviewee 12 added: *"The sense of openness is enhanced by the lack of walls within the apartments, creating a smooth transition from the bedroom to the outdoor space"*.

The inhibiting factors for this strategy included legal and legislative restrictions associated with the economic infeasibility of innovative strategies. During demolition, efficient floor plans are essential, as project pricing is influenced by runtime and distance. Interviewee 11 stated: *"Efficient floor plans can minimize time loss during material transportation, reducing the distance covered and saving time and effort"*. However, the broader urban context in C3 was challenging because space constraints from surrounding buildings required extra care to minimize traffic issues and reduce noise pollution.

Two interviewees from C3 rated the applicability of this strategy as "extremely applicable", one as ‘’very applicable’’, and one as ‘’somewhat applicable’’. Regarding its effectiveness, two rated this strategy as ‘’extremely effective’’, and two ‘’very effective’’.

5.3.15 ALIGNMENT OF THE BUILDING DESIGN WITH THE PROPERTY PORTFOLIO

Place-making, social contributions, and user-oriented design were key components in the real state strategy for developing C3. Interviewee 13 stated: *''The goal was to create aesthetically pleasing and technically advanced apartments using high-quality, sustainable materials, with a particular focus on fostering socially engaging living spaces, especially for starters''*. This was achieved by incorporating features such as a shared laundry room and a yard with greenery that requires communal maintenance. Interviewee 13 stated: *"This social aspect seems to be a common thread in the developer's projects"*.

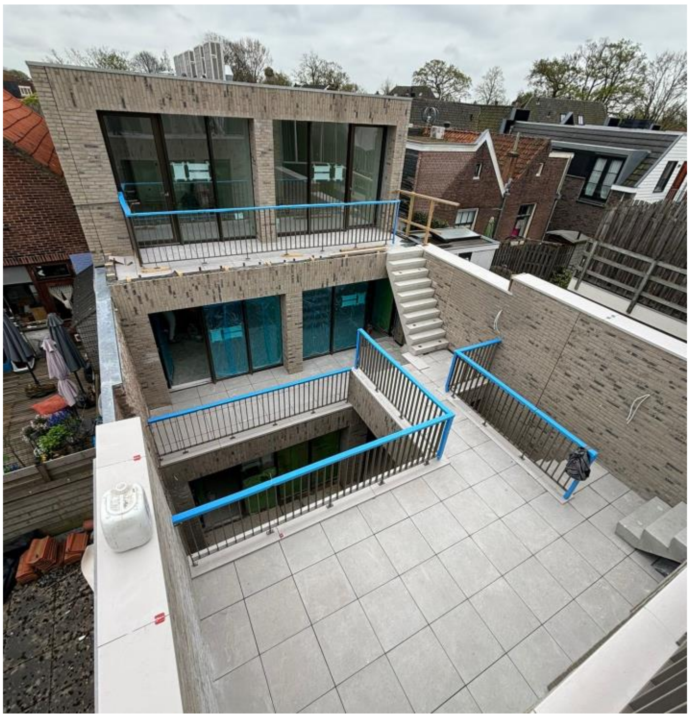


Figure 5.40: Current situation of inner yard (own photo, 2024)

The enabling factor for this strategy was the strong collaboration and partnership between the architect and developer, as both of whom share a socially-driven vision and have a history of working together on projects. Their past collaborations have consistently demonstrated a commitment to social cohesion, with each project making a positive contribution to the environment. Interviewee 13 stated: *"This approach ensures that individuals have privacy in their own spaces while also providing opportunities and facilities for connecting with the neighbourhood and other residents"*. Figures 5.40 and 5.41 illustrate the current and desired states of the yard.

Based on the interviews, there were not any specific inhibiting factors connected to this strategy.

Figure 5.41: Desired situation of inner yard (Res & Smit BV, 2021)

One interviewee from C3 rated the applicability of this strategy as "very applicable", two as ''applicable'', and one as ''not applicable''. Regarding its effectiveness, two rated this strategy as ''effective'', one as ''somewhat effective'', and one as ''not effective''.

5.4. CROSS CASE ANALYSIS C1-C2-C3

Subsections 5.1 to 5.3 covered the individual assessments of the strategies on the basis of each case. In this cross-case analysis, the results from all three cases were combined in Table 5.1. The quantitative part of the empirical research enabled the rating and ranking of each strategy based on participant assessments. Using the formulas from subsection 2.1.2, the RAI (Relative Applicability Index) and REI (Relative Effectiveness Index) were calculated for each strategy, providing rankings in each category.

These rankings enabled the formulation of the final RAEI (Relative Applicability Effectiveness Index) ranking. Table 5.2 presents a summary of all findings from the empirical research, consolidating the insights and rankings across all cases.

The following part provides a cross-case analysis for each strategy in line with the received ranking of RAEI.

Table 5.1: Results for C1-C2-C3 (own work, 2024)

Passive Strategies	Strategies for Circular Building Adaptability in Adaptive Reuse (CBASs)	Applicability										Effectiveness									
		Responses						Results & Interpretation				Responses						Results & Interpretation			
		Extremely Applicable	Very Applicable	Applicable	Somewhat Applicable	Not Applicable	n	Mean	RAI (%)	Rate	Rank	Extremely Effective	Very Effective	Effective	Somewhat Effective	Not Effective	n	Mean	REI (%)	Rate	Rank
*Exploring the Applicability and Effectiveness of Design-Oriented (Passive) CBA Strategies - **Cross Case Analysis C1-C2-C3***																					
1	Design Standardization	2	7	1	5	1	16	2,25	56,25	A	6	6	4	3	2	1	16	2,75	68,75	VE	4
2	Separation of Building Layers (e.g. Separated Walls)	0	5	8	3	0	16	2,13	53,13	A	9	1	7	3	5	0	16	2,25	56,25	E	8
3	Open the Floor Plan	5	8	3	0	0	16	3,13	78,13	VA	1	6	7	2	1	0	16	3,13	78,13	VE	1
4	Provision of Multi-Purpose Spaces	4	8	1	3	0	16	2,81	70,31	VA	2	3	10	3	0	0	16	3,00	75,00	VE	2
5	Modularization of Spatial Configuration (Layout)	1	4	4	4	3	16	1,75	43,75	A	14	1	7	2	3	3	16	2,00	50,00	E	11
6	Utilization of Standardized Building Products	3	4	6	3	0	16	2,44	60,94	A	4	4	5	2	4	1	16	2,44	60,94	E	7
7	Provision of a Core for Building Services	4	2	6	2	2	16	2,25	56,25	A	6	2	3	6	3	2	16	2,00	50,00	E	11
8	Design for Surplus Capacity	0	4	2	5	5	16	1,31	32,81	SA	15	1	4	4	4	3	16	1,75	43,75	E	14
9	Decentralization of Design	1	5	5	5	0	16	2,13	53,13	A	9	3	1	7	5	0	16	2,13	53,13	E	9
10	Design for a Mixed Use (Multifunctionality)	2	2	5	5	2	16	1,81	45,31	A	13	1	6	4	2	3	16	2,00	50,00	E	11
11	Utilization of Secondary (Reused/Recycled) Material	1	5	5	5	0	16	2,13	53,13	A	9	4	5	4	3	0	16	2,63	65,63	VE	5
12	Utilization of Biobased (Biological) Material	0	6	9	1	0	16	2,31	57,81	A	5	2	6	6	2	0	16	2,50	62,50	E	6
13	Utilization of Circular (Reuseable/Recyclable) Material	1	5	5	4	1	16	2,06	51,56	A	12	1	7	3	3	2	16	2,13	53,13	E	9
14	Alignment of the Interconnection Between the Floor Plans	2	6	6	2	0	16	2,50	62,50	A	3	3	10	3	0	0	16	3,00	75,00	VE	2
15	Alignment of the Building Design with the Property Portfolio	0	8	4	3	1	16	2,19	54,69	A	8	0	4	6	4	2	16	1,75	43,75	E	14

Table 5.2: Final ranking of CBASs (own work, 2024)

Circular Building Adaptability Strategies (CBASs)	RAI (%) Applicability	REI (%) Effectiveness	RAEI (%) Final Ranking
1. Open the Floor Plan	78,13	78,13	61,04
2. Provision of Multi-Purpose Spaces	70,31	75,00	52,73
3. Alignment of the Interconnection Between the Floor Plans	62,50	75,00	46,88
4. Design Standardization	56,25	68,75	38,67
5. Utilization of Standardized Building Products	60,94	60,94	37,14
6. Utilization of Biobased Material	57,81	62,50	36,13
7. Utilization of Secondary Material	53,13	65,63	34,87
8. Separation of the Building Layers	53,13	56,25	29,89
9. Decentralization of the Design	53,13	53,13	28,23
10. Provision of a Core for Building Services	56,25	50,00	28,13
11. Utilization of Circular Material	51,56	53,13	27,39
12. Alignment of the Building Design with the Property Portfolio	54,69	43,75	23,93
13. Design for Mixed-Use	45,31	50,00	22,66
14. Modularization of Spatial Configuration	43,75	50,00	21,88
15. Design for Surplus Capacity	32,81	43,75	14,35

5.4.1. OPEN THE FLOOR PLAN

Creating flexible, open layouts by maintaining high ceilings and essential structural elements was a practical solution for this strategy, as noted in C1 and C3. In C2 it was necessary to remove non-load-bearing walls to create large open spaces, supported by a column-based structure that facilitated flexibility and reconfiguration. The results in Table 5.1 indicate that this strategy has the highest applicability, as reflected by the RAI score of 78,13. Its effectiveness is also the highest, with a comparable REI score (Table 5.1).

5.4.2. PROVISION OF MULTI-PURPOSE SPACES

The results show that this strategy is closely linked to the previous one. In C1 and C3, the structural delivery of the buildings offered flexible open floor plans that allowed residents to customize their living spaces and outdoor areas. C2, on the other hand, focused on creating shared spaces that encouraged interaction, with rooms designed for various functions such as work, meetings, and relaxation. This strategy received high marks for both applicability and effectiveness, ranking second in both categories according to Table 5.1.

5.4.3. ALIGNMENT OF THE INTERCONNECTION BETWEEN THE FLOOR PLANS

Each case implemented the strategy differently. C1 preserved monumental corridors and connected apartments through outdoor spaces with cohesive tiles and landscaping. C2 created multifunctional spaces that blended through material choices and zoning, avoiding major structural changes. C3 introduced a vertical yard to connect apartments in a narrow plot, integrating outdoor spaces along circulation routes. This strategy is ranked third for applicability and second for effectiveness, as shown in Table 5.1.

5.4.4. DESIGN STANDARDIZATION

Maintaining the existing window structures seemed to be a possible solution for this strategy, as noted in all three cases. Due to the large size of C1, a standardized window frame could be replicated 150 times across the façade. In contrast, C2 and C3 incorporated standardized openings and uniform window frames that aligned with the existing grid of their façades. Its applicability is moderate, because this strategy was ranked sixth (Table 5.1). However, its effectiveness is high, because it was ranked the fourth.

5.4.5. UTILIZATION OF STANDARDIZED BUILDING PRODUCTS

The use of standardized building products varied across the three cases. In C1, standardized roof panels, steel columns, and prefabricated walls were employed to meet the building's dimensions and safety requirements. C2 focused on standardizing finishes, cladding, façades, and window systems. In C3, most elements adhered to standard dimensions, including panels, wood, insulation materials, installations, fire shaft hatches, and modular window frames that could be easily dismantled. The strategy's applicability is relatively high, ranking fourth in Table 5.1, but its effectiveness is moderate, with a ranking of seventh.

5.4.6. UTILIZATION OF BIOBASED MATERIAL

This strategy's implementation in the three cases prominently featured wood. In C1, wood was used for structural elements like beams and new window frames, with lime mortar for stone repairs. C2 integrated wood with other natural materials, such as bricks and bamboo, to blend indoor and outdoor spaces. C3 also prioritized wood, using it over concrete for much of the structure and base floors. Both C2 and C3 installed green roofs to manage rainwater runoff. This strategy ranks fifth for applicability and sixth for effectiveness, as shown in Table 5.1.

5.4.7. UTILIZATION OF SECONDARY MATERIAL

Some interviewees confused this strategy with reusing materials from the existing building, rather than using secondary materials from other projects. This confusion was particularly evident in C1 and C3. However, in C1, the strategy involved reusing old roof tiles and supplementing them with second-hand ones. In C2, second-hand tiles were used both inside and outside the building. Additionally, the ceiling featured reused beams from a previous project. This strategy ranked low in applicability, placing ninth, while it was considered moderately effective, securing fifth place, as indicated in Table 5.1.

5.4.8. SEPERATION OF BUILDING LAYERS

Each case implemented this strategy differently. In C1, prefabricated partition walls were installed through openings in the roof and floors, using dry connections between the existing building and new sections allowing for easy disassembly. C2 used timber frame construction and box-in-box methods to enable dismantling and repurposing of building sections. In C3, the strategy allowed for flexible apartment layouts by removing non-load-bearing walls without damaging the structure. Due to the challenging adjustments required, this strategy scored low in both categories. Table 5.1 shows it ranked ninth in applicability and eighth in effectiveness.

5.4.9. DECENTRALIZATION OF DESIGN

In C1 and C3, decentralization was achieved by converting the building into individual homes. C2 implemented the strategy by disconnecting floors and functioning as separate rental units, each with its own installations. This strategy received moderate rankings in both categories, ranked ninth in each (Table 5.1).

5.4.10. PROVISION OF A CORE FOR BUILDING SERVICES

Centralizing and stacking wet zones and ventilation systems emerged as a viable solution for this strategy, as seen in C1. C2 also utilized a centralized mechanical system in the pantry zone, alongside a passive ventilation preference. In C3, all building services were centralized, including a shared technical room on the ground floor, optimizing space and maximizing rental income, which was critical due to limited space. The strategy's applicability is moderate, ranking sixth, but its effectiveness is low as it has been ranked the 11th (Table 5.1).

5.4.11. UTILIZATION OF CIRCULAR MATERIAL

Demountable steel columns were used in both C1 and C2, allowing for future reuse and masonry restoration in C1, and supporting the box-in-box construction in C2. Additionally, both C2 and C3 implemented this strategy by choosing durable, recyclable materials, such as built-on elements that could be dismantled and reconfigured in C2, and aluminium window frames and bricks in C3. This strategy scores relatively low in both applicability and effectiveness, ranking 12th in applicability and ninth in effectiveness (Table 5.1).

5.4.12. ALIGNMENT OF THE BUILDING DESIGN WITH THE PROPERTY PORTFOLIO

In C1 and C2, the strategy focused on integrating new constructions that harmonized with the existing architectural context. In C3, the approach aimed to create technically advanced, socially engaging apartments. This strategy ranked eighth in applicability and 14th in effectiveness, as shown in Table 5.1.

5.4.13. DESIGN FOR A MIXED-USE

In C1, the strategy was not implemented due to legal and legislative restrictions that limited the building to residential use. In contrast, C2 was designed with the flexibility to accommodate both residential and office functions, enabled by policy support and economic viability, though it faced challenges with noise insulation and structural adaptations. C3 effectively combined residential and commercial spaces, with an open floor plan that allowed for easy future conversions. The strategy's applicability is relatively low, ranked 13th, and its effectiveness is also low, with a ranking of 11th (Table 5.1).

5.4.14. MODULARIZATION OF SPATIAL CONFIGURATION

In C1, modularization was conceptually applied, treating each home as a replaceable module, but the building's solid structure and need for major modifications limited its practicality. C2 effectively implemented modularization in its fully dismantlable extension. Distinct, easily removable modules were also integrated into the open floor plan to accommodate various working environments. In C3, modularization was used to convert a large warehouse into apartments, offering some flexibility with non-load-bearing walls. This strategy ranks 14th in applicability and 11th in effectiveness, as shown in Table 5.1.

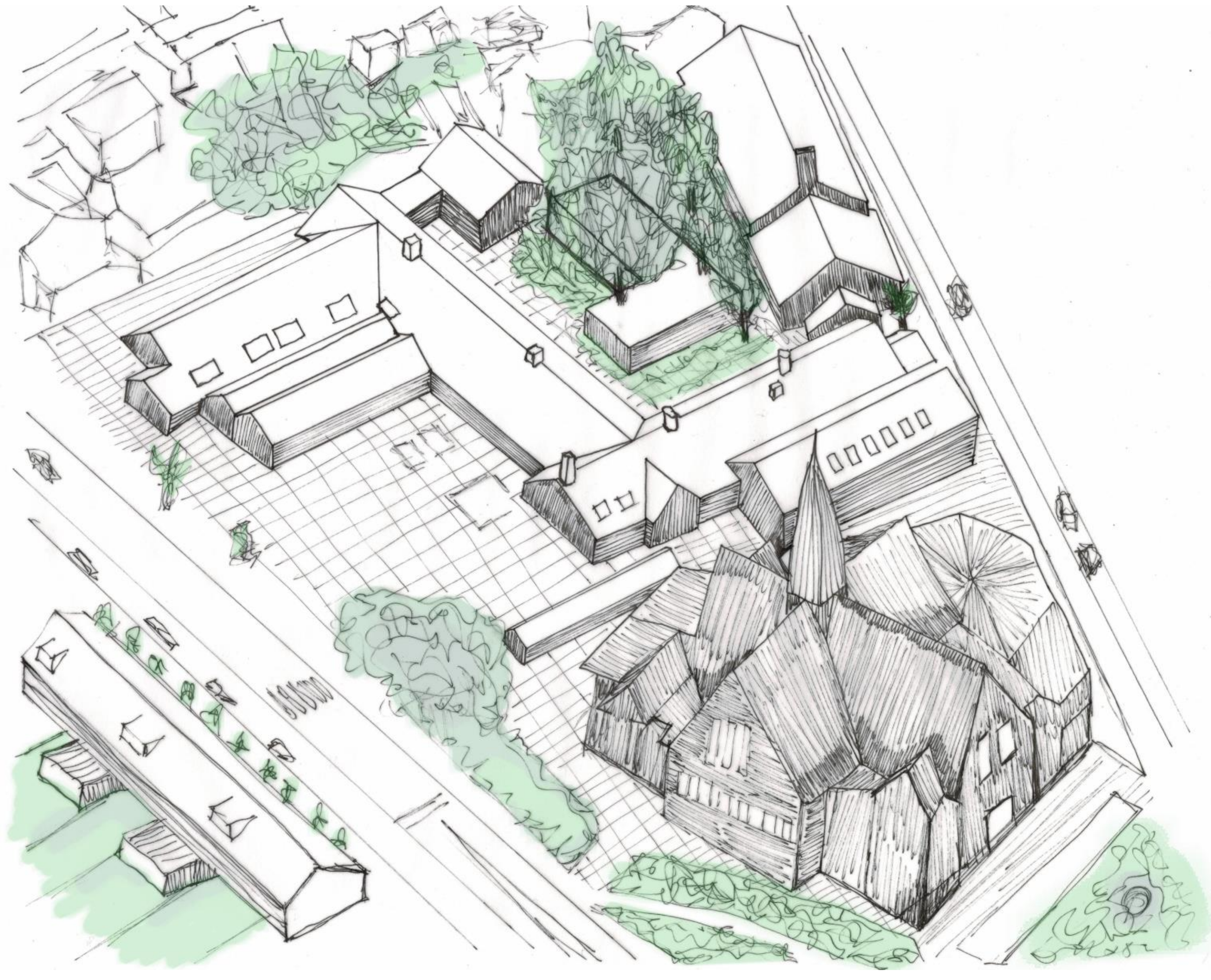
5.4.15. DESIGN FOR SURPLUS CAPACITY

Both C1 and C2 were prepared for future expansion, with C1's foundation reinforced to support potential vertical growth, and C2 designed with a strong concrete structure to accommodate future development. In C3, the strategy focused on modular technical installations that allowed for flexibility in upgrades. However, legal and regulatory restrictions in all three cases limited the potential for adding extra layers. As a result, this strategy ranked lowest in applicability (15th) and near the bottom in effectiveness (14th), as seen in Table 5.1.

Chapter 6

Application of CBASs in a Case Study Design

C4



6. APPLICATION OF CBAS$_S$ IN A CASE STUDY DESIGN

6.1. WORKSHOP 1

In this workshop, the researcher reviewed the empirical study results (Chapter 5) with five practitioners acquainted with the framework and the CBASs. Referring to Table 4.3 in Chapter 4, Table 6.1 presents the participants in this workshop, which include professionals numbered 5, 8, 9, 13, and 14a/b/c.[1] This diverse group included individuals from all three case studies, representing various roles such as architect, landscape architect, project manager, developer, and owner. By selecting participants knowledgeable about CBASs but not directly involved with C4, the researcher aimed to gather objective insights without the influence of specific conditions or limitations of C4. This approach helped in formulating principle-driven design strategies for C4.

Table 6.1: Workshop 1 participants from the three case studies (own work, 2024)

Case 1	Case 2	Case 3
1. FH - Contractor	**6.** AB - Architect	**11.** HH - Circularity Expert
2. HvM - Sub-contractor	**7.** DD - Technical Architect	**12.** NJ - Contractor
3. PS - Architect	**8.** EB - Project Manager	**13.** RJR - Architect
4. RT - Construction Engineer	**9.** RvD - Developer	**14c.** MS - Owner Developer
5. RB - Landscape Architect	**10.** WK - Architect	
14a. MS - Owner Developer	**14b.** MS - Owner Developer	

To set up and ease the discussion of the strategies within the available timeframe, the CBASs were organized into three themes as follows:

1. **Integrated Spaces:** This theme aims to maximize the utility of space by incorporating shared or multi-functional areas that can accommodate different activities, thus promoting community and enhancing social interactions. The strategies related to this theme are depicted in Figure 6.1.

2. **Design Flexibility:** The strategies related to this theme, as shown in Figure 6.2, ensure that adaptive reuse projects can easily be modified or adapted for future needs without significant structural changes.

3. **Material Efficiency:** This theme focuses on optimizing the use of resources by reducing waste and ensuring that building materials can be reused or recycled at the end of their life cycle. The strategies related to this theme are depicted in Figure 6.3.

[1] The highlighted informants in yellow are the informants who participated in Workshop 1.

6.1.1. THEME 1: INTEGRATED SPACES

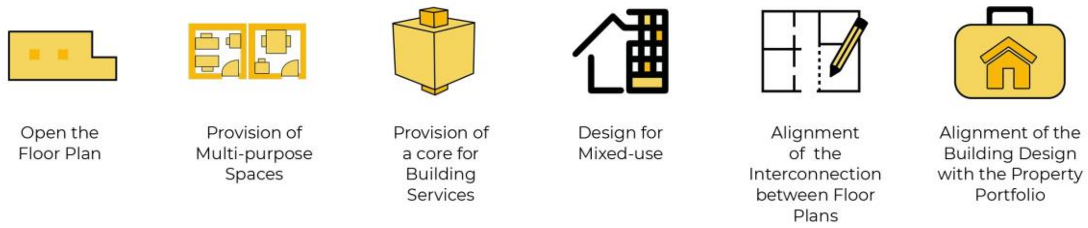


Figure 6.1: CBASs related to theme 1 - Shared Spaces (own work, 2024)

C4 is similar to C2 in terms of the functional profile as it is an old school building with a monumental structure where the "Open the Floor Plan" strategy could be applied at the housing level. Participant 13 explained: *"Instead of demolishing parts, the structure can be used to integrate housing units, allowing for flexible and open layouts within them"*. The current floor plan, illustrating this potential, is depicted in Figure 6.2.

Participant 9 stated: *''By retaining the sport facility, "Provision of Multi-Purpose Spaces" and "Design for Mixed-Use" can be implemented''*. Given the target group of individuals with care needs and seniors, this space could be transformed into a community center that provides a shared living room, kitchen, and laundry facilities. It could also support care-related daytime activities, such as cooking, where community members prepare food for the complex's residents. According to participant 9, this approach would enhance social oversight and create a vibrant hub within the neighbourhood, benefiting not only the residents of the complex but also the surrounding community.

Regarding the provision of a core for building services, the current stretched structure makes this strategy less feasible due to the extensive piping lengths required. Participant 14 indicated that a core for building services is more effective in concentrated, stacked buildings. Participant 9 added that, in this context, it is more practical to manage installations at the individual housing level.

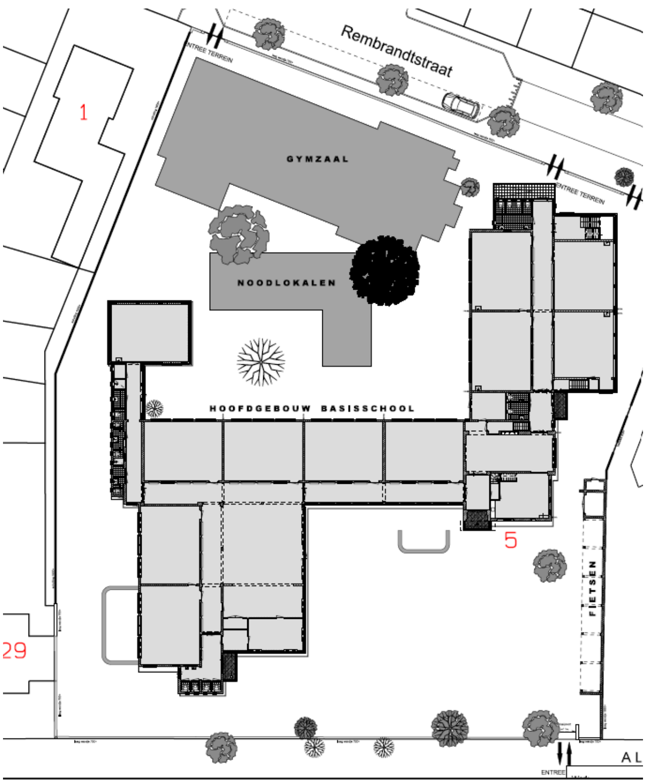


Figure 6.2: Current structure C4 (Res & Smit BV, 2022)

After reviewing the concept drawing depicted in Figure 6.3, participant 14 highlighted the unique opportunity within this project to create a double yard structure, taking advantage of the urban layout. Rather than adding a new building that might not align with the existing urban context, this approach could be achieved by building upon the existing structure instead of choosing demolition and new construction. Participant 5 further suggested orienting the front doors of the housing units to face the yards and incorporating the hallway spaces into the housing units, thereby establishing a communal garden space that enhances the sense of community within the development.

Participant 5 stated: *''Clients in the healthcare sector have strict requirements for addressing care needs, which makes it more challenging to redevelop such buildings and assign new functions''*. Participant 14 added that many buildings being demolished are healthcare facilities because their designs are based on certain demands in a specific period. Participant 14 stated: *"These healthcare organizations design buildings specifically around their current needs, which can be very different in ten or twenty years"*. Consequently, participant 5 recommended involving the right stakeholders at the beginning of the process to develop a long-term plan and incorporate features that allow for easier adaptation and change over time.

Figure 6.3: Concept drawing with newly built part (Res & Smit BV, 2022)

6.1.2. THEME 2: DESIGN FLEXIBILITY

Figure 6.4: CBASs related to theme 2 - Design Flexibility (own work, 2024)

Participant 14 stated: *''The degree of standardization in this project is low due to its limited size. For projects larger than 10,000 m^2, such as [name of C1], standardization becomes appealing due to the repetition possible at that scale"*. In contrast to urban projects like C3, there is much construction space at C4, making on-site building more cost-effective.

If it turns out that more housing is needed than the current structure can accommodate, parts of the school that were added over the years could be demolished to make way for new construction. Figure 6.5 illustrates these additions over time. Participant 9 stated: *"In the historical part of the school, it is challenging to incorporate modularity or separate building layers, whereas this is feasible if there are newly built parts"*.

Participant 5 stated: *"New buildings are increasingly being constructed with less structural integrity to save on materials and costs, limiting the potential for adding extra floors"*. In contrast, older buildings like C4 often feature a degree of overengineering, which offers potential for vertical expansion. However, participant 9 pointed out that obtaining a permit for such expansion from the municipality is unlikely due to C4's heritage status.

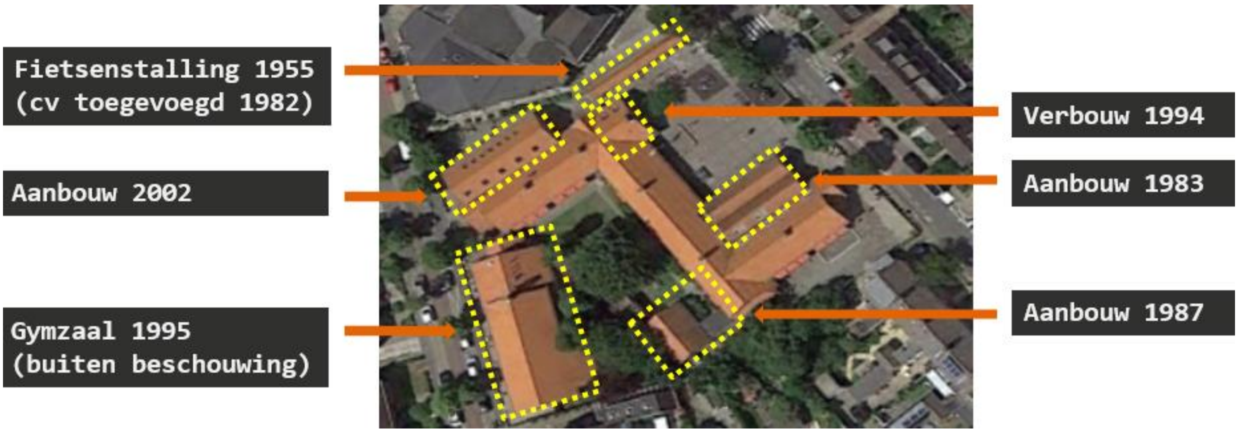


Figure 6.5: New added parts over time (Res & Smit BV, 2022)

From a developer's perspective, participant 14 added that vertical expansion would be possible if it involves owner-occupied homes, as it would increase the total square footage. Participant 14 stated: *"For any home over 80 m², each additional square meter doesn't yield much benefit because the absolute rent price becomes too high"*.

Participant 5 suggested that it would be beneficial to have housing installations centrally managed by professional caregivers. In response, participant 9 explained that for residents with low-care needs, it is preferable for the homes to operate independently, as this allows caregivers to provide more personalized care. Participant 9 stated: *''A centralized design suits yards better, as it fosters community, mutual care, and independence without relying heavily on professional caregivers''.* Participant 9 also mentioned that incorporating a communal living room and kitchen centrally in the design would support this concept.

6.1.3. THEME 3: MATERIAL EFFICIENCY

Figure 6.6: CBASs related to theme 3 - Material Efficiency (own work, 2024)

Participant 13 stated: *''Standard construction products could be effectively utilized in this project by employing prefabricated partition walls and assembly kits for sanitary elements, which would be put together on-site''*. Participant 5 suggested that timber frame construction would be a valuable method for this project. Additionally, participant 14 proposed that prefabricated wooden units could be stacked for any new construction parts.

The use of secondary materials, however, depends on the condition of the existing building. Participant 9 stated: *''It would be more practical to consider demolishing and rebuilding certain sections if the current structure is in such poor condition that extensive work would be required to make materials reusable''*. Participant 13 explained that materials from the demolished parts of the old building could potentially be repurposed for use in the new construction sections.

6.1.4. DESIGN STRATEGY FOR C4

Together with the participants, the design strategy in Table 6.2 was formulated based on the outcomes of Workshop 1:

Table 6.2: Design strategy based on Workshop 1 (own work, 2024)

Theme 1: **Integrated Spaces**	**Theme 2:** **Design Flexibility**	**Theme 3:** **Material Efficiency**
1. Removing non-load-bearing walls to create flexible and open residential spaces; thereby improving adaptability for future uses. **2.** Creating multifunctional spaces by transforming the sports facility into a community center that support various community and recreational activities. **3.** Centralizing essential building services within easily accessible cores. **4.** Fostering community engagement by creating yards around the school building that facilitates interaction, promotes shared activities like gardening, and improves the social environment. **5.** Designing for long-term flexibility and adaptability to meet changing needs.	**6.** Using modular and demountable construction methods for new construction, and preserving the historical sections of the building where possible. **7.** Future-proofing the building by reserving space for potential growth and designing for additional technical systems or structural elements. **8.** Designing housing units to function independently for low-care needs.	**9.** Using standardized building components for easier reuse. **10.** Integrating biobased, renewal materials like timber frame construction and prefabricated wooden units for all new construction. **11.** Evaluating the building's condition to determine if materials from demolished sections can be reused in new construction. Where feasible, these materials will be retained to preserve historical integrity and minimize waste.

6.2. WORKSHOP 2

The second workshop was conducted with professionals who had not participated in the empirical phase of this research and were therefore unfamiliar with the CBASs. These participants, who were also direct stakeholders in the project, were selected to provide an unbiased and fresh perspective on the design strategy. Table 6.3 lists the workshop participants, identified as professionals 15, 16, and 17. The participants included the project leader from the housing corporation that owns the project, an external project manager, and the architect responsible for the new design.

Table 6.3: Workshop 2 participants (own work, 2024)

Case 4
15. MP - Owner (Housing Corporation)
16. BD - Project Manager
17. NA - Architect

These participants were selected based on their direct connection to C4 and knowledge about its distinctive characteristics, including its physical structure, historical significance, and user requirements. By involving professionals associated with C4, the researcher ensured that the design strategy developed during the first workshop could be adapted to meet the specific needs of C4. This approach facilitated the provision of context-specific and practical feedback for developing an action plan based on design proposals aligned with the CBASs.

6.2.1. DESIGN PROPOSALS

To maintain continuity with the first workshop, the same themes—Integrated Spaces, Design Flexibility, and Material Efficiency—were employed to guide discussions in the second workshop. Figure 6.7 illustrates the interrelation between Workshop 1 and Workshop 2. Firstly, the researcher categorized the CBASs under the three themes. During Workshop 1, which consisted of three rounds, each theme was addressed, and together with the participants, a design strategy was developed for C4. This design strategy then served as the foundation for creating the design proposals, which were discussed in detail during Workshop 2. In these discussions, participants from Workshop 2 critically evaluated the design proposals, arguing why certain elements were or were not applicable. The insights gained from this second workshop contributed directly to the development of an action plan based on the design proposals.

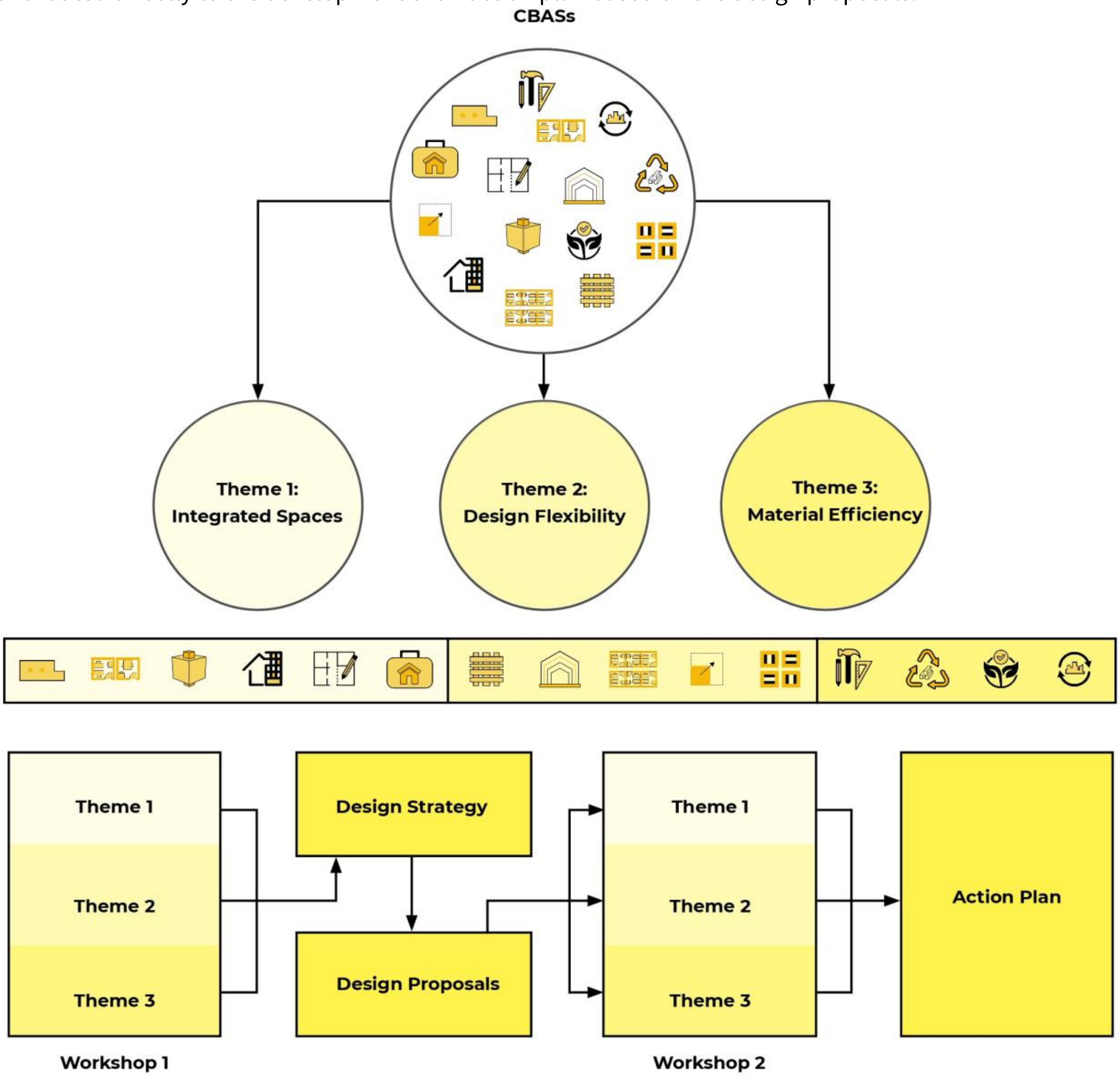


Figure 6.7: Interrelation between Workshop 1 and 2 (own work, 2024)

THEME 1: INTEGRATED SPACES

*Design Proposal 1 aligns with the strategy **Open the Floor Plan**, and involves removing non-load-bearing walls to create flexible and open residential spaces; thereby improving adaptability for future uses.*

In relation to design proposal 1, the former assembly hall offers the most open space, presenting a significant advantage for the design of residential units. Additionally, each classroom in C4 is rectangular and enclosed by load-bearing walls. Participant 17 stated: ‘’*The benefits of the existing layout, with load-bearing walls that reduce sound transmission, provide flexibility, making the building highly multifunctional*’’.

Furthermore, the intended tenants in this project belong to a specific target group—individuals in need of care. Participant 16 noted: *"This allows us to design smaller residential units, transforming each classroom—ranging from 40 m² to 50 m²—into a functional living space’’.*

Figure 6.8: Part with the stained glass window (Bouwer, 2017)

However, there are areas where creating residential units is not feasible. Participant 15 stated: *‘’In existing buildings, achieving openness is more challenging, particularly in this project, where the new layout is directly influenced by the building's original structure’’*. Figure 6.8 illustrates the part of the building with the stained glass window, which exemplifies a complex space with load-bearing walls and multiple staircases. Participant 15 further explained: *‘’Our target group consists of autistic young adults who are sensitive to busy and visually overwhelming environments. Additionally, we cannot simply remove the window due to its heritage value, which significantly contributes to the monumental character of the project’’*.

*Design Proposal 2 aligns with the strategies **Provision of Multi-Purpose Spaces** and **Design for Mixed-Use**, and involves creating multifunctional spaces by transforming the sports facility into a community center that support various community and recreational activities.*

Participant 16 stated: *‘’Initially, we explored transforming the sports facility—a large open space—into residential units by adding non-load-bearing walls. However, the limited number of units made the project financially unfeasible’’*. To meet the required density, the project team decided to demolish sections, including the sports facility, and proceed with new construction. Figure 6.9 presents the design sketches depicting the transformation of the sports facility into residential units.

Figure 6.9: Initial design sketches with housing in the sport facility (Res & Smit BV, 2022)

Another early concept was to connect the neighbouring church, which included a small community center, with the new design. However, participant 15 stated: *‘’We realized that the need for communal spaces in our design was too large and too specific to be accommodated within the available space in the church’’*. For this reason, communal spaces such as shared living rooms, laundry areas, and kitchens have been integrated into C4, making it a mixed-use building that combines healthcare and residential functions. Participant 15 further noted: *''The target group is unable to live independently, relying on the communal spaces for most daily activities, while their private units are used primarily for sleeping or hosting visitors''*.

Participant 16 added: *''These multifunctional spaces are not financially profitable, as they do not generate direct rental income. However, despite the negative financial outlook, we chose to include them due to our social responsibility to provide housing for vulnerable groups''*.

Design Proposal 3 aligns with the strategy ***Provision of a Core for Building Services****, and involves centralizing essential building services within easily accessible cores.*

In relation to design proposal 3, participant 16 stated: *''The building's length can be utilized by placing installations in the attic space of the existing structure and distributing the pipes horizontally above the residences''*. Figure 6.10 illustrates the attic where the installations could potentially be placed. Participant 17 further noted: *''In the new construction section, an installation core can be integrated in the underground parking area''*.

Participant 15 added: *''The stacking of sanitary facilities is possible in the new construction section, with piping aligned vertically by connecting as many service shafts as possible''*.

Figure 6.10: Old situation of the attic used as storage space (Bouwer, 2017)

Design Proposal 4 aligns with the strategy ***Alignment of the Interconnection Between Floor Plans****, and involves fostering community engagement by creating yards around the school building that facilitates interaction, promotes shared activities like gardening, and improves the social environment.*

Participant 15 stated: *''Creating a double yard structure is not feasible, as the municipality's urban planning and heritage departments have specified that only green spaces can be added to the existing schoolyard, with no other modifications permitted''*. Figure 6.11 shows the existing schoolyard, which is part of the municipal heritage. To address parking, an underground garage is proposed, which requires a sufficient number of housing units to be financially viable. Participant 16 noted: *''With the double yard structure, achieving the required number of housing units to make underground parking feasible would not have been possible''*.

Figure 6.11: Current situation of the schoolyard (Res & Smit BV, 2022)

Additionally, the building's façade is part of the municipal heritage, preventing the addition of front doors facing the yard. Participant 16 stated: *''Although it is technically feasible to create larger units by removing the wall separating the hallway from the residences, heritage restrictions do not allow this modification''*.

Participant 17 added: *"The new design incorporates a triangular yard, achieved by positioning the new construction slightly farther from the existing building. This was done to create a low-stimulus outdoor space for our target group''*. The layout of the new design, along with a render showcasing the triangular yard, is presented in Figures 6.12 and 6.13.

Figure 6.12: Render of the yard (Res & Smit BV, 2022)

Figure 6.13: Most recent design (Res & Smit BV, 2022)

Design Proposal 5 aligns with the strategy ***Alignment of the Building Design with the Property Portfolio****, and involves designing for long-term flexibility and adaptability to meet changing needs by allowing for easy conversion between different housing types.*

Regarding design proposal 5, participant 15 stated: *''If the care providers leave in the long term, I am confident that the care units can be transformed into regular housing due to the open floor plans without complex load-bearing structures''*. Participant 17 added: *''The studios we have designed on the upper floors can easily be converted into two-bedroom apartments by combining multiple studios''*.

Participant 17 stated: *''A limitation in the new construction is the inability to optimize floor heights due to financial constraints and zoning regulations, resulting in ceilings that meet only minimum building code requirements''*. In contrast, the old school building offers greater flexibility with higher ceilings and attic space, though this is somewhat limited by its historical status.

Additionally, participant 16 noted: *''This project is being developed for multiple care foundations, with long-term lease agreements in place, ensuring that changing care needs will not be an issue for the housing association''*.

THEME 2: DESIGN FLEXIBILITY

Based on the outcomes of Workshop 1, there was not any specific design proposal mentioned that aligned with the strategy, ***Design Standardization***. However, participant 16 stated: *''In the new construction section, the façade openings are uniform, with all window frames being the same size''*. Participant 17 added: *''The floor plans in the existing school building can be repeated in the classrooms''*. The repeating floor plans in C4 are shown in Figure 6.14. Additionally, the kitchen and bathroom layouts are fairly standard. However, they are not prefabricated elements due to the small and specific space available for construction.

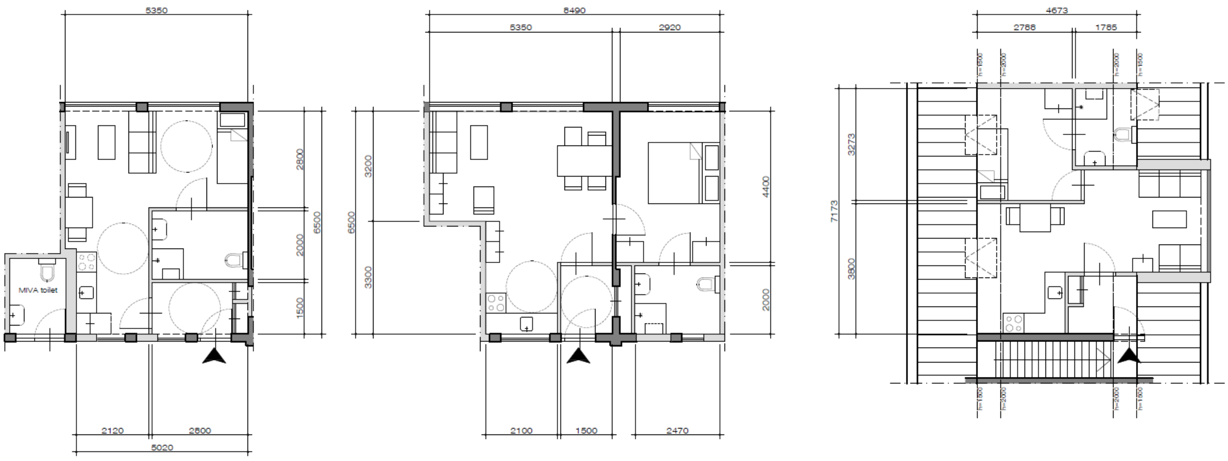


Figure 6.14: Repeating floorplans in C4 (Res & Smit BV, 2022)

*Design Proposal 6 aligns with the strategies **Separation of the Building Layers** and **Modularization of Spatial Configuration**, and involves using modular and demountable construction methods for new construction, and preserving the historical sections of the building where possible.*

In relation to design proposal 6, participant 16 explained that modular construction is too complex for C4 due to two reasons. First, the diverse layouts of the apartments make modular solutions impractical and costly. Second, the contractors involved tend to be traditional and hesitant to adopt different construction methods. Interviewee 16 stated *''While there are linear sections suitable for modular construction and corners that could be handled with traditional methods, this approach remains unsuitable for the project, as no contractor is willing to adopt such an innovative approach''.*

According to participant 17, the construction sector limits its own potential in many ways. Participant 17 stated: *''Due to traditional thinking and the drive to complete projects quickly, there is little room for innovation and improvement''*.

Participant 15 further added: *''In traditional building methods, as used in this project, demounting is generally more complex, though components such as window frames, windows, and doors can still be removed during demolition. The main distinction lies in larger elements like façades and floors, which are significantly easier to deconstruct in modular construction compared to traditional methods''*.

*Design Proposal 7 aligns with the strategy **Design for Surplus Capacity**, and involves future-proofing the building by reserving space for potential growth and designing for additional technical systems or structural elements.*

Participant 17 stated: *''The existing school building cannot be extended vertically due to technical challenges related to insufficient foundations. Additionally, the municipality of Westland has set a height limit for* *construction. Even if it were technically feasible, the neighbourhood would likely oppose it, and there would be a shortage of parking spaces''.*

Participant 16 explained further that it is not practical to allocate extra budget on reinforcing the foundation of the new construction for future expansions, as it is hard to justify given the limited experience with vertical extensions. Participant 16 stated: *''Expansions are only considered when there is a clear demand''*. Participant 15 added: *''Within the limited possibilities and available resources, considering the zoning plan and budget, we have managed to design the most optimal layout focused on the current needs''*. Figure 6.15 shows the façade view of the front, highlighting the height of the newly constructed section of C4.

Figure 6.15: Façade view of the front (Res & Smit BV, 2022)

Participant 16 noted: *''What we could do, however, is initiate discussions about potential short-term changes. For instance, if the communal spaces are eventually transformed into residential units, it would be more efficient to install larger air handling units now, with higher capacities than originally planned''*.

*Design Proposal 8 aligns with the strategy **Decentralization of the Design**, and involves designing housing units to function independently for low-care needs.*

In relation to this design proposal, participant 15 stated: *''Since our target group consists of individuals with care needs, the requirements for indoor climate may vary from person to person. Therefore, an individualized approach within the homes is essential. However. the communal spaces will be managed by the care providers''*.

Participant 16 added: *''A decentralized solution is also desirable for future scenarios where a different target group might use the building. In the case of regular rental, each homeowner could manage and settle their energy bills individually''*.

THEME 3: MATERIAL EFFICIENCY

*Design Proposal 9 aligns with the strategy **Utilization of Standardized Building Products**, and involves using standardized building components for easier reuse.*

Regarding this design proposal, participant 15 stated: *''Due to the relatively small scale of the project, installing prefab bathrooms would have been costly and labour-intensive, requiring multiple openings in the roof to place the units''*. Participant 17 added: *''We considered using a click-brick system for the new construction* *façade instead of traditional bricks, but we needed to match the existing building's appearance and couldn't find a contractor willing to work with the system''*.

Participant 16 commented on this, stating: *''Innovative ideas are often unfamiliar to the parties we work with, making them less appreciated and ultimately not chosen. I believe that if you have a clear vision as a client, you should take the time to fully develop it and select the right partners. In this project, due to time pressure and the need for quick decisions, we choose for the safest route. With more time and knowledge of these strategies, we could have explored them further''*. Participant 17 added: *''Sustainability doesn't have to be more expensive if it's integrated from the start. New construction offers that opportunity, whereas existing buildings often present limitations and require compromises''*.

Design Proposal 10 aligns with the strategy ***Utilization of Biobased Material****, and involves integrating biobased, renewal materials like timber frame construction and prefabricated wooden units for all new construction.*

Regarding this design proposal, participant 15 stated: *''In our project, we mainly chose concrete because mass production makes it cheaper than wood, and at the end of its life cycle, it can be recycled into concrete aggregate''*. Participant 17 added: *''We also added green roofs and façades to capture water, as the vegetation slows runoff and reduces peak load on the roof''*. Figure 6.16 illustrates the green roof in the newly constructed section.

Figure 6.16: Render of the green roof (Res & Smit BV, 2022)

Participant 16 commented negatively on this design proposal, by stating: *''Building with wood is an interesting development in our sector, but I'm not yet convinced. A few years ago, we shifted widely to concrete due to the environmental impact of deforestation. Now, with the focus on climate change, we're moving back to wood. I wonder if production forests can grow quickly enough to meet the increasing demand for timber construction''*.

Design Proposal 11 aligns with the strategies ***Utilization of Secondary Material*** *and* ***Utilization of Circular Material****, and involves evaluating the building's condition to determine if materials from demolished sections can be reused in new construction. Where feasible, these materials will be retained to preserve historical integrity and minimize waste.*

In relation to this design proposal, participant 16 stated: *''We haven't discussed this yet due to the time pressure and pace of the project, but I can certainly see the value in doing so. Parts of the existing building will be demolished, allowing us to construct the new rear façade using these bricks. We could potentially supplement this with secondary materials sourced from construction marketplaces''*.

Participant 17 further noted: *''Additionally, we could reuse the existing window frames in the plan, though there is a risk that they may not be suitable for double or triple glazing. While this approach would be circular, the product might no longer meet current standards''*. Participant 15 added: *''It would be especially ideal to use as much original building material as possible in the areas where the new structure connects with the existing one''*

6.2.2. ACTION PLAN

This sub-subsection outlines specific actions needed to effectively implement the design proposals, taking into account the limitations and opportunities identified during discussions with Workshop 2 participants. Table 6.4 presents the action plan (AP), comprising 11 items based on the design proposals (DP) from Workshop 2, which build on the design strategies developed in Workshop 1.

Table 6.4: Action plan (AP) and related design proposals (DP) (own work, 2024)

Theme 1: Integrated Spaces			
DP-1	Removing non-load-bearing walls to create flexible and open residential spaces; thereby improving adaptability for future uses.	**AP-1**	Conduct structural assessments of load-bearing walls and implement space planning that maintains flexibility for future use.
DP-2	Creating multifunctional spaces by transforming the sports facility into a community center that support various community and recreational activities.	**AP-2**	Finalize demolition plans and develop detailed designs for new construction and ensure that communal areas are aligned with user needs and spatial constraints.
DP-3	Centralizing essential building services within easily accessible cores.	**AP-3**	Conduct detailed assessments of the attic space in terms of its capacity to accommodate installation and central service cores.
DP-4	Fostering community engagement by creating yards around the school building that facilitates interaction, promotes shared activities like gardening, and improves the social environment.	**AP-4**	Finalize yard designs and initiate coordination with the municipal heritage department for approval of green space modifications.
DP-5	Designing for long-term flexibility and adaptability to meet changing needs by allowing for easy conversion between different housing types.	**AP-5**	Develop adaptable interior layouts and engage with stakeholders to ensure long-term lease agreements are in place for care providers.
Theme 2: Design Flexibility			
DP-6	Using modular and demountable construction methods for new construction, and preserving the historical sections of the building where possible.	**AP-6**	Collaborate with contractors to explore hybrid construction methods to balance traditional and modular approaches.
DP-7	Future-proofing the building by reserving space for potential growth and designing for additional technical systems or structural elements.	**AP-7**	Coordinate with design and engineering teams to reserve space and install surplus technical capacity during construction, ensuring compliance with regulations and budget.
DP-8	Designing housing units to function independently for low-care needs.	**AP-8**	Develop HVAC and electrical plans that provide decentralized control systems within individual units.
Theme 3: Material Efficiency			
DP-9	Using standardized building components for easier reuse.	**AP-9**	Begin material procurement, focusing on standardized products that meet both current project needs and future reuse potential, such as modular façade systems that match existing building aesthetics.
DP-10	Integrating biobased, renewal materials like timber frame construction and prefabricated wooden units for all new construction.	**AP-10**	Collaborate with sustainability consultants and material experts to assess the feasibility of using certified sustainable timber, addressing concerns about deforestation and supply limitations.
DP-11	Evaluating the building's condition to determine if materials from demolished sections can be reused in new construction. Where feasible, these materials will be retained to preserve historical integrity and minimize waste.	**AP-11**	Work with suppliers to source secondary and recycled materials, and finalize designs for areas where these materials will be used.

Chapter 7

Conclusions, Limitations & Recommendations

7. CONCLUSIONS, LIMITATIONS & RECOMMENDATIONS

7.1. OVERVIEW

This research aimed to explore the applicability and effectiveness of circular building adaptability strategies (CBASs) in adaptive reuse projects within the Dutch context, by answering the following research question: **''How can the applicability and effectiveness of design-oriented circular building adaptability strategies (CBASs) be promoted in adaptive reuse projects?''**

The research makes a valuable contribution to determining how CBASs could be integrated into design and decision-making processes. A combination of theoretical and empirical research methods were employed, including archival research, field observations, semi-structured interviews, questionnaires and design workshops with industry professionals. This allowed for an in depth analysis, making this the first research that tests and ranks the practical implementation of the CBASs based on real world-projects.

7.2. CONCLUSIONS

This subsection answers the research sub-questions outlined in subsection 1.4 in Chapter 1, followed by the main research question.

SQ-A: WHAT ARE THE EFFECTIVE WAYS TO USE THE CBA-AR FRAMEWORK IN THE DESIGN & DECISION-MAKING PROCESSES OF ADAPTIVE REUSE PROJECTS?

The findings of this study demonstrate that in the pre-project phase, the CBA-AR framework functions as a knowledge-sharing and informative tool, guiding stakeholders through its three key components: CBA-determinants, CBASs, and the associated inhibiting or enabling factors. The research highlights the importance of early-stage planning and collaboration among stakeholders—*such as developers, architects, and regulators*—to ensure that circularity and adaptability are integrated into adaptive reuse projects from the beginning. Insights from chapters 5 and 6 of this research can inspire stakeholders and help them to identify suitable CBASs for their adaptive reuse projects.

Regarding the framework use, the framework can be used as an informative tool in the pre-project and preparation phases—*planning and design phases*—in a manner that shifts from being purely descriptive to acting as a benchmarking tool, respectively. It serves as a resource for subjectively assessing the feasibility of the selected CBASs, allowing decision-makers to evaluate the adaptive reuse potential of their project while integrating circular principles into the design process.

SQ-B: WHAT ARE THE MOST APPLICABLE AND EFFECTIVE DESIGN-ORIENTED CBASs FOR CIRCULAR AND ADAPTABLE ADAPTIVE REUSE PROJECTS?

The findings from subsection 5.4 in Chapter 5 reveal that, specifically in the cases examined in this study, the three most effective and applicable CBASs are: *Open the Floor Plan*, *Provision of Multi-Purpose Spaces*, and *Alignment of the Interconnection Between Floor Plans*. The high scores of these strategies can be attributed to building characteristics, such as non-load bearing partition walls, column-based structures, and high ceilings. These features support open floor plans to enable easy reconfiguration without compromising structural integrity. By preserving these adaptable elements, the spaces can serve multiple purposes and remain flexible to user needs or market demands, while creating well-connected, flexible, and socially engaging environments.

On the other hand, the three least applicable and effective strategies identified in the examined cases are: *Design for Mixed-Use*, *Modularization of Spatial Configuration*, and *Design for Surplus Capacity*. These strategies scored the lowest for various reasons, mainly due to legal and structural challenges. For instance, restrictive zoning policies have been seen as a barrier for mixed-use developments, while legal and regulatory constraints have been perceived as an obstacle to expanding structures in transformation projects. Furthermore, structural limitations, such as inadequate foundations capacity and inflexibility of existing building configurations, can make vertical expansion or modularization technically complex and economically infeasible.

SQ-C: HOW CAN THE APPLICABLE AND EFFECTIVE DESIGN-ORIENTED CBASs BE IMPLEMENTED IN ADAPTIVE REUSE DESIGN?

An important contribution of this research is looking into ways of facilitating using a tool—*the CBA-AR framework*—to improve certain outcomes—*circular building adaptability (CBA)*—in a specific type of practices—*adaptive reuse projects*. Based on the findings of this study, it has been concluded that a lack of knowledge among professionals involved in adaptive reuse projects is among the key barriers that hinder innovation and implementation of the CBASs. The absence of sufficient understanding and awareness of CBASs leads to missed opportunities for implementing more adaptable and sustainable design strategies. For example, in this study, participants successfully integrated the CBASs into the design of C4 by learning about the CBA-AR framework during the workshops. These discussions ultimately led to the development of an action plan based on the design proposals. Therefore, knowledge sharing about the CBASs during the early planning (pre-project) phase is a prerequisite for their implementation, which can take place in the form of a user guide or brainstorming and knowledge-sharing workshops.

MAIN RESEARCH QUESTION: HOW CAN THE APPLICABILITY AND EFFECTIVENESS OF DESIGN-ORIENTED CIRCULAR BUILDING ADAPTABILITY STRATEGIES (CBASs) BE PROMOTED IN ADAPTIVE REUSE PROJECTS?

This research concludes that promoting the applicability and effectiveness of design-oriented CBASs in adaptive reuse projects involves several key steps, guided by the CBA-AR framework. Firstly, it is crucial for professionals to become familiar with the principles of circular building adaptability (CBA) and the strategies associated with it. Subsequently, the selection of applicable CBASs is essential, as not all strategies are suitable for every adaptive reuse project. Therefore, it is important to assess which solutions align best with the specific needs and constraints of the building. Once the applicable CBASs are identified, it is necessary to develop concrete plans for their implementation. The insights gained from the empirical part of this research can inspire professionals how to apply these strategies, ensuring they are grounded in practical, real-world cases.

7.3. RECOMMENDATIONS

This study puts forward the following recommendations:

- Further research is needed to explore the active and operational strategies within the CBA-AR framework and assess how these additional strategies contribute to the overall adaptability and sustainability of the adaptive reuse project
- Practitioners should draw inspiration from the cases examined in this research regarding the implementation of CBASs, their rankings based on applicability and effectiveness, and the enabling and inhibiting factors involved.
- Practitioners need to recognize that each case is unique and that the scores from the empirical part of this study are based solely on the cases examined in this research.
- Practitioners need to explore and get acquainted with the CBA-AR framework in order to integrate suitable CBASs into their own decision-making processes in future transformation projects.
- It is essential to invest in training and educating stakeholders on the benefits and practical applications of CBASs to ensure that circularity and adaptability are integrated into the early stages of design and planning.
- Municipalities can consider guiding applicants for transformation permits on the design-oriented CBASs.

7.4. LIMITATIONS

This study has five limitations. First, it focuses solely on 15 passive strategies within the CBA-AR framework, excluding active and operational strategies. Second, the empirical research is confined to the Dutch building industry, limiting broader applicability. Third, economic feasibility was not examined, as the study prioritized practical applicability. Fourth, the small number of cases and professionals involved limits the generalizability of the findings; future research should include a larger sample for more consistent insights. Lastly, the types of cases included in this study were different, as each one presented unique characteristics and challenges. The generalizability of the findings is limited, highlighting the need for future research, but it is worth noting that the outcomes are useful for scholars, policymakers and practitioners concerned about circularity and futureproofing in adaptive reuse projects.

Chapter 8

Reflection

8. REFLECTION

My search for a thesis topic was driven by my interest in entrepreneurship, combined with the transition towards a circular economy in the built environment. Convinced that, alongside new construction, we should better utilize our existing building stock by focusing on transformation projects, I found the 'Circular Adaptable Real Estate Reuse' graduation lab to be the ideal choice for me. During the P1 phase, I was particularly curious about the relationship between circular business models, strategies, and tactics. The feedback I received from my first supervisor, Hans, was that I was writing a master's thesis, not a PhD, which meant I needed to narrow down my research focus.

Around the same time, my second supervisor, Mohammad, published a new scientific paper introducing the CBA-AR framework to the academic community. His previous publications had been primarily theoretical, with a key recommendation to test the CBA-AR framework in practice. From the start of my thesis process, my goal was to choose a topic that not only piqued my interest but also provided fundamental knowledge for my future career as a real estate developer. Seizing this opportunity, I decided to refine my research further, focusing on circular strategies.

Even after narrowing down my topic, the scope of the research remained too broad, as the framework consists of three parts with a total of 33 strategies. After discussions, I further refined the research by focusing on the 15 design-oriented (passive) CBASs. However, this didn't stop me from delving into the entire framework. Mohammad's work had inspired me so much that during my elective course, BK-Launch, I explored the full framework by developing a platform that connected the supply and demand sides of all the strategies. I would like to thank Hans Wamelink for his critical and insightful mentorship, as well as providing inspiring electives that significantly contributed to my entrepreneurial journey with Yellow Rock.

Impressed by my work, Mohammad invited me to join the research team focusing on the broader CBA theme. In addition to my thesis, I collaborated with Mohammad to develop the website https://cba-ar.com/. This entire experience has inspired me to continue making contributions to the academic world throughout my career as a real estate developer, aiming to bridge the gap between theory and practice. I am grateful to Mohammad Hamida for his guidance and the trust he placed in me, as he was a key source of inspiration throughout the entire thesis process.

Lastly, I would like to reflect on the valuable experience I gained during my graduation internship at Res & Smit. I chose this internship to resolve my personal dilemma of whether to pursue a career in project management or project development. Since the company operates in both fields, the experience allowed me to make a well-informed decision about my future path, ultimately steering me toward a career as a real estate developer. I would like to thank Benny Duimel for guiding me in selecting relevant cases that strengthened my research. I also want to thank all the interviewees and workshop participants for their valuable insights, which greatly contributed to my research findings.

References

REFERENCES

Aedes. (2023, March 20). Conceptueel bouwen veel sneller, goedkoper én van hogere kwaliteit. https://aedes.nl/de-bouwstroom/conceptueel-bouwen-veel-sneller-goedkoper-en-van-hogere-kwaliteit

Almashaqbeh, M., & El-Rayes, K. (2021). Optimizing the modularization of floor plans in modular construction projects. Journal of Building Engineering, 39, 102316. https://doi.org/10.1016/j.jobe.2021.102316

Arfa, F. H., Zijlstra, H., Lubelli, B., & Quist, W. (2022). Adaptive Reuse of Heritage Buildings: From a Literature Review to a Model of Practice. The Historic Environment: Policy & Practice, 13(2), 148–170. https://doi.org/10.1080/17567505.2022.2058551

Austin, R. L., Forrester, R. A., Steward, W. C., & Woodstock, D. G. (1988). Adaptive Reuse: Issues and case studies in building preservation. Van Nostrand Reinhold; First Edition (US) First Printing. https://ci.nii.ac.jp/ncid/BA04321495

Bergold, J., & Thomas, S. (2012). Participatory Research Methods: a Methodological approach in motion. DOAJ (DOAJ: Directory of Open Access Journals). https://doaj.org/article/b9be448fc5b24630afda62b392a117f3

Bertino, G., Kisser, J., Zeilinger, J., Langergraber, G., Fischer, T., & Österreicher, D. (2021). Fundamentals of Building Deconstruction as a Circular Economy Strategy for the Reuse of Construction Materials. Applied Sciences, 11(3), 939. https://doi.org/10.3390/app11030939

Besten, D. (2023). The Future of Our Past: Current implementation of circular economy strategies in the adaptive reuse of heritage buildings and mitigating remaining barriers [Master Thesis TU Delft, TU Delft]. http://resolver.tudelft.nl/uuid:1250b5ae-5ec6-489f-a0fd-1314f32a0574

Bhatia, A. (n.d.). Centralized Vs. Decentralized Air Conditioning Systems. www.cedengineering.com, M05-012. https://www.cedengineering.com/courses/centralized-vs-decentralized-air-conditioning-systems

Bouwer, P. A. (2017). R.K,. Jongensschool 1955, Rembrandtstraat 5 te Monster: Bouwhistorisch Overzicht. In Cultureel Erfgoed Westland. Cultureel Erfgoed Westland.

Bullen, P. A. (2007). Adaptive reuse and sustainability of commercial buildings. Facilities, 25(1/2), 20–31. https://doi.org/10.1108/02632770710716911

Bullen, P. A., & Love, P. E. (2011a). A new future for the past: a model for adaptive reuse decision-making. Built Environment Project and Asset Management, 1(1), 32–44. https://doi.org/10.1108/20441241111143768

Bullen, P. A., & Love, P. E. (2011b). Adaptive reuse of heritage buildings. Structural Survey, 29(5), 411–421. https://doi.org/10.1108/02630801111182439

Circubuild. (2021, August 2). De circulaire shift: "Standaardisatie leidt niet tot saaie architectuur." Circubuild. Retrieved March 27, 2024, from https://www.circubuild.be/nl/nieuws/de-circulaire-shift-standaardisatie-leidt-niet-tot-saaie-architectuur/#:~:text=Standaardisatie%20is%20geen%20doel%20op,materialen%20een%20langere%20levensduur%20hebben.

Conejos, S., Langston, C., & Smith, J. (2011). Improving the implementation of adaptive reuse strategies for historic buildings. Safeguard of Architectural, Visual, Environmental, Heritage Conference, Naples., 1–10. https://pure.bond.edu.au/ws/files/27956715/2011_Improving_the_implementation_of_adaptive_reuse_strategies_for_historic_buildings.pdf

C.V. C van Bloemendaal, Heiko Hulskar Architecten B.V., Hosper NL B.V., & PUUR Makelaars. (2016). Carré van Bloemendaal: Verkoopbrochure. IAAY | It's All Around You.

C.V. C van Bloemendaal, Heiko Hulskar Architecten B.V., Hosper NL B.V., & PUUR Makelaars. (2017). Carré van Bloemendaal: Stijlvol wonen aan de rand van de Kennemerduinen. IAAY | It's All Around You.

Davison, N., Gibb, A. G., Austin, S. A., Goodier, C. I., & Warner, P. D. (2006, January 1). The multispace adaptable building concept and its extension into mass customisation [Adaptables 2006]. TU/E, International Conference on Adaptable Building Structures, Eindhoven, Netherlands. http://adaptablefutures.com/wp-content/uploads/2011/10/Davison-et-al-20061.pdf

De Graaf, D., Gruis, V., Hamada, K., & Schuitemaker, S. (2022). Circular Buildings: constructing a sustainable future. In Holland Circular Hotspot. Holland Circular Hotspot. https://hollandcircularhotspot.nl/publications/

Ellen Macarthur Foundation. (n.d.). Circular Economy Introduction. Retrieved November 5, 2023, from https://www.ellenmacarthurfoundation.org/topics/circular-economy-introduction/overview

Foster, G. J. (2020). Circular Economy Strategies for adaptive reuse of cultural heritage buildings to reduce environmental impacts. Resources, Conservation and Recycling, 152, 104507. https://doi.org/10.1016/j.resconrec.2019.104507

Foster, G. J., & Kreinin, H. (2020). A Review of Environmental Impact Indicators of Cultural Heritage Buildings: A Circular Economy Perspective. Environmental Research Letters, 15(4), 043003. https://doi.org/10.1088/1748-9326/ab751e

Girard, L. F. (2020). The circular economy in transforming a died heritage site into a living ecosystem, to be managed as a complex adaptive organism. Zenodo (CERN European Organization for Nuclear Research). https://doi.org/10.13128/aestim-9788

Groat, L. N., & Wang, D. (2013). Case Studies and Combined Strategies. In Architectural research methods. http://ci.nii.ac.jp/ncid/BB15770501

Gustafsson, J. (2017). Single case studies vs. multiple case studies: A comparative study. Academy of Business, Engineering and Science. Halmstad University. http://hh.diva-portal.org/smash/record.jsf?pid=diva2%3A1064378

Hamida, M. B. (2023, August). Exploring the Relation Between Circularity and Adaptability in Adaptive Reuse [Video]. Circularity for Educators. https://circularityforeducators.tudelft.nl/article/exploring-the-relation-between-circularity-and-adaptability-in-adaptive-reuse/

Hamida, M. B., & Hassanain, M. A. (2021). A framework model for AEC/FM knowledge in adaptive reuse projects. Journal of Engineering, Design and Technology, 20(3), 624–648. https://doi.org/10.1108/jedt-05-2020-0203

Hamida, M. B., Jylhä, T., Remøy, H., & Gruis, V. (2022). Circular Building Adaptability and its Determinants – A literature review. International Journal of Building Pathology and Adaptation, 41(6), 47–69. https://doi.org/10.1108/ijbpa-11-2021-0150

Hamida, M. B., Remøy, H., Gruis, V., & Jylhä, T. (2023). Circular building adaptability in adaptive reuse: multiple case studies in the Netherlands. Journal of Engineering, Design and Technology. https://doi.org/10.1108/jedt-08-2022-0428

Hamida, M. B., Remøy, H., Gruis, V., & Van Laar, B. (2023). Co-Development of a Framework for Circular Building Adaptability in Adaptive Reuse: A Participatory Study. SBEUT-Sustainable Built Environment and Urban Transition Conference.

Hammond, G. P., & Jones, C. I. (2008). Embodied energy and carbon in construction materials. Proceedings of the Institution of Civil Engineers, 161(2), 87–98. https://doi.org/10.1680/ener.2008.161.2.87

Harris, L. R., & Brown, G. (2010). Mixing interview and questionnaire Methods: Practical Problems in Aligning data. Practical Assessment, Research and Evaluation, 15(1), 1–19. https://doi.org/10.7275/959j-ky83

Hecker, J., & Kalpokas, N. (2023a, September 14). The Ultimate Guide to Qualitative Research - Part 2: Handling Qualitative Data. ATLAS.ti. https://atlasti.com/guides/qualitative-research-guide-part-2

Hecker, J., & Kalpokas, N. (2023b, September 14). What is a conceptual framework? ATLAS.ti. https://atlasti.com/guides/qualitative-research-guide-part-1/conceptual-framework#:~:text=A%20conceptual%20framework%20serves%20multiple,data%20collection%20and%20analysis%20process.

Heiko Hulskar Architecten. (2016). Verkooptekeningen Casco [Dataset]. C.V. C van Bloemendaal.

Heilijgers. (2024, March 6). Transformatie ziekenhuis Meerenberg. https://heilijgers.nl/projecten/carre-van-bloemendaal

Hennink, M., Hutter, I., & Bailey, A. (2011). Chapter 6: In-Depth Interviews. In Qualitative Research Methods (pp. 108–131). SAGE Publications London.

Hobbs, G., & Adams, K. T. (2017). Reuse of building products and materials – barriers and opportunities. International HISER Conference on Advances in Recycling and Management of Construction and Demolition Waste, 109–113. https://repository.tudelft.nl/islandora/object/uuid%3Ad511af0d-2c03-4234-a6c2-ffb38ab0f232

Holt, G. D. (2014). Asking questions, analysing answers: relative importance revisited. Construction Innovation: Information, Process, Management, 14(1), 2–16. https://doi.org/10.1108/ci-06-2012-0035

Husain, Z., Maqbool, A., Haleem, A., Pathak, R. D., & Samson, D. (2021). Analyzing the Business Models for Circular Economy Implementation: A Fuzzy TOPSIS approach. Operations Management Research, 14(3–4), 256–271. https://doi.org/10.1007/s12063-021-00197-w

Isaac, S., Bock, T., & Stoliar, Y. (2014). A New Approach to Building Design Modularization. Procedia Engineering, 85, 274–282. https://doi.org/10.1016/j.proeng.2014.10.552

Iselin, D. G., & Lemer, A. C. (1993). The Fourth Dimension in Building : Strategies for Minimizing Obsolescence. National Academies Press. https://ci.nii.ac.jp/ncid/BA36126398

Jabareen, Y. (2009). Building a conceptual framework: philosophy, definitions, and procedure. International Journal of Qualitative Methods, 8(4), 49–62. https://doi.org/10.1177/160940690900800406

Joensuu, T., Edelman, H., & Saari, A. (2020). Circular economy practices in the built environment. Journal of Cleaner Production, 276, 124215. https://doi.org/10.1016/j.jclepro.2020.124215

Kalee, M., & Vugts, J. (2020). Ritsevoort 25 in Alkmaar: Beoordeling bouwfysica en akoestiek. In https://www.lbpsight.nl/ (R0490157aa.207634M.mkl). LBP|SIGHT.

Kamara, J. M., Heidrich, O., Tafaro, V. E., Maltese, S., Dejaco, M. C., & Cecconi, F. R. (2020). Change factors and the adaptability of buildings. Sustainability, 12(16), 6585. https://doi.org/10.3390/su12166585

Kaya, D. I., Dane, G., Pintossi, N., & Koot, C. A. (2021). Subjective circularity performance analysis of adaptive heritage reuse practices in the Netherlands. Sustainable Cities and Society, 70, 102869. https://doi.org/10.1016/j.scs.2021.102869

Kaya, D. I., Pintossi, N., & Dane, G. (2021). An Empirical Analysis of Driving Factors and Policy Enablers of Heritage Adaptive Reuse within the Circular Economy Framework. Sustainability, 13(5), 2479. https://doi.org/10.3390/su13052479

Kirchherr, J., Reike, D., & Hekkert, M. P. (2017). Conceptualizing the Circular Economy: An analysis of 114 definitions. Resources, Conservation and Recycling, 127, 221–232. https://doi.org/10.1016/j.resconrec.2017.09.005

Komijn, J. (2014, September 16). De Sloterschool. Geheugen Van West. https://geheugenvanwest.amsterdam/page/21935/de-sloterschool

Kurul, E. (2007). A qualitative approach to exploring adaptive re-use processes. Facilities, 25(13/14), 554–570. https://doi.org/10.1108/02632770710822634

Langston, C., Wilkinson, S. J., & Remøy, H. (2014). Designing for Future Adaptive Reuse. In Sustainable Building Adaptation: Innovations in Decision-Making (p. Chapter 12, pp. 250–272). John Wiley & Sons, Chichester, West Sussex.

Lardner, H., Parsons, L., Sutherland, G., & Moloney, D. (2013). Adaptive Reuse of Industrial Heritage: Opportunities & Challenges. Melbourne: Heritage Council of Victoria.

Leavy, P. (2014). Part 3 Narrative Inquiry, Field Research, and Interview Methods Expand. In The Oxford Handbook of Qualitative Research. https://doi.org/10.1093/oxfordhb/9780190847388.001.0001

Meyer, C. B. (2001). A case in case study methodology. Field Methods, 13(4), 329–352. https://doi.org/10.1177/1525822x0101300402

Mohamed, R., Boyle, R., Yang, A. Y., & Tangari, J. (2017). Adaptive Reuse: A review and analysis of its relationship to the 3 es of sustainability. Facilities, 35(3/4), 138–154. https://doi.org/10.1108/f-12-2014-0108

MOOI Noord-Holland. (2020, August 3). Carré van Bloemendaal - Bloemendaal. https://www.mooinoord-holland.nl/mooinoord-holland-inzendingen/carre-van-bloemendaal-bloemendaal/#:~:text=Carr%C3%A9%20van%20Bloemendaal%20%E2%80%93%20Bloemendaal&text=Het%20originele%20plan%2C%20een%20rechthoekig,architect%20%26%20landschapsarchitect%20J.D.%20Zocher%20jr

Mrad, C., & Ribeiro, L. F. (2022). A review of Europe's circular economy in the building sector. Sustainability, 14(21), 14211. https://doi.org/10.3390/su142114211

Mulderblauw Architecten. (2010). Res & Smit kantoor [Dataset; Res & Smit server]. In 17RES-AMS.01. Res & Smit BV.

Munaro, M. R., Tavares, S. F., & Bragança, L. (2020). Towards circular and More Sustainable Buildings: A Systematic Literature Review on the Circular Economy in the built environment. Journal of Cleaner Production, 260, 121134. https://doi.org/10.1016/j.jclepro.2020.121134

Ness, D., & Xing, K. (2017). Toward a Resource-Efficient Built Environment: A Literature Review and Conceptual Model. Journal of Industrial Ecology, 21(3), 572–592. https://doi.org/10.1111/jiec.12586

Omgevingsloket. (2023). Herontwikkeling Aloysiusschool te Monster. In Omgevingsloket (NL.IMRO.1783.MONREMBRANDTSTR5pb-ON01).

Pomponi, F., & Moncaster, A. (2017). Circular Economy for the Built Environment: a Research framework. Journal of Cleaner Production, 143, 710–718. https://doi.org/10.1016/j.jclepro.2016.12.055

Potting, J., Hekkert, M. P., Worrell, E., & Hanemaaijer, A. (2017). Circular Economy: Measuring innovation in the product chain (Issue 2544). https://dspace.library.uu.nl/handle/1874/358310

R Architecture. (n.d.). From Brief to Design: The importance of spatial relationships in achieving a quality design outcome. rarchitecture.com.au. Retrieved March 28, 2024, from https://rarchitecture.com.au/from-brief-to-design/

Regionaal Archief Alkmaar. (n.d.). Ritsevoort & Baanstraat [Foto]. In Fotocollectie Monumentenzorg Gemeente Alkmaar. Fotocollectie Monumentenzorg gemeente Alkmaar, Almaar, Noord-Holland, Netherlands.

Res & Smit BV. (2018). Res & Smit kantoor [Dataset; Res & Smit server]. In 17RES-AMS.01. Res & Smit BV.

Res & Smit BV. (2021). Hofje van Ritsevoort [Dataset; Res & Smit server]. In 20IPR-ALK.01 Ritsevoort. Res & Smit BV.

Res & Smit BV. (2016). Foto's Carré van Bloemendaal [Dataset; Res & Smit server]. In 15MEB-BLO.01 Carré.

Res & Smit BV. (2022). Aloyschiusschool Monster [Dataset; Res & Smit server]. In 18WWA-WAT.01 Aloysiusschool Monster.

Saunders, M. N. K., Lewis, P., & Thornhill, A. (2019). 10 Collecting primary data using research interviews and research diaries. In Research methods for business students (Eight Edition). UK: Pearson Education Limited. https://www.pearson.com/nl/en_NL/higher-education/subject-catalogue/business-and-management/Research-methods-for-business-students-8e-saunders.html

Shahi, S., Esfahani, M. E., Bachmann, C., & Haas, C. T. (2020). A definition framework for building adaptation projects. Sustainable Cities and Society, 63, 102345. https://doi.org/10.1016/j.scs.2020.102345

Slaughter, E. S. (2001). Design strategies to increase building flexibility. Building Research and Information, 29(3), 208–217. https://doi.org/10.1080/09613210010027693

Stadsarchief Amsterdam. (1953–1955). Sloterweg 796 [Foto]. Collectie Stadsarchief Amsterdam: foto's eigen fotodienst, Amsterdam, Noord-Holland, Netherlands.

Sullivan, G. M., & Artino, A. R. (2013). Analyzing and interpreting data from Likert-Type scales. Journal of Graduate Medical Education, 5(4), 541–542. https://doi.org/10.4300/jgme-5-4-18

Swedberg, R. (2020). Exploratory Research. In The production of knowledge: Enhancing progress in social science (pp. 17–41). Cambridge University Press.

Szarejko, W., & Trocka-Leszczynska, E. (2007). Aspect of functionality in modernization of office buildings. Facilities, 25(3/4), 163–170. https://doi.org/10.1108/02632770710729755

Tholens, K., & Van Steenhardt Carré, L. J. G. M. (2002). 10063 Archief van K.P. Tholens, L. van Steenhardt Carré: bouwtekeningen [Dataset]. In Lagere Tuinbouwschool, bouw en uitbreiding, in samenwerking met architect J.M. van Daal. 1963-1981 (Version 462-468, 1194 Sloterweg 794). Gemeente Amsterdam Stadsarchief. https://archief.amsterdam/inventarissen/details/10063/path/1.1.2.1

Up Architecture. (n.d.). Ritsevoort. Retrieved April 14, 2024, from https://uparchitecture.nl/project/19

Van Dam, M. C., & Moerman, S. (2021). Bouwhistorische verkenning met waardenstelling: Ritsevoort 25, Alkmaar Gemeente Alkmaar (NH). In IDDS Archeologie En Bouwhistorie. IDDS.

Van Der Voordt, T., Rocco, R., Thomas, A., & Novas-Ferradás, M. (2022). Value-Sensitive Design & Management of Buildings and Facilities. In Teaching Design for Values: Concepts, Tools & Practices (pp. 220–243). TU Delft Open Publishing.

Vinke, J., & Van Der Lubbe, M. (2014). Learning from Multifunk: Een onderzoek naar flexibele & multifunctionele gebouwen. ANA Architecten. Retrieved March 27, 2024, from https://ana.nl/onderzoek/learning-from-multifunk/

Wilkinson, S., Remøy, H., & Langston, C. (2014). Sustainable building adaptation: Innovations in decision-making. https://opus.lib.uts.edu.au/handle/10453/33285

WUR. (2023). Biobased Construction Materials: Contributing to a sustainable housing system in Europe and enhancing climate neutral and resilient cities. In https://edepot.wur.nl/ (KB 34 Circular and climate neutral society). Wageningen University & Research.

Yaldız, E., & Gül, N. (2013). Definition of a New Design Process for the Reuse of Monumental Buildings. Central Europe Towards Sustainable Building 2013 Sustainable Refurbishment of Existing Building Stock. https://dissem.in/p/33144720/central-europe-towards-sustainable-building-2013-sustainable-refurbishment-of-existing-building-stock-definition-of-a-new-design-process-for-the-reuse-of-monumental-buildings

Yin, R. K. (2009). Case Study Research: Design and Methods (4th ed.). Sage Publications, Los Angeles, CA.

Yung, E. H., & Chan, E. H. (2012). Implementation challenges to the Adaptive reuse of heritage buildings: towards the goals of sustainable, low carbon cities. Habitat International, 36(3), 352–361. https://doi.org/10.1016/j.habitatint.2011.11.001

Zimmerman, J., Stolterman, E., & Forlizzi, J. (2010, August 16). An analysis and critique of Research through Design: towards a formalization of a research approach. https://doi.org/10.1145/1858171.1858228

Appendices

APPENDICES

APPENDIX A – INTERVIEW PROTOCOL

Introduction
I want to start by saying thank you for agreeing to take part in this interview. As previously stated, this study is part of my graduation thesis at the Faculty of Architecture and the Built Environment at the TU Delft. As I explained before, the research focuses on exploring the applicability and effectiveness of circular building adaptability strategies in adaptive reuse; particularly the aim of the study is to understand the applicability and effectiveness of these strategies in the decision-making and design processes for adaptive reuse projects. I would like to remind you that there are no right or incorrect answers in this interview, and the information you submit will only be utilized for academic purposes. The interview is divided into two major parts. Therefore, I would want to record this interview with your permission just for the purpose of transcribing it; the recordings will then be removed. Your responses during this interview will not be shared with anybody. Remember that you have the option to decline to answer any questions and to leave the study at any moment.
Part 1: General
• Can you briefly describe your role within the company and your involvement in projects related to circular and adaptable adaptive reuse? • How is your role involved in the design and decision-making processes of these adaptive reuse projects?
Part 2: Understanding CBASs Integration (SQ-A)
• In your experience, how have the circularity and adaptability related strategies or solutions been integrated into the design phase of adaptive reuse projects where you have been involved in? • Can you share specific examples of the CBA-strategies? • What were the aspects that influenced the implementation of these strategies?
Part 3: Identifying Applicable CBASs (SQ-B)
• From your experience, which design-oriented circular or adaptable strategies have shown the most promise in achieving circularity in adaptive reuse projects? • Can you provide examples of projects where specific strategies were particularly effective in promoting circularity and adaptability of the design? • What criteria do you consider when selecting design-oriented strategies for a particular adaptive reuse project?
Part 4: Tools and Methodologies (SQ-A)
• Are there specific tools or methodologies that you find particularly effective in promoting circularity and adaptability in adaptive reuse projects? • Can you discuss any successes or lessons learned from implementing these strategies in previous adaptive reuse projects?
Part 5: Ending
• Is there anything else you would like to share or additional insights that have not been addressed in specific questions? • What were some key findings or impressions from our conversation? I express my gratitude for your involvement in this study. I will process the date, time, and any noteworthy observations immediately after the interview. By sharing your experiences, you contribute to improving the practical application of CBASs and, consequently, the quality of the built environment. If you have any further questions in the future, I would like to receive them. When my graduation project is complete, I will share my studies with you if you're interested.

APPENDIX B – QUESTIONNAIRE FOR THE PRACTITIONERS

1. Respondent Information:

Name : ____________________
Company : ____________________
Company Adress : ____________________
Phone : ____________________
E-mail Adress : ____________________

2. Respondent Occupation:

- ☐ Architect
- ☐ Developer
- ☐ Contractor
- ☐ Sustainability Expert
- ☐ Project Manager
- ☐ Other (Please Specify): ____________

3. Number of Years of Experience:

- ☐ Less than 5 years
- ☐ 5 tot 10 years
- ☐ 10 tot 20 years
- ☐ More than 20 years

4. Have you ever dealt with adaptive reuse projects before?

- ☐ Yes
- ☐ No

5. Please indicate the number of adaptive reuse projects that you have been involved with:

- ☐ 1-5 projects
- ☐ 5-10 projects
- ☐ More than 10 projects

6. Types of Projects that you mostly deal with (multiple selection is allowed):

- ☐ Apartment Buildings
- ☐ Single Houses (Villas)
- ☐ Shops
- ☐ Office Buildings
- ☐ Educational Buildings
- ☐ Recreational Buildings
- ☐ Commercial centers/shopping malls
- ☐ Other (Please Specify): ____________

7. List of Strategies

Passive Strategies	Strategies for Circular Building Adaptability in Adaptive Reuse (CBASs)	Level of Applicability					Level of Effectiveness				
		Extremely Applicable	Very Applicable	Applicable	Somewhat Applicable	Not Applicable	Extremely Effective	Very Effective	Effective	Somewhat Effective	Not Effective
Exploring the Applicability and Effectiveness of Design-Oriented (Passive) CBA Strategies											
1	Design Standardization										
2	Seperation of Building Layers (e.g. Seperated Walls)										
3	Open the Floor Plan										
4	Provision of Multi-Purpose Spaces										
5	Modularization of Spatial Configuration (Layout)										
6	Utilization of Standardizes Building Services										
7	Provision of a Core for Building Services										
8	Design for Surplus Capacity										
9	Decentralization of Design										
10	Design for a Mixed Use (Multifunctionality)										
11	Utilization of Secondary (Reused/Recycled) Material										
12	Utilization of Biobased (Biological) Material										
13	Utilization of Circular (Reuseable/Recyclable) Material										
14	Allignment of the Interconnection Between the Floor Plans										
15	Allignment of the Building Design with the Property Portfolio										

APPENDIX C – RESPONSES FROM THE SURVEYS

AC.1. CASE 1[2]

Table AC.1: Survey findings for C1 (own work, 2024)

Passive Strategies	Strategies for Circular Building Adaptability in Adaptive Reuse (CBASs)	Level of Applicability					Level of Effectiveness				
		Extremely Applicable	Very Applicable	Applicable	Somewhat Applicable	Not Applicable	Extremely Effective	Very Effective	Effective	Somewhat Effective	Not Effective
*Exploring the Applicability and Effectiveness of Design-Oriented (Passive) CBA Strategies - **Single Case Analysis C1***											
1	Design Standardization	5/14a	3	1	2/4		1/3/5/14a		2	4	
2	Separation of Building Layers (e.g. Separated Walls)		3	2/4/5/14a	1			1/2/3/14a	4/5		
3	Open the Floor Plan	5	1/2/3/4	14			1/5	3/4/14a	2		
4	Provision of Multi-Purpose Spaces	2/5	1/4		3/14a		1/5	2/3/4	14a		
5	Modularization of Spatial Configuration (Layout)		4	2/14a	1/5	3		2/4/14a	5		1/3
6	Utilization of Standardized Building Products	14a	5	1/2/3/4			14a	1/2/5		4	3
7	Provision of a Core for Building Services		3	1/2/4	1	5/14a			2/3/4	14a	1/5
8	Design for Surplus Capacity		2/4		14a	1/3/5	2	4	1	3/14a	5
9	Decentralization of Design	5	1/2/14a	3	4		3/5/14a		1/2	4	
10	Design for a Mixed Use (Multifunctionality)				2/4/5/14a	1/3		2		4/5	1/3/14a
11	Utilization of Secondary (Reused/Recycled) Material		1/4/14a	2/5	3		1/5/14a	2/4		3	
12	Utilization of Biobased (Biological) Material		2/4/5/14a	1/3			5	4/14a	1/3	2	
13	Utilization of Circular (Reuseable/Recyclable) Material		4/14a	5	2/3	1		2/14a	5	1/3	4
14	Alignment of the Interconnection Between the Floor Plans		4/5	1/2/14a	3			1/4/5/14a	2/3		
15	Alignment of the Building Design with the Property Portfolio		2/4/14a	3/5	1			2	1/5/14a	3/4	

[2] *Note: The numbers in Table C.1 are related to the key informants of C1, depicted in Table 4.2 (chapter 4.3).*

AC.2. CASE 2[3]

Table AC.2: Survey findings for C2 (own work, 2024)

Passive Strategies	Strategies for Circular Building Adaptability in Adaptive Reuse (CBASs)	Level of Applicability					Level of Effectiveness				
		Extremely Applicable	Very Applicable	Applicable	Somewhat Applicable	Not Applicable	Extremely Effective	Very Effective	Effective	Somewhat Effective	Not Effective
*Exploring the Applicability and Effectiveness of Design-Oriented (Passive) CBA Strategies - **Single Case Analysis C2***											
1	Design Standardization		6/7/8/9/10		14b			6/8/10/14b	7/9		
2	Separation of Building Layers (e.g. Separated Walls)		7/9/10/14b	8	6		10	7/9/14b	8	6	
3	Open the Floor Plan	7/10/14b	6/9	8			7/10/14b	6/8/9			
4	Provision of Multi-Purpose Spaces	10/14b	6/7/9		8		14b	6/7/9/10	8		
5	Modularization of Spatial Configuration (Layout)	14b	9/10	6	7	8	10	9/14b	6	7/8	
6	Utilization of Standardized Building Products	15	10	7	6/8/9		10/14b		9	6/7/8	
7	Provision of a Core for Building Services		6	8/9/10	7/14b			6/8	9/14b	7/10	
8	Design for Surplus Capacity		6/7	8/9	10/14b			6/7/8	9/10/14b		
9	Decentralization of Design		9	6/7/10	8/14b			9	6/7/8/14b	10	
10	Design for a Mixed Use (Multifunctionality)	14b	6/7/9/10	8				6/7/8/9/14b	10		
11	Utilization of Secondary (Reused/Recycled) Material	14b		6/9/10	7/8			10/14b	6/8/9	7	
12	Utilization of Biobased (Biological) Material		14b	6/7/8/9/10				10/14b	6/8/9	7	
13	Utilization of Circular (Reuseable/Recyclable) Material	14b	8/9	6/7/10			14b	7/8/9	6/10		
14	Alignment of the Interconnection Between the Floor Plans		6/9/10	7/8/14b			10	6/7/9/14b	8		
15	Alignment of the Building Design with the Property Portfolio		6/9/10/14b		7/8			6/9/14b	10	7	8

[3] *Note: The numbers in Table C.2 are related to the key informants of C2, depicted in Table 4.2 (chapter 4.3).*

AC.3. CASE 3[4]

Table AC.3: Survey findings for C3 (own work, 2024)

Passive Strategies	Strategies for Circular Building Adaptability in Adaptive Reuse (CBASs)	Level of Applicability					Level of Effectiveness				
		Extremely Applicable	Very Applicable	Applicable	Somewhat Applicable	Not Applicable	Extremely Effective	Very Effective	Effective	Somewhat Effective	Not Effective
*Exploring the Applicability and Effectiveness of Design-Oriented (Passive) CBA Strategies - **Single Case Analysis C3***											
1	Design Standardization		14c		11/13	12	11/14c			13	12
2	Separation of Building Layers (e.g. Separated Walls)			11/13/14c	12					11/12/13/14c	
3	Open the Floor Plan	13	11/12	14c			13	14c	12	11	
4	Provision of Multi-Purpose Spaces		12/13/14c	11				12/13/14c	11		
5	Modularization of Spatial Configuration (Layout)		11	12	13	14c		11/12		14c	13
6	Utilization of Standardized Building Products	14c	11/13	12			13	11/14c	12		
7	Provision of a Core for Building Services	11/12/13/14c					13/14c	11	12		
8	Design for Surplus Capacity				13/14c	11/12				11/13	12/14c
9	Decentralization of Design		14c	13	11/12				13	11/12/14c	
10	Design for a Mixed Use (Multifunctionality)	14c	12/13	11			14c		11/12/13		
11	Utilization of Secondary (Reused/Recycled) Material		13/14c		11/12		14c	13	11	12	
12	Utilization of Biobased (Biological) Material		14c	12/13	11		13	12/14c	11		
13	Utilization of Circular (Reuseable/Recyclable) Material		14c	11	12/13			11/14c		13	12
14	Alignment of the Interconnection Between the Floor Plans	13/14c	12		11		13/14c	11/12			
15	Alignment of the Building Design with the Property Portfolio		14c	11/13		12			13/14c	11	12

[4] *Note: The numbers in Table C.3 are related to the key informants of C3, depicted in Table 4.2 (chapter 4.3).*

APPENDIX D – DESIGN WORKSHOP 1

Workshop 1: Design Strategy for Adaptive Reuse Projects **Duration: 2 hours**
1. Introduction (10 minutes)
• Welcome and introductions. • Overview of the workshop objectives and agenda. • Explanation of the case study that will be covered during the workshop.
2. Reflecting on the outcomes (20 minutes)
• Brief presentation of key findings from interviews and questionnaires conducted with participants. • Discussion of the applicability and effectiveness of different design-oriented CBASs based on empirical data.
3. Group Discussion: Design Strategy (1 hour)
• Participants will be divided into small groups. • Strategies will be divided in advance by the researcher into three themes. - *Theme 1: Shared & Integrated Spaces* - *Theme 2: Design Flexibility* - *Theme 3: Material & Resource Efficiency* • The workshop will consist of three 20-minute rounds. Each round, participants receive a booklet with descriptions of the strategies within each theme. • First 10 minutes: Group discussion on how the strategies can be applied in the case study project. • Second 10 minutes: Central discussion where groups share their perspectives, insights, and experiences related to each strategy. • The researcher will guide the discussion, ensuring that all participants have an opportunity to contribute and that diverse viewpoints are considered.
4. Closing Remarks (15 minutes)
• Researcher will summarize the key findings and outcomes of the workshop. • Different design proposals will be identified. • Final design strategy will be formulated based on group discussions and collective agreement. • Closing remarks, acknowledgments, and next steps will be provided.
5. Optional Networking Session (15 minutes)
• Participants are encouraged to network and continue informal discussions. • Refreshments may be provided during this optional networking session.

APPENDIX E – DESIGN WORKSHOP 2

Workshop 2: Design Proposals and Action Plan for Case Study Design **Duration: 2 hours**
1. Introduction (10 minutes)
• Welcome and introductions: • Explain the purpose of the workshop, including information about the research aim and the CBA-AR framework. • Explain that the focus of Workshop 2 is to refine the design strategy specific to C4. • Provide an overview of C4 and its characteristics, including its historical and structural significance. Emphasize the different perspectives from Workshop 1 and how this workshop will refine those ideas.
2. Reflecting on the outcomes (20 minutes)
• Present the design proposals developed during Workshop 1 • Open a discussion on the relevance of these design proposals for C4. Consider the physical structure, historical value, and specific user needs of the building. • Encourage participants to provide input based on their expertise with C4, adapting the proposals where necessary.
3. Group Discussion: Design Strategy (1 hour)
• Strategies will be divided in advance by the researcher into three themes. - *Theme 1: Shared & Integrated Spaces* - *Theme 2: Design Flexibility* - *Theme 3: Material & Resource Efficiency* • The workshop will consist of three 20-minute rounds. Each round, participants receive a booklet with descriptions of the strategies within each theme. • First 10 minutes: Group discussion on how the strategies can be applied in the case study project. • Second 10 minutes: Central discussion where participant share their perspectives, insights, and experiences related to each strategy. • The researcher will guide the discussion, ensuring that all participants have an opportunity to contribute and that diverse viewpoints are considered.
4. Closing Remarks (15 minutes)
• Researcher will summarize the key findings and outcomes of the workshop. • Identify the final set of design proposals and strategies for C4 based on the discussion. • Outline the next steps for the implementation of the refined strategies and action plan.
5. Optional Networking Session (15 minutes)
• Participants can continue their discussions over refreshments. • Highlight the importance of maintaining communication and collaboration as the project progresses.

APPENDIX F – FORM OF CONSENT

Research: *Exploring the applicability and effectiveness of circular building adaptability strategies in adaptive reuse*
Institution: *Technische Universiteit Delft*
Interviewer: *Fatih Sarikaya*

Please tick the appropriate boxes

Taking part in the study	*YES*	*NO*
1. I have read and understood the study information dated 15/04/2024, or it has been read to me. I have been able to ask questions about the study and my questions have been answered to my satisfaction.	☐	☐
2. I consent voluntarily to be a participant in this study and understand that I can refuse to answer questions and I can withdraw from the study at any time, without having to give a reason.	☐	☐
3. I understand that taking part in the study involves answering questions that will be audio-recorded, with the sole purpose of transcribing the interview, after which, the recordings will be deleted.	☐	☐
Use of the information in the study		
4. I understand that information I provide will be used only for academic purposes for the graduation project and corresponding presentation at TU Delft, unless indicated that certain information is confidential.	☐	☐
5. I understand that personal information collected about me that can identify me, such as [e.g. my email address or personal contact details], will not be shared beyond the study team.	☐	☐
6. I agree that my information can be quoted in research outputs.	☐	☐
7. I agree that my real name can be used for quotes.	☐	☐
Future use of information by others		
8. I give permission for the publication of graduation thesis results at the TU Delft educational respository, which are partialy based on the anonymized transcripts of this interview, to be used for future research and learning.	☐	☐

________________ ________________ ________________

Name of participant *Signature* *Date*

APPENDIX G – DATA MANAGEMENT PLAN

Plan Overview

A Data Management Plan created using DMPonline

Title: Exploring the Applicability and Effectiveness of Circular Building Adaptability Strategies in Adaptive Reuse
Creator: Fatih Sarikaya
Affiliation: Delft University of Technology
Template: TU Delft Data Management Plan template (2021)

Project abstract:

C Circular building adaptability (CBA) offers substantial benefits to the built environment, including reducing building costs through material efficiency and waste reduction, while enhancing the long-term value of structures through improved flexibility (Hamida et al., 2023). Next to this, CBA contributes to long-term sustainability in the built environment by making it possible to generate new business opportunities within the circular economy (CE). However, the Dutch building industry faces significant challenges in adopting CBA principles, particularly in the context of adaptive reuse (AR) projects. These challenges hinder the industry's transition towards a sustainable and circular built environment.

This research primarily concentrated on testing part of a relatively new framework that links determinants, strategies and the enabling and inhibiting factors of CBA in adaptive reuse projects to support the shift towards a circular economy. Accordingly, this study aimed to answer the following research question: ***"How can the applicability and effectiveness of design-oriented circular building adaptability strategies (CBASs) be promoted in adaptive reuse projects?"***. A stepwise research design of two approaches was followed, namely case studies and Research-through-Design (RtD). The methods include archival research, field observations, semi-structured interviews with key informants, questionnaires, and workshops focused on practical design solutions.

The results indicate that the CBA-AR framework is a useful tool that integrates CBA-determinants, strategies, and associated enabling or inhibiting factors, and can be useful during early-stage planning and collaboration in adaptive reuse projects. Second, based on the findings of the case study, three strategies have been identified as the most applicable and effective, namely: opening the floor plan, providing multi-purpose spaces, and aligning the interconnection between floor plans. In contrast, the less applicable and effective strategies for the cases examined in this study are designing for mixed-use, modularizing spatial configuration, and designing for surplus capacity. Finally, the successful implementation of CBASs requires raising awareness among professionals, as the lack of knowledge often leads to missed opportunities for integrating adaptable and sustainable design strategies.

The scope of the research has been limited to the design-oriented (passive) CBASs, and therefore, directions for future research have been put forward in the conclusion. Moreover, the findings of this study are not generalizable because they are case-specific; however, they provide valuable lessons for future research, policy-making, and practitioners seeking to promote resource efficiency and future-proofing in adaptive reuse projects.

ID: 142383

Start date: 01-02-2024

0. Administrative questions

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

- My faculty data steward, Janine Strandberg, has reviewed this DMP on 22-1-2024.

2. Date of consultation with support staff.

- 2024-01-22

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 CBASs implemented in adaptive reuse projects	word files	Interviews	Understanding to what extent the CBASs are implemented in adaptive reuse projects.	Project storage drive + backup	Main Researcher
Data on the implentation of CBASs implemented in adaptive reuse projects	video or audio recording	Interviews	Understanding to what extent the CBASs are implemented in adaptive reuse projects.	Project storage drive + backup	Main Researcher
Data on the implentation of CBASs implemented in adaptive reuse projects	word files	Questionnaire	Understanding to what extent the CBASs are implemented in adaptive reuse projects.	Project storage drive + backup	Main Researcher
Data on the implentation of CBASs implemented in adaptive reuse projects	video or audio recording	Design Workshop	Understanding to what extent the CBASs are implemented in adaptive reuse projects.	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) If you are not sure which option to select, first ask your Faculty Data Steward for advice. You can also check with the privacy website . If you would like to contact the privacy team: privacy-tud@tudelft.nl, please bring your DMP.

- No

8B. Will you work with any other types of confidential or classified data or code as listed below? (tick all that apply)
If you are not sure which option to select, ask your Faculty Data Steward for advice.

- 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?
For projects involving commercially-sensitive research or research involving third parties, seek advice of your Faculty Contract Manager when answering this question. If this is not the case, you can use the example below.

- 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

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

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 with another institution called RES&SMIT. 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?

- First Mentor: Hans Wamelink - j.w.f.wamelink@tudelft.nl
- Second Mentor: Mohammad B. Hamida - m.b.hamida@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)?
Question not answered.

Exploring the applicability and effectiveness of circular building adaptability strategies in adaptive reuse

TU Delft
Department of Management in the Built Environment
BK Bouwkunde