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Advancing an Adaptable Building Framework through Action Design Research

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RESEARCH

Making Circular Strategies Work: Advancing an Adaptable Building Framework through Action Design Research

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Abstract

Circular and adaptable strategies in building reuse are key to achieving a resource-efficient and future-proof built environment. Despite significant advances in circular building research, this field is affected by a significant theory–practice gap. To bridge this gap, we applied an action design research methodology, implementing a circular building design framework over a five-month period in the context of a Dutch monumental office building reuse. The objective of these interventions was to observe practitioners engaging with the framework and identify the barriers they encountered when considering and applying circular building strategies. We observed that the framework primarily functioned as a descriptive tool. Enhancing its usability and effectiveness required several refinements, including simplifying its self-description, clarifying its strategies through practical solutions and connections to related models, providing robust assessment tools, and improving its accessibility. Through iterative action research conducted during the observation and intervention period, we addressed these issues and advanced the framework. Our design-oriented approach led to the development of key design artifacts: a prescriptive guiding, assessment, and reporting tool; a stepwise approach to streamline application; and a hands-on worksheet for practitioners. These artifacts were integrated into a user-friendly platform, transforming the framework into a practical tool for real-world implementation. For theory, this study incorporates a circular perspective into a usable framework and demonstrates how an action design research approach can co-develop and improve frameworks and their usability and relevance. For practice, the produced artifacts represent boundary objects tailored to practitioners' needs; thereby paving the way for future circular adaptive reuse. Clinical trial number: not applicable.

Keywords Action research · Adaptability · Adaptive reuse · Built environment · Circular building adaptability · Design research

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Introduction

The building sector is seen as a major player in environmental sustainability-related concerns in societies, such as high energy consumption, waste generation, and greenhouse gas emissions (European Commission 2020). Accordingly, fostering resource-efficient practices in this sector can play a vital role in promoting environmental sustainability and paving the way for the transition to circular economy (CE) – a resource efficiency paradigm aiming at decoupling economic growth from resource use – in the future (Zimmann et al. 2016). In this context, research on the building sector widely acknowledges the adaptive reuse of buildings as a promising strategy to facilitate a CE, owing to its capacity to reuse and prolong building assets and reduce waste (Foster 2020; Gravagnuolo et al. 2017; Kaya et al. 2021). 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"*(Iselin and Lemer 1993). It refers to the process of repurposing existing buildings or structures for new uses to serve new requirements (Douglas 2006) and is implemented as a means to cope with different consequences of market dynamics, such as transforming vacant offices into residential apartments (Remøy, 2010). It is a sustainable approach to urban development and conservation that extends the lifecycle of buildings, reduces waste (Remøy, 2014), and minimizes the environmental impact of demolition and new construction (Foster 2020).

Despite the booming of research in adaptive reuse over the past two decades, the field still suffers from a significant theory–practice divide (Greco et al. 2024). A key reason identified in research for this divide is the way the design processes are organized. This divide stems from the fragmented and often linear nature of traditional design processes, which should become material-centric. This requires a systemic shift in how contemporary design practices unfold: material decisions currently constitute one of the last and list design steps. Traditional design approaches also fail to account for the iterative, collaborative, and interdisciplinary approaches required for adaptive reuse (Greco et al. 2024). Effective adaptive reuse demands a design process that integrates diverse stakeholder perspectives, balances competing priorities, and embraces the complexity of transforming existing structures into sustainable, functional, and context-sensitive spaces (van Laar et al. 2024).

To address the call for bridging the theory–practice divide in adaptive reuse and advancing its integration with circularity, we draw on the existing body of research and practice to develop a set of practical resources tailored to practitioners aiming to promote circularity. While research has identified numerous strategies to foster Circular Building Adaptability (CBA) (Hamida et al. 2023a, see Sect. 3) — such as demountability, surplus capacity, and design standardization (Akhimien et al. 2021; Rockow et al. 2021)—there remains a gap in translating these strategies into actionable tools that can be seamlessly adopted in real-world projects. This gap is further compounded by barriers like technical constraints, legislative restrictions, and the lack of expertise in circular design processes (Hamida et al. 2023b).

To bridge this divide, we leverage insights from the theory of adaptive reuse and circularity to co-create user-friendly, guidance-oriented tools aimed at addressing the challenges practitioners face. By focusing on practical applicability, these resources are designed to foster the adoption of CBA strategies, offer solutions to common obstacles, and enhance the overall adaptability and longevity of reused buildings. Through this approach, we aim to empower professionals to implement circular practices more effectively, contributing to the broader goal of a sustainable and circular built environment. This paper addresses the practical gap in circular building adaptability by testing and refining the usability and

effectiveness of the CBA-AR framework through an action- and design research-oriented approach. We used a mixed action design research, as proposed by Collatto et al. (2018), because action design research considers and can integrate both object- and process-related aspects, namely the design of an artifact and its utilization (Sein et al. 2011). The combination of design research and action research also contributes to effectively conducting practical research, paving the way for interventions and evaluation in practice, design development, and knowledge creation (Goldkuhl 2013). In this paper, usability refers to the ease of use for practitioners, while effectiveness measures the framework's capacity to enhance circular adaptability in design. The outcomes contribute to the literature by providing methodological insights for the future development of decision-making tools, such as those proposed by Hong and Chen (2017), and offer practical guidance tools for practitioners. Additionally, policy-makers can integrate the refined tools into regulatory frameworks to promote circular adaptive reuse. By bridging this gap, the study aims to advance the circular reuse of built assets and foster sustainable design practices; thereby paving the way for the transition to a circular and future-proof built environment and contributing to environmentally sustainable societies.

We structure the paper as follows. First, we provide an overview of the research field and its relevant concepts, followed by an identification of the research problem and the focus of the paper. Second, we introduce the literature on adaptive reuse and its circularity frameworks in Sect. 2. Third, we present the mixed-action design research approach we followed and the data collection and analysis methods we used in Sect. 3. Section 4 presents the results of our observations, interventions, designed prototypes, and reflections. Section 5 presents our discussion of the key findings, implications, and limitations of our study. Finally, Sect. 6 summarizes the focus of our study, draws the main conclusion, and puts forward a series of recommendations for scholars, practitioners, and policymakers.

Adaptive Reuse and Its Circularity-Oriented Frameworks

Adaptive Reuse

As mentioned in the introduction, adaptive reuse refers to the process of converting existing buildings or part of them to serve new requirements (Iselin and Lemer 1993). It is also known as building conversion, across-use adaptation, and building transformation, which is a common type of building reuse project. It requires implementing major physical alterations for repurposing and adapting the building to a use different from its original purpose (Douglas 2006; Shahi et al. 2020; Wilkinson 2014). It is implemented in existing buildings as a coping strategy to reuse vacant properties (Remøy, 2014), as well as preserve and revitalize heritage buildings and locations (Tu 2020; Wang and Liu 2021). In practice, it can be triggered by other factors, such demographic changes, building obsolescence, and market volatility (Ross 2017).

Adaptive reuse is in line with the sustainability triangle principles, as it can contribute to reducing greenhouse emissions and the costs spent in demolishing existing buildings and rebuilding them (Mohamed et al. 2017). Moreover, this type of building project has been seen as a practice aligning with the principle of CE, owing to its great potential to reuse building assets, prolong their functionality, and therefore, reduce waste and the need for new materials (Foster 2020). Therefore, as a newly emerging practice, several frameworks and models have been conceptualized to capture the alignment between adaptive reuse and

CE and ease its decision-making- and design-related practices (Foster 2020; Gravagnuolo et al. 2017; Hamida et al. 2024).

Frameworks for Circularity in Adaptive Reuse

Conceptual frameworks act as a concept-based constructed network that links and interprets a certain approach, phenomenon, or philosophy (Jabareen 2009); thereby, they contribute to advancing and systematizing knowledge about their components (Rocco and Plakhotnik 2009). Their construction usually entails appropriating terminologies and usable information associated with the relevant concepts and rules to the particular phenomenon of interest in the form of a specialized system. Therefore, their application in practice involves information-oriented uses such as providing generalized resources for giving meaning and adapting action systems (Hills and Gibson 1992). In the built environment, frameworks can be used as a means to promote new principles and emerging concepts such as circular design and construction, (Marchesi and Tavares 2025; Saradara et al. 2024).

For circular adaptive reuse, Gravagnuolo et al. (2017) conceptually positioned adaptive reuse in a CE-oriented framework, namely the ReSOLVE framework, to provide a series of evaluation criteria for circular adaptive reuse. The ReSOLVE framework– standing for Regenerate, Share, Optimize, Loop, Virtualize and Exchange – is transition-oriented and jointly developed by Ellen MacArthur Foundation and McKinsey Center for Business and Environment as means to contextualize and demonstrate how CE can be promoted in the industry (Ellen MacArthur Foundation and McKinsey Center for Business and Environment 2015). Similarly, Foster (2020) conceptualized a framework mapping a series of strategies for circular adaptive reuse to the R-ladder – a CE-oriented model developed by the PBL to bring together a series of 10 strategies gradually ordered based on their level of circularity (Potting et al. 2017) – model as a construct-capturing solution for promoting circularity in adaptive reuse. Both of the above-mentioned frameworks are merely conceptual and based on material-oriented models of CE.

Hamida et al. (2024) developed a content-wise framework for circular and adaptable adaptive reuse projects based on a multi-source approach, leveraging knowledge from theoretical, empirical, and participatory approach. The framework is based on the defined CBA by Hamida et al. (2023a) 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.*". As a content-wise framework, the CBA-AR is a descriptive synthesis that maps a series of CBA-oriented strategies for adaptive reuse to the defined ten determinants of CBA. The CBA determinants were defined based on critically analyzing and resynthesizing concepts and models related to adaptability and circularity in the building environment (see Akhimien et al. 2021; Foster 2020; Ellen MacArthur Foundation 2019; Kyrö et al. 2019; Rockow et al. 2021). Therefore, the CBA determinants can be guiding when pursuing resource efficiency and long-lasting functionality in buildings across different contexts other than building reuse (Ollár, 2024).

The enabling and inhibiting factors to implement these strategies are incorporated in the framework. The framework comprises 33 strategies, including 15 passive, 7 active, and 11 operational strategies, alongside 10 enablers and 7 inhibitors (Fig. 1). Passive design strategies comprise solutions that can promote CBA through the building design, while active strategies encompass solutions that foster CBA through altering the building configuration and user intervention. Operational strategies are process-oriented solutions that promote CBA.

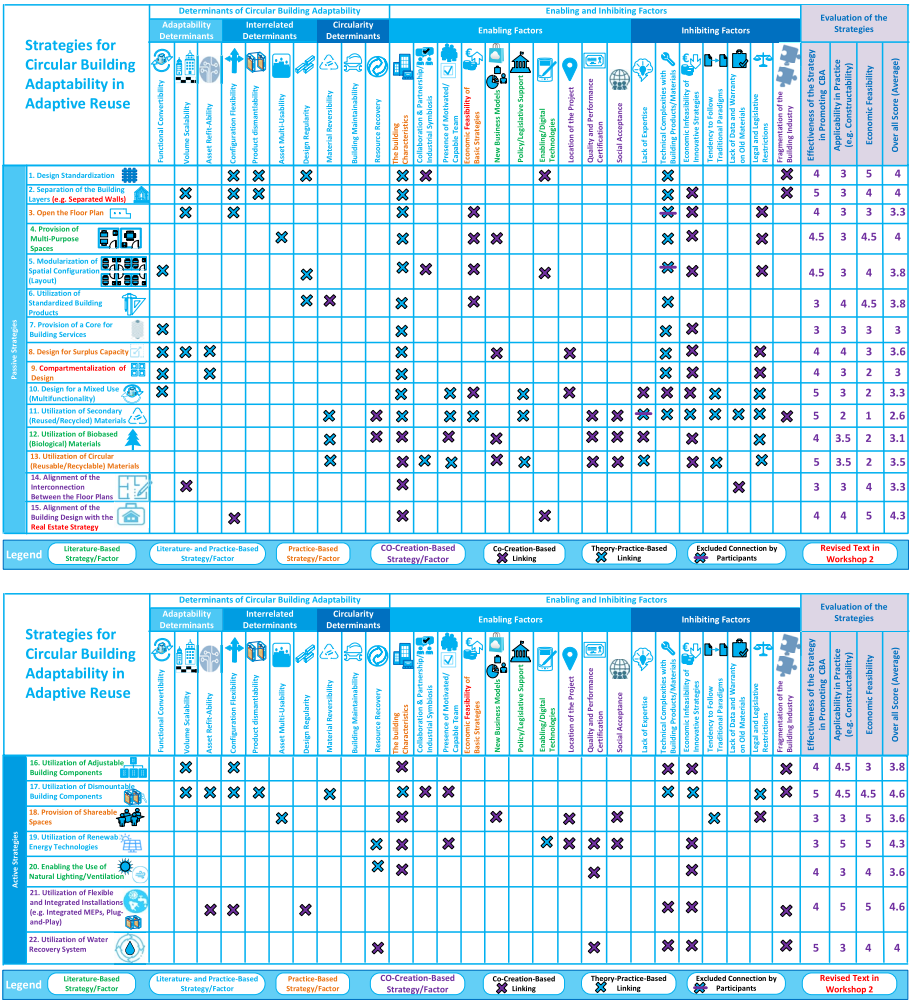


Fig. 1 The CBA-AR framework. Source: figure courtesy of Hamida et al. (2024)

Content-wise, the CBA-AR framework is comprehensive, as it is based on previous literature reviews (Hamida et al. 2023a), empirical evidence from demonstration cases (Hamida et al. 2023b), and collaborative development and validation (Hamida et al. 2024). Usability-wise, the CBA-AR framework has been developed as a knowledge-based tool to help scholars and partitioners within the building and real estate fields in determining possible strategies for circular and adaptable building reuse (Hamida et al. 2024). This can be realized by exploring the interconnection between the strategies and the CBA determinants – as a checklist, as well as the collective evaluation of the effectiveness, feasibility, and applicability of each strategy as shown in Fig. 1. Generally, the practical contribution of this framework lies in its alignment with the EU Taxonomy compass (2020). In particular, the framework guides practitioners to consider key aspects mentioned in the EU Taxonomy Navigator (2020), namely design for resource efficiency, adaptability, flexibility, and disassembly to enable for reusability

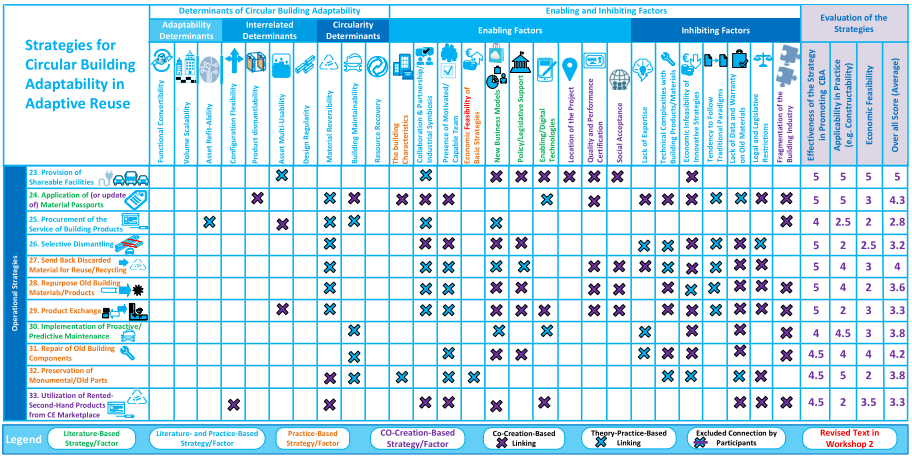


Fig. 1 (continued)

and recyclability of materials in renovating existing buildings. It also contributes to fostering circularity through design as a key accelerating player in the built environment (Greco et al. 2024). However, how it can be used in practice as a tool has not been investigated yet, as pointed out by Hamida et al. (2024), which necessitates exploring its usability and effectiveness in practice.

Methodology

Overview and Theoretical Background of the Research Approach

Research Approach

We followed mixed action research- and design research-oriented approach in this paper in line with Collatto et al., (2018), as the overall focus of our study is on generating knowledge about promoting circularity and adaptability in adaptive reuse projects by using a developed framework as a boundary object. To apply the framework, we selected a reuse project of a vacant monumental office building located in South Holland, the Netherlands (see subsection 3.2). We collected data during a 5-month period– between April 2024 and September 2024 – as shown in Fig. 2. During this time, we used archival research, field observations and interventions, and reflection workshops as primary research methods. The iterative and simultaneous data collection logic was carried out, instead of a sequential logic, as indicated by Collatto et al., (2018), due to the twofold aim of this study: testing and reflecting on the usability and effectiveness of the CBA-AR framework in practice. In this paper, usability concerns all aspects of the ease of using the framework by practitioners, while effectiveness concerns the capacity of the framework to enhance the design outcomes for promoting CBA.

The planning of this action design research study began in December 2023. During that time, we formed the research team and worked together on designing the action design research methodology, setting the criteria for the case project, and contacting real estate

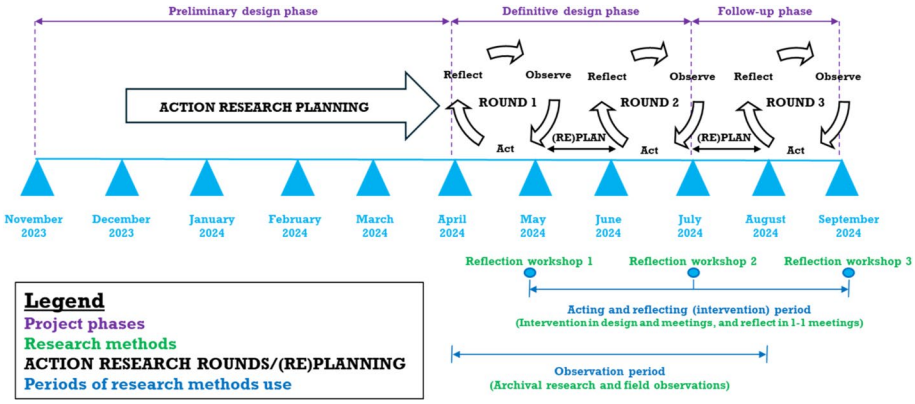


Fig. 2 Timeline and methods of observations, interventions, and reflections in this study. Source: authors' own creation

developers interested in experimenting with us. As shown in Fig. 2, we iterated through three rounds, using the workshops as key milestones to enable participatory co-reflection on the framework's usability and effectiveness. Between these rounds, we reflected on the outcomes of each workshop and planned and replanned the next phase while improving the framework, as well as the processes of observing and intervening in the case project, based on discussions among the authors and the developing manager of the selected case project.

Background of Action Research and Design Research and their Use in this Study

Kemmis and McTaggart (1988) defined action research (AR) as *"a form of collective self-reflective inquiry undertaken by participants in social situations in order to improve the rationality and justice of their own social or educational practices, as well as their understanding of these practices and the situations in which these practices are carried out."*. Such an approach has been recognized as a practically useful way of bringing research and practice together to deeply produce theoretical insights into a process or practice (Altrichter et al. 2002). Based on Lewin's (1946) description of the steps of action research, Kemmis and McTaggart (1988) described the process of action research as a series of self-reflective spirals (cycles) that follow the following sequence: planning, acting and observing, reflecting, and replanning and so on, respectively.

Action research can be conducted to serve different purposes. For instance, action research can be conducted for technical purposes to empower practitioners to improve the outcomes of practice. For instance, Alves et al. (2021) conducted an action research study to promote implementing an e-waste management program in São João del-Rei in Brazil and observe the outcomes of implementing the program in the city. Action research can be also carried out for practical purposes to enlighten practitioners and provide them with the education they need to act more wisely to improve the consequences and outcomes of a practice in the long term (Kemmis et al. 2014). In this regard, researchers using AR-oriented approaches should pay close attention to the way of bridging mutual impacts between research and practice (Greco et al. 2023). Recently, action research has been used as a valid approach to sustainable development-related studies by virtue of its potential to influence and transform policies and current practices (Keahey 2021; Greco and Long 2022).

In this study, action research was incorporated into the research approach to bring about both technical and practical implications, as the aim of the study is to enable practitioners from the building industry and real estate market to actively promote CBA in building reuse projects through the use of a framework as a guiding tool.

Design research (DR) is characterized as a systematic approach that is concerned with the physical configuration and performance of human-made things, besides how the design process works (Bayazit 2004). Archer (1981) defined DR as *"systematic enquiry whose goal is knowledge of, or in, the embodiment of configuration, composition, structure, purpose, value and meaning in man-made things and systems."*, also shortly as a *"systematic enquiry into the nature of design activity."*. In this regard, Frayling (1993) categorized DR into three forms, namely research into art and design – researching the practice of designing objects/processes, research through art and design – researching through developing design, and research for art and design – researching to serve design. These forms are interrelated and can be indispensable in some situations.

In the design-related fields, AR can be integrated with design and DR to facilitate knowledge creation, improving a certain situation, and solving a problem through a design practice of demonstrating or building a new thing (Collatto et al. 2018; Goldkuhl 2013). Combining AR with DR enables innovative design, while intervening, evaluating, and reflecting on the outcomes of process interventions (Sein et al. 2011). AR and DR can also be brought together to apply and test a framework in the built environment design (seeGaete Cruz et al. 2022; Pikas et al. 2020).

In conclusion, bringing AR and DR together facilitates research on process- and object-related themes (see Fig. 3). In the built environment, AR- and DR- approaches can be philosophically positioned within the so-called emancipationist philosophical perspective, owing to the epistemological (reality-related) and ontological (knowledge-related) assumptions (Salama 2019).

Description of the Case Project

The context of this study is a monumental office building in the Netherlands, built in 1907, that will be transformed into a multiple-office building by a real estate developer that acquired the building in 2021. Although this project is used as a single case to test and reflect on the usability and effectiveness of the CBA-AR framework, this case is relevant for three reasons. First, this study explores an emerging topic using multiple sources of

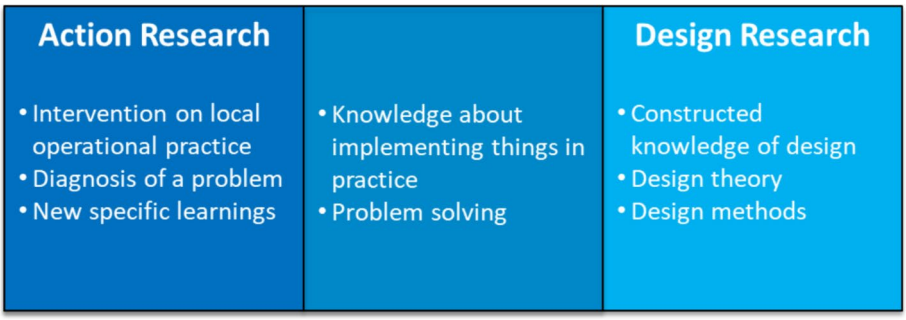


Fig. 3 Conceptual mapping of the potential outcomes of combining AR and DR. Source: authors' adaptation from (Collatto et al. 2018; Goldkuhl 2013)

evidence according to Yin (2009) (see subsection 3.3). Second, the research methods were used iteratively, aligning with what Eisenhardt (1989) indicated about reaching saturation in case study research. Third, the project reuse process is unconventional – redevelopment of a listed cultural heritage asset – which can contribute to providing insights into other dynamics and relationships for drawing inferences based on rich field experiences (Sharma et al. (2024).

The building is a 4-story structure with a gross floor area of 6,500 m^2, lettable floor area of 3,500 m^2, and land area of 6,000 m^2. The architectural style of the building is classic, as it was built using different types of typically local construction methods and materials, including a brick facade, steel structure, concrete slabs, and flat and pitched roofs.

We selected this case project for its alignment with the focus of our study in two main respects. First, the project was about to enter the definitive design phase, during which key design decisions are typically made. Second, the project developer was willing to experiment with circular design and the use of the CBA-AR framework.

Data Collection

As indicated in subsection 3.1, we iteratively used three methods in this study: archival research, field observations and interventions, and reflection workshops. Table 1 provides an overview of the type of data collected in each method. Next follows a further explanation of these methods and their data.

Archival Research

Archival research refers to reviewing or investigating various documents produced by organizations or individuals for using information produced in the past for specific research-oriented purposes (Ventresca and Mohr 2002). In this study, we reviewed and investigated design documents, technical reports, and inventory sheets (Table 1), to understand the project context and draw inferences about the possibility of implementing certain strategies during the observation and intervention periods.

We acquired as-built drawings and the ongoing definitive design proposals in a digital format, from the developer. These design documents have iteratively been used and investigated during the observation and intervention periods, along with the field observations

Table 1 Research methods and their data

Method	Type	Number
Archival research	Design documents	2
	Technical reports	2
	Inventory sheets	4
Field observations and interventions	Design meetings	3
	Walkthrough audit	10
	Field inspections	3
	Reflection/follow-up meetings between the researchers and a practitioner	6
Workshops	Reflection workshop	3

Source: Authors' own creation

and reflection workshops (see Fig. 2 and sub-subsection 3.3.3). In addition, we acquired two technical reports, namely the project plan – issued by the real estate developer itself – and documentation of the building history – issued for the developer by an advisory organization specialized in advising and developing policies for preserving and restoring cultural heritage buildings in the Netherlands. We used both technical reports during the observation and intervention periods as well. They effectively contributed to getting a better grasp on the context of the case project and building its profile (subsection 3.2). Finally, inventory sheets of the available building materials, products, and systems were developed, frequently updated, and used during the intervention period.

Field Observations and Intervention

The purposeful combination of field study, incorporating participant observation and action research, positions the researcher in a unique setting to ground evidence in practice which is key when dealing with environmental, social, and economic impacts (Jay 2013; Greco and Long 2022). In this study, this technique was adopted and implemented by the first author who joined the developing team on the project site once a week between April 2024 and July 2024. During that period, the first author collected data by joining three design meetings between the developer and architect, conducting ten walkthrough audits during the weekly participation on site, joining the developer team in three field inspections with other stakeholders (including municipality, acoustical consultants, collateral heritage specialist, HVAC specialist, and fire safety department), and holding six 1–1 follow-up and reflection meetings with the developing manager. (Table 1). The CBA-AR framework was introduced to the developing team at the beginning of the observation period in a 1–1 meeting, which contributed to defining the CBA strategies that have already been implemented in the original design of the building.

Aligning observation-, intervention- and reflection-related activities is a crucial step in action research-based studies (Postholm 2020). Accordingly, the first author reported observations, interventions, and reflections every week for both on-site and remote work. The notes clearly make a distinction between planned and unplanned observations and interventions. The reported observations, interventions, and reflections were abductively processed, meaning that the possibility of emerging themes was considered along with the process of testing the CBA-AR framework –this study's main theme and guiding scheme.

Abduction is a form of reasoning logic used for acquiring knowledge and drawing inferences about observed reality to generate, and properly test, new ideas, knowledge, and even theories based on empirical data and reasons without necessarily having presuppositions. Therefore, it enables researchers to spontaneously acquire new knowledge based on observations from the real world without being neither limited to literature nor ignorant of it (Reichertz 2014), which makes it useful for case-based research (Dubois and Gadde 2002).

Reflection Workshops

We organized three action- and-design-oriented reflection workshops on the 21 st of May 2024, 9 th of July 2024, and 27 th of September 2024, respectively. We held these workshops as milestones to collaboratively reflect back on the useability and effectiveness of the CBA-AR framework as a design guiding tool in the case project during the observation and intervention periods (Fig. 2). Action research-wise, workshops can be incorporated into the phases of action research as short cycles of actively acting in or reflecting

on a phenomenon of interest (Fisher 2004; List 2006). For instance, Aigwi et al. (2021) organized a workshop to collaboratively validate a developed process-oriented framework for an effective decision-making process in adaptive reuse projects. In design-related fields, workshops have been used as an effective method for designing and evaluating artifacts (Thoring et al. 2020), as demonstrated by van Stijn and Gruis (2020) and Gaete Cruz et al. (2022).

In this study, these workshops also served as brainstorming sessions to feed the design proposals and the framework improvements. The program of the first two workshops included an activity of collaborative mapping of the utilized CBA strategies to the definitive design drawings to enhance forward-looking co-creation (Sharma et al. 2022). In this study, the methodological framework of Storvang et al. (2018) for planning, diagnosing, facilitating, and analyzing workshops as a research method was followed. Table 2 provides an overview of the protocol of the three workshops, including the purpose, roles and responsibilities, participants, and boundary objects in each workshop. All the participants were from the developing team of the case project. During these workshops, we allowed the participants to express their perception of the actionable part of the study and we gave them the flexibility to use their own terminologies to refer to their own experiences, thereby enhancing the credibility of the research. According to, Champion and Stowell, (2003) empowering participants in action research to express their judgment on the research inquiry and also giving them access to the research process are substantial for establishing the credibility and validity of AR.

Two members of the developing team – including the developing manager and a specialist in cultural heritage redevelopment – participated in the reflection workshops, as project representatives with a design background, along with us, as action researchers. Regarding the workshop facilitators, the first author – who has hands-on the project – moderated the three workshops along with the fourth author. The other authors were active participants, iteratively checking taken actions in real-time while also reflecting on the usability and effectiveness of the CBA-AR framework and design outcomes. We used CBA-AR framework along with the drawings of the definitive design as key boundary objects in the first two workshops. In the second workshop, we also used the outcome of reflecting on the useability of the framework – a compiled prescriptive booklet as a prototype – as a boundary object. In the final workshop, the focus was mainly on the finalized improvements of the framework, so the digitized prototype – a platform – was the main boundary object.

Data Analysis and Validation

We immediately analyzed and interpreted the collected data abductively (see 3.3.2.). We used the components of CBA-AR framework (Hamida et al. 2024) as a coding scheme while spontaneously enabling other themes to emerge from the observations.

To uphold the construct validity of this study, we validated the collected data by adhering to two principles of validity of AR data, namely *reflexivity* and *dialectics*. *Reflexivity* in AR is related to the main philosophy of AR in which researchers would have reflective thinking and consciously reflect on their experience about interaction with the participants along with the epistemological and ontological assumptions, while *dialectics* refers to the consideration of different voices through facilitating interactive discussions and interpretations during the conduct and reporting of AR (Heikkinen et al. 2012).

In this study, we established *reflexivity* by maintaining an ongoing reflection on the collected data from the archival research, observations, interventions in the field, and

Table 2 Protocol of the three reflection workshops

Workshop	Purpose	Roles and responsibilities	Boundary objects
Workshop 1	Reflecting on the useability and effectiveness of the first version of the CBA-AR framework as well as the implementation of the CBA strategies in the definitive design proposal	Facilitators: Moderating the workshop as well as observing and reporting the outcomes Researchers: Reflecting on the design outcomes and framework usability Participants: Defining the implemented CBA strategies and other possible strategies for implementation in the project, as well as reflecting on the usability and effectiveness of the framework	• Version 1 of the CBA-AR framework • Definitive design drawings • Presentation about the project profile
Workshop 2	Reflecting on the useability and effectiveness of the revised version of the CBA-AR framework and its prescriptive booklet as well as a series of CBA strategies that were perceived as possible in workshop 1	Facilitators: Moderating the workshop as well as observing and reporting the outcomes Researchers: Reflecting on the outcomes of workshop 1, the possibility of easing the implementation of a series of perceived strategies possible in workshop 1, and the usability of the revised version of the framework and its prescriptive (user) booklet Participants: Reflecting on the outcomes of workshop 1, the possibility of easing the implementation of a series of perceived strategies as possible in workshop 1, and the usability of the revised version of the framework and its prescriptive (user) booklet	• Version 2 of the CBA-AR framework (embedded in a compiled prescriptive user booklet) • Definitive design drawings • Summary of outcomes of workshop 1
Workshop 3	Reflecting on the useability and effectiveness of the finalized and digitized versions of the CBA-AR framework (including its prescriptive guide)	Facilitators: Moderating the workshop as well as observing and reporting the outcomes Researchers: Reflecting on the outcomes of workshop 2, the usability of the revised and digitized version of the framework (including its user guide), and the research conclusion Participants: Reflecting on the outcomes of workshop 2 and the usability of the revised and digitized version of the framework (including its user guide)	Version 3 of the CBA-AR framework (embedded in a developed platform)

Note: All the participants were from the developing team of the case project

Source: Authors' own creation

reflection workshops. The analyzed data from the archival research was reported by the first author and discussed with the developing manager in some 1–1 meetings. The reported observations and interventions along with the reflections were shared with the other authors as other interpreters. We analyzed, reported, and shared the outcomes of each reflection workshop with the participants for reflection. *Dialectics* was fulfilled by engaging and bringing together the authors – as action researchers – and members of the developing team – as practitioners – in the workshops and empowering them to reflect together on the amendment of the CBA-AR framework and the research progress in general.

Findings

As our paper focuses on bridging the gap between the theory and practice of adaptive reuse by testing and reflecting on the useability and effectiveness of utilizing a developed content-wise framework – the CBA-AR framework by Hamida et al. 2024 – as a guiding tool in practice, we present in this section the results of this twofold extermination followed by other outcomes that emerged through the action design research approach we used. In general, our participants perceived the descriptive version of the CBA-AR framework (Fig. 1) as an informative tool at the beginning of the observation and intervention period. However, they perceived it as a complicated tool that needed a simplified general explanation on one hand, and further elaboration, description, and practical examples of its content on the other hand.

Examination of the Usability of the Framework

As the ease of using the framework is a key determinant of its usability, the findings of the first two rounds of iteration enabled us to refine the framework and make it easier to use. Introducing the framework to the developing manager contributed to defining 18 CBA strategies already implemented in the project and considered in the initial definitive design proposals, which has been a useful mapping exercise for us. The following are the 18 strategies along with their practical applications:

- *Design standardization:* Acoustical installations.
- *Separation of the building layers:* The partitions are designed for a lifespan of 20–25 years, while the fit-outs will be considered to last for 10–15 years.
- *Open the floor plan:* The main hall (in the original design)
- *Provision of multi-purpose spaces:* The hall is a multi-use space.
- *Modularization of spatial configuration:* Modular layout of spaces.
- *Provision of a core for building services:* Two cores for stairs, MEPs shafts, and toilets
- *Compartmentalization of design:* Compartmentalizing the building. horizontally, meaning that each floor is a compartment on its own
- *Utilization of biobased materials:* Timber, wooden studs, and biobased paintings
- *Utilization of reusable products:* Removable partitions.
- *Alignment of the interconnection between the floor plans:* Placing all the plumbing services in two shafts in the same location on each floor
- *Alignment of the building design with the real estate strategy:* Preserving the heritage assets in the building within the redevelopment process while diversifying the users (type of tenants) in the building.

- *Provision of shareable spaces:* A shareable hall, toilets, and meeting rooms
- Enable the use of natural lighting and ventilation: All offices have windows that can be opened.
- *Provision of shareable facilities:* Shareable charging stations and pantries.
- *Send back old materials for reuse:* Glass panels.
- *Implementation of proactive/predictive maintenance:* Adoption of multi-year maintenance plan.
- *Repair of old building components:* Façade renovation
- *Preservation of monumental parts:* Preserving closets, chandeliers, busts, and old radiators in the hall and stairs as well as on the ground floor.

In the first reflection workshop, the participants pointed out that the descriptive framework (Fig. 1) can be used as a checklist tool (see Appendix A). In contrast, they concluded that it needs further improvements, namely simplifying its description, elaborating on the strategies – specifically by adding a description, practical examples, phase of implementing, advantages and disadvantages of each strategy, and aligning the CBA strategies with the shearing layers model by Brand (1994). Furthermore, they concluded that the framework outline should be described in a simplified manner. Some textual amendments were recommended too; for example, reformulating 'product dismantlability' to 'building demountability' to ease its comprehension by the framework users.

Accordingly, we revised the framework in line with the inputs in the first round of observing, intervening, and reflecting. We compiled a prescriptive user booklet – as a first user-oriented prototype – and shared it with the participants to ease the framework's usability. The booklet contains three main sections: an overview, a description of the strategies, and a user guide. The second section includes an in-depth description of the CBA strategies, while the third section includes a newly designed approach and worksheet for the user (see sub-Sect. 4.3).

In the second reflection workshop, the participants reflected on the revised CBA-AR framework (Fig. 4) and the compiled prescriptive use booklet, preceded by a discussion on the potential to implement another 12 strategies in the definitive design of the project. The participants proposed rephrasing 4 strategies (No. 11, 13, 16, and 31) as well as mapping the strategies to the R-ladder model by Potting et al. (2017) as another circularity-oriented measure. In addition, the participants emphasized the need to digitize the framework in a user-friendly way.

Accordingly, between the last two workshops, we incorporated the R-ladder model into the framework and mapped it to the CBA strategies as a proxy for circularity measurements. Then, a platform was established as a digitally accessible prototype of the framework. In the third workshop, the participants reflected on the useability of this platform and recommended minor improvements to further enhance its user-friendliness.

Examination of the Framework Effectiveness

In this paper, the effectiveness of the CBA-AR framework refers to its capacity to enhance the design for CBA promotion. The developing team of the project, in collaboration with other collaborators and the first author, has been able to expand 4 out of the 18 strategies mentioned in subsection 4.1, and also incorporate another new 6 strategies into the definitive design, effectively amounting to a total of 24 strategies considered for implementation in the project. Following is an elaboration on the expanded 4 strategies:

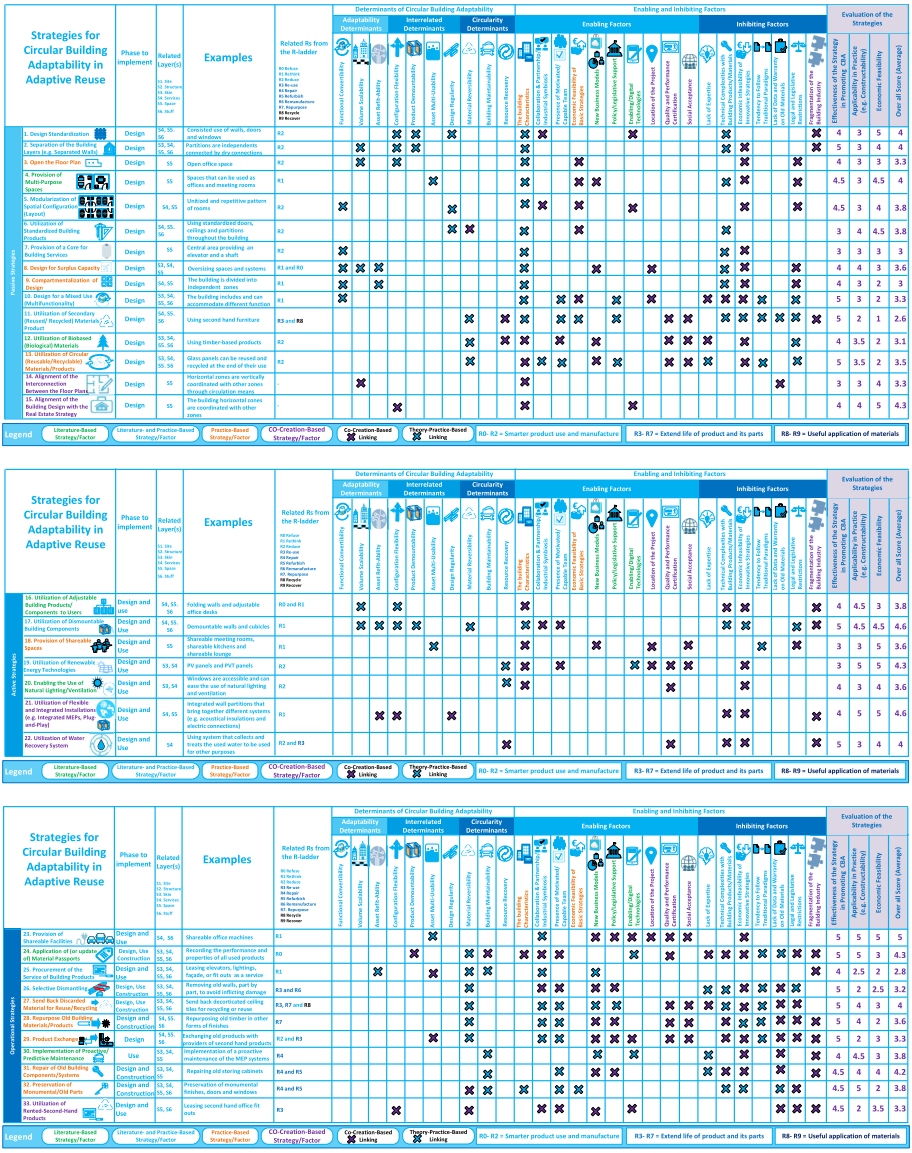


Fig. 4 The revised version of the framework based on the first two rounds of observing and intervening. Source: Authors' own creation

- *Design standardization*: Standardized wall panels and acoustical installations
- *Send back discarded materials for reuse/recycling*: Old glass panels from the façade have been sent for reuse, whereas old lighting fixtures and ceiling tiles have been considered to be sent for reuse
- *Repair of old building components*: Repairing old radiators and refurbishing old wall panels.

- *Preservation of monumental parts*: Preserving closets, chandeliers, busts, and old radiators in the hall and stairs as well as on the ground floor.

The following are the 6 newly added strategies to be considered for implementation in the case project:

- *Utilization of standardized building products*: Standardized partitions
- *Utilization of second-hand (reused/recycled) materials/products*: Using second-hand fit-outs on the first floors.
- *Utilization of adjustable building components/products*: Using some adjustable cubicles and office fit-outs
- *Utilization of demountable building components*: Old demountable partitions – made of gypsum board – will be reused on the second floor. New demountable wooden partitions will be used on the ground floor.
- *Selective dismantling*: Removing all partitions, ceiling tiles, vaults, and lighting fixtures systematically in a manner that would not cause damage.
- *Repurpose old building materials/products*: Wooden ceilings have been considered to be reused in the reception while vaults have been considered for reuse as cabinets.

Using the CBA-AR framework has enabled us to observe the enabling and inhibiting factors for the CBA strategies within the context of the case project. We observed that the intrinsic motivation of the developing team was a key enabler for paving the way for implementing the aforementioned strategies. On the other hand, we observed that there were many challenges for implementing many of the strategies in the project, namely physical – e.g. deterioration of the old building assets; information availability-related – e.g. lack of a record on the building assets, and economic—e.g. high investment costs. Below follows an elaboration on the inhibiting factors for other CBA strategies that were deemed impossible to implement in the project:

- *Design for surplus capacity*: The structure of the building was already designed for surplus capacity through its double-height ground floor and a high-strength steel structure. This overcapacity has already been used by the previous owner by adding a floor between the ground and the first floor and a third floor on the roof.
- *Design for mixed-use*: This strategy was impossible in the project because of a certain agreement between the developer and the original owner of the land.
- *Utilization of renewable energy technologies*: Solar PV panels have been considered, yet financial constraints on the project budget have been an obstacle to their use. However, future market research on cooperative solutions could take place during the detailed design phase afterward
- *Utilization of flexible and integrated installations*: During the design process, the team considered using plug-and-play (PNP) office booths and call cabinets that bring together lighting and electrical receptacles. However, their incompatibility with the sprinkler system – as a mandatory safety requirement – hindered the use of this kind of product in the building.
- *Utilization of water recovery system*: In the first workshop, it was concluded that using a water recovery system is impossible due to the configuration and composition of the monumental floorings of the building.
- *Application of material passports*: This strategy was seen as impossible due to financial constraints on the project budget, though it was perceived as effective by the participants in workshop 1.

- *Procurement of the service of building products*: Providing the new elevator as a service was considered as the net present value (NPV) comparison with owning a new elevator pointed out its feasibility for a service life of 20 years. However, the limited number of providers for this type of elevator raised concerns among the developing team regarding the viability of the service.
- *Product exchange*: The first author and the developing team have reached out to several providers of second-hand building products and materials during the observation and intervention period to exchange the these providers. However, in workshop 2, it was concluded that such kind of exchange has been difficult and time- and product-specific, so it might be carried out with the projects of the developing organization.
- *Utilization of rented-second-hand products*: This strategy has been considered to be implemented for office booths; however, the developing team excluded that in workshop 2 due to quality- and cost-related reasons as it was concluded, based on market research, that they are economically less feasible and the quality is not insured in comparison with the case of renting new office fit-outs.

We noticed that the framework was perceived as informative as a method for spontaneous screening. However, the participants requested additional clarification and elaboration on how it could be utilized as an indicative and assessment tool to enhance the decision on selecting strategies. More specifically, in the first workshop, the participants indicated that there is a need to have a measurable impact within the CBA-AR framework, along with practical examples. To bridge the distance between the descriptive nature of the framework and the need to make it more effective in practice, we compiled a user-prescriptive booklet was to include further content, instruments, and instructions to enhance its effectiveness (see Sect. 4.3).

To conclude, the effectiveness of the framework we used as a boundary object in practice can be enhanced by providing further informative, exemplary, and guiding content along with indicative measures of the impact of the CBA strategies.

Improving the Usability and Effectiveness of the Framework: The Emergence and Validation of a Simplified Description and a User Booklet Brought Together in a User-Friendly Platform

Based on the results of testing and reflecting on the usability and effectiveness of the CBA-AR framework during the first three rounds of iterations (see Sects. 4.1 and 4.2), we concluded that both qualities could be concluded by adding further explanatory, guiding, and assessment-oriented contents to the framework. We have taken three actions, namely simplifying the framework description, compiling a user guide, and establishing a platform.

Simplification of the Framework Description

First, to simplify the description of the CBA-AR framework and the interconnection among its components, we created Fig. 5 to demonstrate how the components of the framework are brought together under four blocks: quality-related aspects, solution-related aspects, contextual aspects, and possibility-related aspects. The quality-related aspects are "what" related, as they provide indicative attributes and characteristics of circularity and adaptability They include the CBA determinants and the R-Ladder model according to Potting et al.,

(2017). The solution-related aspects are "how" related and they mainly relate to the strategies, including examples, phase of implementation, and the corresponding building layers according to the shearing layers model by Brand (1994). The context-related aspects relate to the factors that could facilitate or impede the implementation of the CBA strategies. Finally, the possibility-related aspects relate to the applicability, effectiveness, and feasibility of the CBA strategies. The description and visualization of the framework components have been revised on a continuous basis during the different rounds of reflection.

A User Booklet

We compiled a user booklet between the first and second rounds of reflection to provide practitioners with three facilitating resources: a simplified elaboration on the framework structure (See Fig. 5 and subsection 4.3.1), an in-depth description of the CBA strategies, and a usable tool. Previous research has shown that providing users of a certain product or a service with a guidance document (e.g., a handbook or a booklet) has proven effective and useful in cases where there is a gap or disconnect between user behavior and the intended use of a product or a service (Akasaka et al. 2020; Watson 2015).

The usable tool we developed is a worksheet integrated and aligned with the CBA strategies through a stepwise iterative approach to simultaneously enhance the usability and effectiveness of the CBA-AR framework in practice. Figure 6 presents the stepwise approach we developed for using the CBA-AR framework as a guiding, assessment, and reporting instrument, while Fig. 7 presents the adapted worksheet. The booklet's content has been improved and revised between the second and third rounds of reflection. Adapting a worksheet and a stepwise approach to facilitate the adoption of new methods in practical contexts was inspired by some examples in the literature (see McKenna et al. 2017; Hassanain et al. (2022);.

The worksheet we developed (Fig. 7) has a threefold use: identification of the applicable CBA strategies and their solutions in the building layers, assessment of the CBA determinants, and reporting of the CBA performance. The tool would be used iteratively during different phases of the building design and development. Moreover, to arrive at an informative decision about the applicability of various CBA strategies, using the worksheet requires, as prerequisites in practice, an interdisciplinary collaboration among different professionals – designers, developers, and other technical specialists – in addition to obtaining accurate design documents and asset inventory.

As shown in Fig. 7, using the worksheet requires the users to acquaint themselves with the framework design and content (Fig. 4 and Fig. 5) and the in-depth description of the strategies which are the first two sections of the booklet. To ease the use of the framework, we added a hypothetical example to the booklet as well along with an explanatory video recorded by the first author. The worksheet utilization as a determining, assessment, and reporting instrument requires the user to fill out the last five columns on the right. To validate its use in the case project, the first author has used it with the developing manager for the case project (Appendix B).

A User-Friendly Digital Platform

Before the third and final reflection workshop, we developed a knowledge-sharing online platform to integrate the framework with the associated guiding and usable tools

an accessible manner. Digital platforms have been considered useful for fostering learning and disseminating knowledge about sustainable building practices, owing to their potential accessibility by a wide range of users (see Dipasquale et al. 2024; Kovacic et al. 2020). We developed the platform during the summer of 2024. The platform brings together seven pages (Fig. 8), namely: "Overview", "The CBA Concept", "Framework Explanation", "The CBA-Strategies", "User Guide", "Collaborators", and "Readings", respectively. Before the third workshop, we provided the participants In the third workshop, we asked the participants to use the platform and reflect on its user-friendliness by asking them the following two key questions: How did you see the improvements we made? Any other suggestions.

Content-wise, the platform has been deemed coherent and comprehensive; however, specific design and minor textual improvements were proposed. Therefore, we incorporated those recommendations and changes in finalizing and launching the platform to the public. These changes mainly comprised: revising the colores used in worksheet design, reorganizing the design of the page which includes the description of the CBA strategies, and re-recording the explanatory video included on the "user guide" to align it with the worksheet design and the layout of "The CBA Strategies" page.

Discussion

In this study, we aimed to engage with practitioners to test and provide insights into the usability and effectiveness of using CBA-AR framework as a guiding boundary object for circular adaptive reuse; thereby contributing to bridging the gap between theory and practice We adopted a mixed action research- and design research-oriented approach.

Discussion of the Main Findings

Our findings indicate that the descriptive version of the CBA-AR framework by Hamida et al. (2024) (Fig. 1) has been perceived as an inspiring tool that can be used as a checklist for a spontaneous screening of possible solutions. Although many CBA strategies have been expanded or newly added to the definitive design of the case project by dint of the followed actionable approach in this study, the results show that using the CBA-AR framework as a guiding tool has been difficult because the descriptive version of the CBA-AR framework lacks simplicity in terms of design elaboration, clarity in terms of an adequate description of the strategies, user guide as instructions for professionals, and an indicative

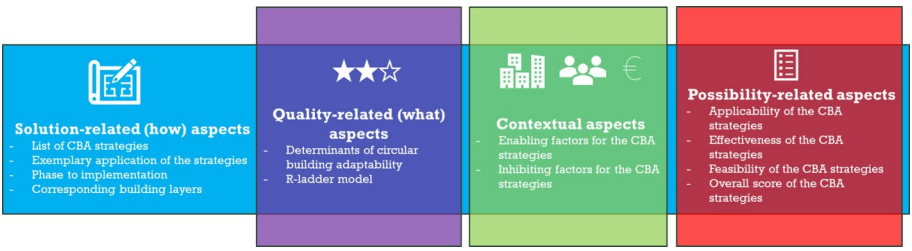


Fig. 5 A simplified visualized description of the 4 blocks bringing together the framework components. Source: Authors' own creation

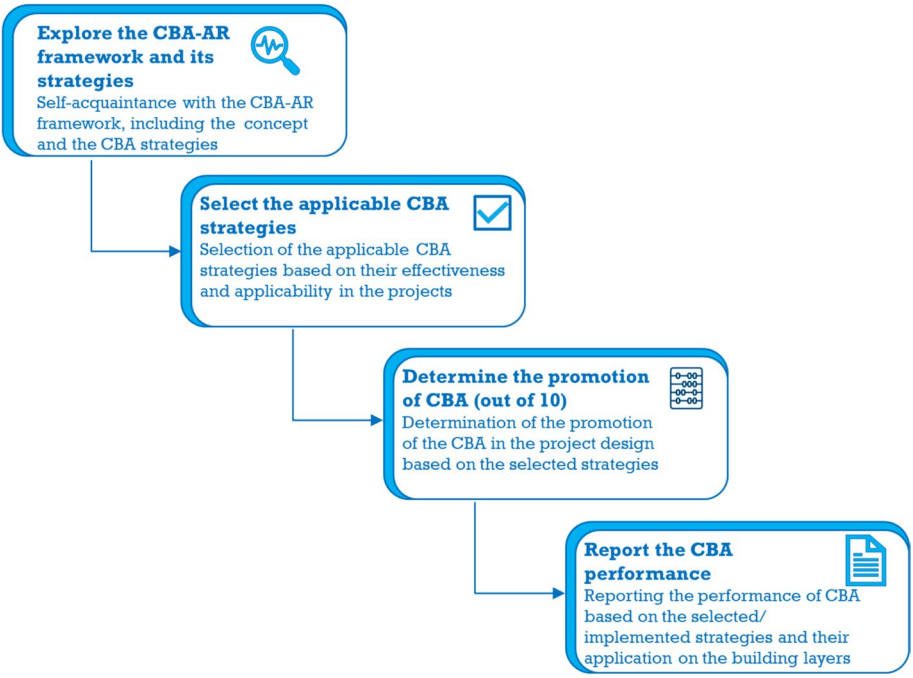


Fig. 6 A 4-stepwise approach for using the CBA-AR framework as a guiding, assessment, and reporting instrument. Source: Authors' own creation

means to assess the outcomes of implementing certain CBA strategies. These observations agree Heldal et al. (2016) and Gogolla and Selic (2020) indicating that, in practice, *descriptive* models can be used for documenting or predicting purposes, and *prescriptive* models are oriented toward development or implementation, whereas both types of models can be flexibly connected.

In this regard, based on the aforementioned observations, we iteratively reacted to these practical shortcomings by adding further components to the framework and developing new tools as prototypes. First, content-wise, we simplified the description of the CBA-AR framework textually and visually. Based on suggestions from the developing team, we supplemented the 33 CBA strategies with a description, practical examples, and information about their advantages and disadvantages. Second, we compiled and refined a user booklet – including a worksheet and a stepwise approach alongside a hypothetical example – to provide practitioners from the building and real estate market with a practical guide to using the framework as a tool in practice. Third, to improve the usability of the framework and its accessibility by a wider range of professionals, we established an online platform to coherently and comprehensively bring together these components alongside explanatory videos in an accessible and dynamic manner. The platform and its content and design have been considered user-friendly and useful for sharing knowledge about the framework's use. Collaboratively using these outcomes has been deemed a prerequisite for their effectiveness in practice, along with obtaining accurate design documents and asset inventory. This corroborates the conclusion of an action-based study by Aigwi et al. (2021) which necessitates adopting a collaborative process in adaptive reuse projects to optimize the decision-making process.

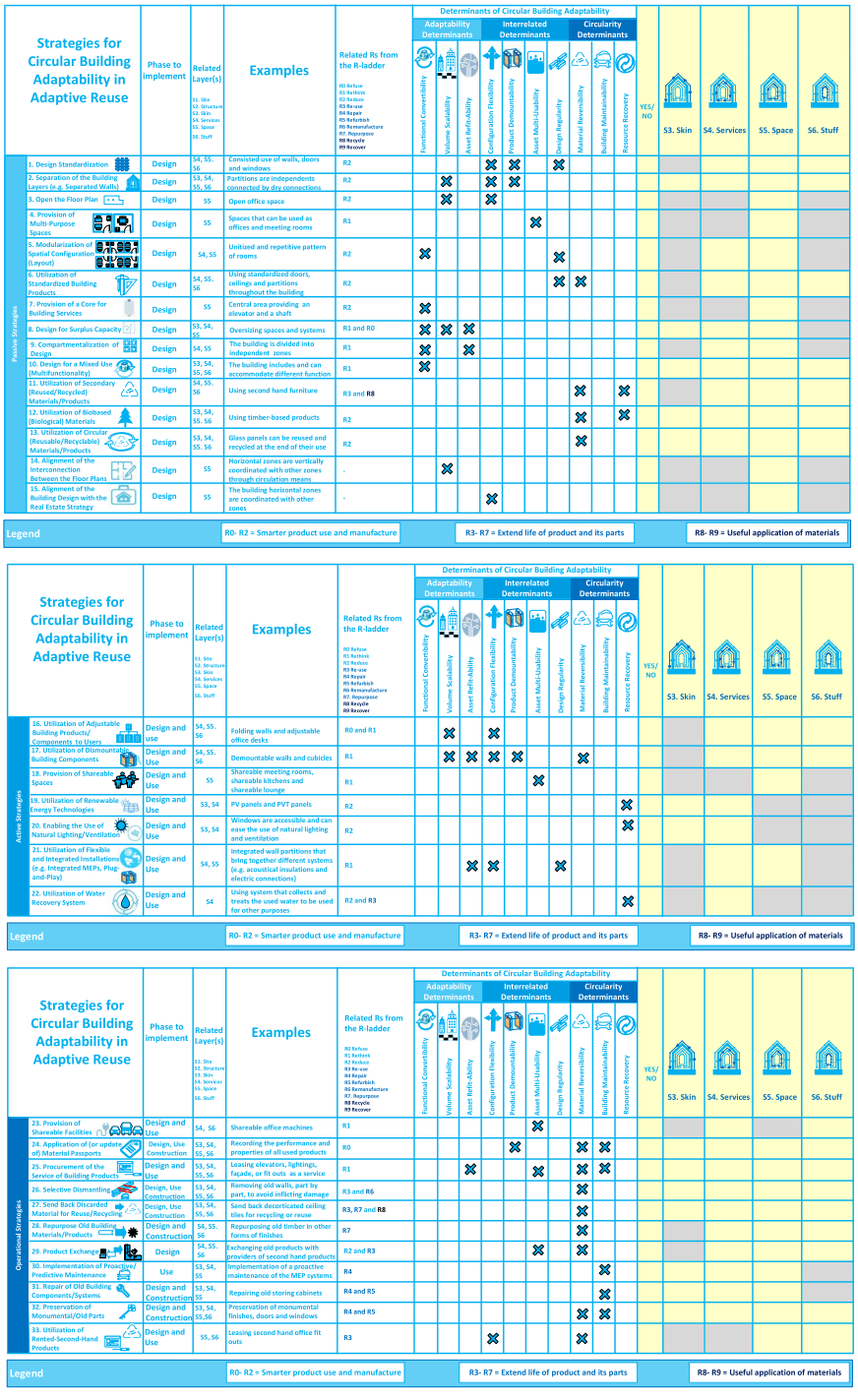


Fig. 7 A worksheet for exploring, determining, assessing, and reporting the promotion of CBA in building reuse. Note: Yellow fields must be filled out by the user, if applicable. Source: Authors' own creation

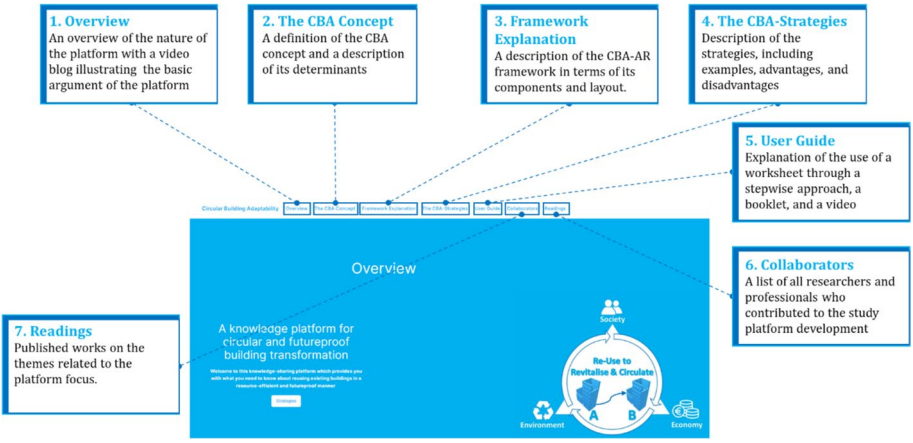


Fig. 8 The 7-pages structure of the established platform. Source: Authors' work

Reflection on the Practical Implications of the Outcomes

By our mixed design-originated and actionable approach, we have been able to bridge the gap between the relevant theory and practice to CBA while bringing about a change in a case project as an experimentation and demonstration in the real world. More specifically, our approach has been pragmatically flexible and enabled us to spontaneously collaborate with practitioners by developing new prototypes based on an iterative way of reflecting on observations and interventions in the real world. These outcomes are manifested in the simplified description of the CBA-AR framework, newly added components to the framework and its strategies, a compiled booklet, and an established online platform. These outcomes turned the CBA-AR framework into a perspective synthesis; thereby, paving the way for transformative change in promoting circularity and adaptability in building reuse projects, not merely by showcasing the collaboration between scholars and practitioners, but also by providing an accessible means for knowledge-sharing. Moreover, the platform and the worksheet can also be used for educational purposes. In light of the call for speeding up the transition to CE and promoting sustainable development goals (SDGs), the resulting outcomes of our study represent contributions to the micro level – systematically enhancing practices by individual practitioners and design and real estate organizations involved in adaptive reuse projects – that can ultimately contribute to bringing about a positive change in societies on the macro level. This is possible by laying the ground for policy amendments and work practice changes. As concluded by the authors of the research brief of a project titled "InContext", action research can form the basis for transition by its potential to influence dynamics in society (Wittmayer et al. 2013).

Finally, adopting action research in this practice-oriented study enabled us to observe and touch upon other considerations that were not planned to be revealed, similar to what Alves et al. (2021) observed and pointed out in their action research study. In our final observations, this has been manifested in the prerequisites we pointed out as requirements for using the framework and its worksheet in practice. Action researchers can learn from our study about how to use mixed action design research in developing and improving frameworks, instruments, or boundary objects tailored for practice and in line with theory.

Indication of the Study Limitations and Possibilities for Future Research

Our study has two limitations. First, context-wise, it does not explicitly address the role of regulatory actors and legislation in both the process of using the CBA-AR framework and its tools. Second, although we have improved the CBA-AR, its improvements are based on lessons extracted from a single case, where the findings of a single case research have limited generalizability according to Yin (2009). These two limitations have been beyond the scope of this study. Therefore, future research can focus on exploring how to align the outcomes of this study with existing regulatory policies, as well as testing it in multiple cases and different contexts. This can be carried out using a transdisciplinary approach, as transdisciplinary research in the built environment can bring together participating partners to contribute to sustainable problem-solving and innovation (Femenías and Thuvander 2018). For instance, van Laar et al. (2025) demonstrate how transdisciplinary approaches – including collaborative scenario-building – can facilitate alignment among diverse actors' considerations in circular building reuse. Building on these insights, transdisciplinary methods can help actors navigate complexity and uncertainty by surfacing organizational tensions and supporting collective sensemaking in the reuse of existing buildings.

Conclusions and Recommendations

Reusing vacant or obsolete buildings is an inevitable type of building alteration, whereas its implementation in a circular and adaptable manner contributes to a resource-efficient and future-proof redevelopment of the built environment. Several frameworks have been developed to provide building stakeholders with the knowledge they need for circular adaptive reuse. However, promoting circularity in this type of project is still an emerging and immature practice. In this study, we focused on theory–practice divide by testing and contributing to the useability and effectiveness of a developed framework as a guiding tool in practice. The CBA-AR framework is the tool we experimented with in this paper. We followed an action research- and design research-oriented approach to test the usability of this framework during the definitive design phases of a vacant historic office building in the Netherlands. We incorporated three rounds of reflection, between April 2024 and September 2024, iteratively using archival research, field observations and interventions, and reflection workshops as research methods.

Our approach contributed to getting a better grasp on the useability and effectiveness of the framework in practice based on an iterative process of observing and intervening; thereby reacting to and reflecting on the outcomes from the case project. The results show that the knowledge-based and descriptive version of the CBA-AR framework by Hamida et al. (2024) has been usable as an inspiring tool for a quick scan of possible solutions, limiting its effectiveness in improving the outcomes for CBA design. In this context, simplifying the framework description, elaborating on the practicalities of the strategies, incorporating indicative measures, and explaining the use have been perceived as essential prerequisites for improving the usability and effectiveness of the CBA-AR framework. To satisfy these 4 prerequisites, we took the following actions: visually and textually simply describing the framework components in a simple manner; adding an in-depth explanation of the CBA strategies; incorporating the R-ladder model of the framework along with the adaptation of a worksheet; and compiling a user booklet with a stepwise approach as well

as establishing a user-friendly online platform, respectively. We refined the outcomes of these actions during the different moments of reflection based on inputs from the developing team of the case project.

By following a pragmatic mixed research approach bringing design and actionable components together, we have been able to bridge the distance between what has been conceptualized in the literature of CBA and what occurs in practice. More specifically, the lessons learned from the case project, as a demonstration case, along with produced outcomes – manifested in the form of a prescriptive prototype, assessment tool, and the integrated, self-explained accessible knowledge-sharing platform pave the way – pave the way for operationalizing CBA in future building reuse projects by means of accessible learning, user guide and usable instruments in design. By facilitating the design for circularity and adaptability in building reuse practices on the micro level, this can contribute to speeding up the transition to a circular economy and an environmentally sustainable built environment on the macro level (Greco et al. 2024). Circular design plays a pivotal role in driving this transition by enabling the adaptive reuse of buildings, minimizing material waste, and extending the service life of the built environment. Our study contributes to this broader sustainable development agenda by demonstrating how circular strategies can be translated into practical solutions, which can support real estate organizations to adopt and implement sustainable practices. Among others, this is possible by virtue of knowledge dissemination – manifested in the platform we established – and enhancement of unfolding practices – manifested in the tools we produced for practitioners. For the relevant body of knowledge to building adaptation, circularity, and adaptability, scholars can build on the lessons learned to further develop integrative decision-making tools that are function- or scenario-specific.

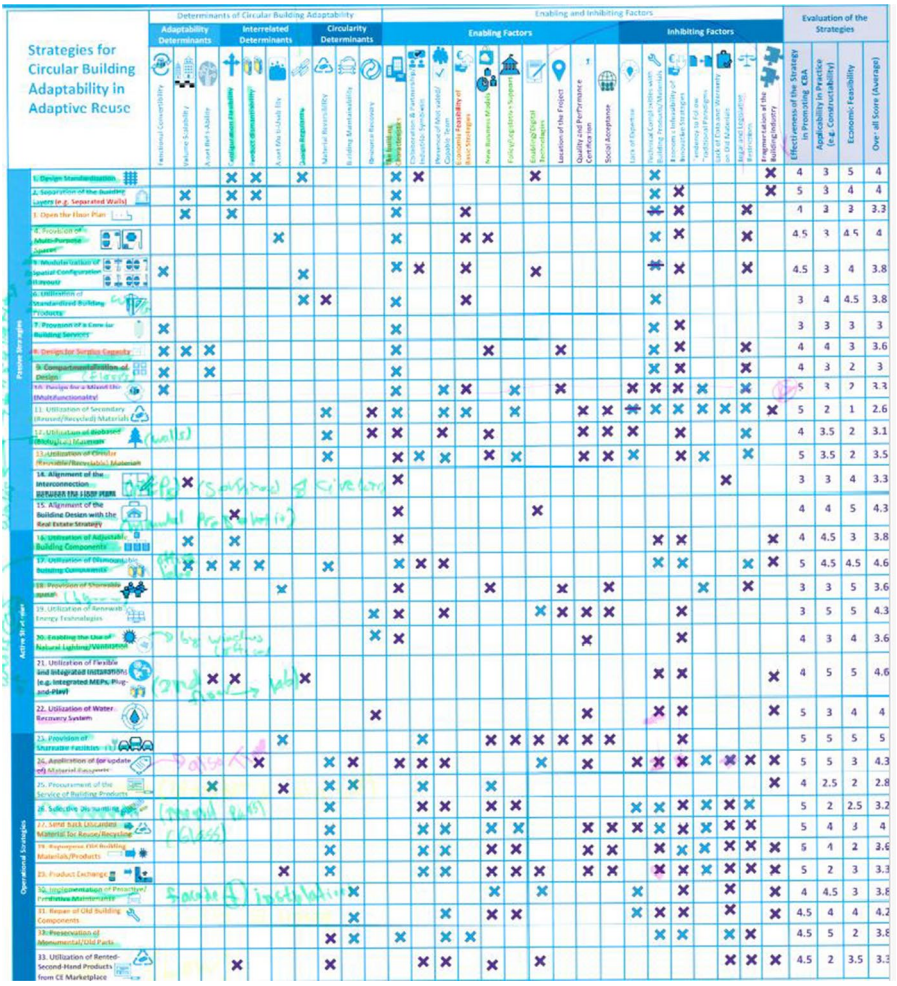
Based on the outcomes of this study, we put forward the following recommendations for practitioners:

- Users of the CBA-AR framework need to compile an inventory of the building assets and documents before using the CBA-AR framework as a guiding, assessment, and reporting instrument.
- An interdisciplinary approach needs to be used while designing for CBA in building reuse projects to contribute to arriving at informed decisions on the applicable strategies and their practical and effective solutions.

Our study did not explicitly consider the role of policies and legislation in the use of the used framework. Additionally, the empirical part has been limited to a single case. Thus, future research can focus on aligning the CBA-AR framework with existing regulatory processes and guidelines using a transdisciplinary approach, exploring the use of the framework in other case projects with different contexts. Ultimately, the outcomes of our study can contribute to a transformative change by incorporating circular principles in building reuse projects. For action researchers, our study shows an application of using mixed action design research as a theory–practice approach to improving and enhancing frameworks from the literature and appropriating them for practice. These are efforts toward closing the persistent divide between theory and practice, demonstrating how action research can serve as a bridge by iteratively adapting conceptual frameworks to contemporary organizational challenges and practitioners' needs. This bridging is essential for impact-driven research that aims to meaningfully address complex societal issues and foster actionable, context-sensitive change.

Appendix A

Mapping the CBA Strategies to the Case Project



Outcomes of reflecting on the CBA strategies

Source: Authors' own work

Appendix B

Using the CBA-AR Worksheet as a Determining, Assessment, and Reporting Tool for the Case Project

Strategies for Circular Building Adaptability in Adaptive Reuse	Phase to implement	Related Layer(s) (S1. Site, S2. Structure, S3. Skin, S4. Services, S5. Space, S6. Stuff)	Examples	Related Rs from the R-ladder (R0 Refuse, R1 Rethink, R2 Reduce, R3 Re-use, R4 Repair, R5 Refurbish, R6 Remanufacture, R7. Repurpose, R8 Recycle, R9 Recover)	Determinants of Circular Building Adaptability: Adaptability Determinants — Functional Convertibility; Volume Scalability; Asset Refit-Ability. Interrelated Determinants — Configuration Flexibility; Product Demountability; Asset Multi-Usability; Design Regularity. Circularity Determinants — Material Reversibility; Building Maintainability; Resource Recovery	YES/NO	S3. Skin	S4. Services	S5. Space	S6. Stuff
Passive Strategies											
1. Design Standardization	Design	S4, S5. S6	Consisted use of walls, doors and windows	R2			✕	✕	✕			✓		Acoustical installations	Wall panels	
2. Separation of the Building Layers (e.g. Separated Walls)	Design	S3, S4, S5, S6	Partitions are independents connected by dry connections	R2		✕	✕	✕				✓			Partitions (20-25 years)	Fit-outs (10-15 years)
3. Open the Floor Plan	Design	S5	Open office space	R2		✕	✕					✓			Hall	
4. Provision of Multi-Purpose Spaces	Design	S5	Spaces that can be used as offices and meeting rooms	R1					✕			✓			Multi-purpose hall (cafe, co-working, & congress)	
5. Modularization of Spatial Configuration (Layout)	Design	S4, S5	Unitized and repetitive pattern of rooms	R2	✕					✕		✓			Modular configuration and consistent number of offices of	
6. Utilization of Standardized Building Products	Design	S4, S5. S6	Using standardized doors, ceilings and partitions throughout the building	R2						✕	✕	✓			Standardized partitions	
7. Provision of a Core for Building Services	Design	S5	Central area providing an elevator and a shaft	R2	✕							✓			Two cores for stairs, MEPs shafts and toilets	
8. Design for Surplus Capacity	Design	S3, S4, S5	Oversizing spaces and systems	R1 and R0	✕	✕	✕					✓				
9. Compartmentalization of Design	Design	S4, S5	The building is divided into independent zones	R1	✕		✕					✓			Each floor is a compartment	
10. Design for a Mixed Use (Multifunctionality)	Design	S3, S4, S5, S6	The building includes and can accommodate different function	R1	✕							✓				
11. Utilization of Secondary (Reused/Recycled) Materials/Products	Design	S4, S5. S6	Using second hand furniture	R3 and R8							✕	✓	✕			Second-hand fit-outs on the first floor
12. Utilization of Biobased (Biological) Materials	Design	S3, S4, S5. S6	Using timber-based products	R2							✕	✓	✕		Biobased paintings and wooden studs	
13. Utilization of Circular (Reusable/Recyclable) Materials/Products	Design	S3, S4, S5. S6	Glass panels can be reused and recycled at the end of their use	R2							✕	✓			Removable wall partitions	
14. Alignment of the Interconnection Between the Floor Plans	Design	S5	Horizontal zones are vertically coordinated with other zones through circulation means	-		✕						✓			Two services shafts are in the same location on each floor	
15. Alignment of the Building Design with the Real Estate Strategy	Design	S5	The building horizontal zones are coordinated with other zones	-			✕					✓			Preserving heritage assets while diversifying sources of income	

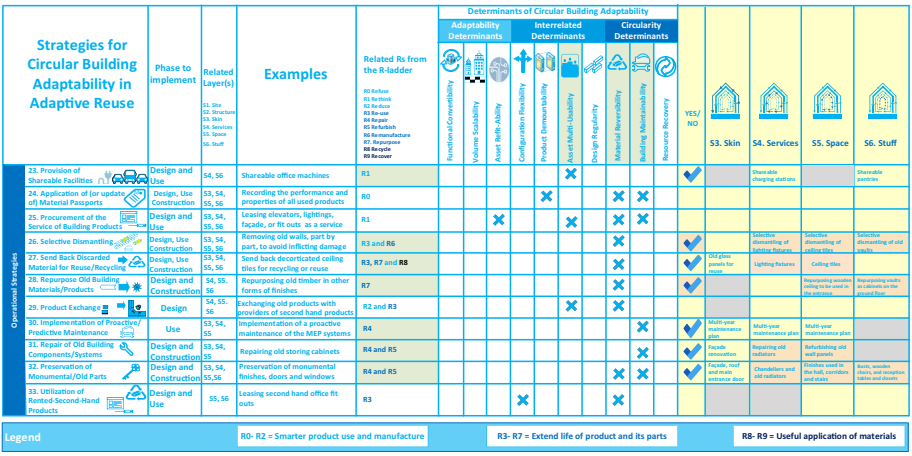
Legend: R0- R2 = Smarter product use and manufacture; R3- R7 = Extend life of product and its parts; R8- R9 = Useful application of materials

Note: Green = promoted CBA determinants and R-ladder measures; Orange = newly added solutions to the project or expanded strategies/determinants
Source: Authors' own work

Strategies for Circular Building Adaptability in Adaptive Reuse	Phase to implement	Related Layer(s) (S1. Site, S2. Structure, S3. Skin, S4. Services, S5. Space, S6. Stuff)	Examples	Related Rs from the R-ladder (R0 Refuse, R1 Rethink, R2 Reduce, R3 Re-use, R4 Repair, R5 Refurbish, R6 Remanufacture, R7. Repurpose, R8 Recycle, R9 Recover)	Determinants of Circular Building Adaptability: Adaptability Determinants — Functional Convertibility; Volume Scalability; Asset Refit-Ability. Interrelated Determinants — Configuration Flexibility; Product Demountability; Asset Multi-Usability; Design Regularity. Circularity Determinants — Material Reversibility; Building Maintainability; Resource Recovery	YES/NO	S3. Skin	S4. Services	S5. Space	S6. Stuff
Active Strategies											
16. Utilization of Adjustable Building Products/ Components to Users	Design and use	S4, S5. S6	Folding walls and adjustable office desks	R0 and R1		✕		✕				✓				Adjustable cubicles and office fit-outs
17. Utilization of Dismountable Building Components	Design and Use	S4, S5. S6	Demountable walls and cubicles	R1		✕	✕	✕	✕		✕	✓			Demountable wooden partitions (ground floor)	
18. Provision of Shareable Spaces	Design and Use	S5	Shareable meeting rooms, shareable kitchens and shareable lounge	R1					✕			✓			Shareable hall, toilets, and meeting rooms	
19. Utilization of Renewable Energy Technologies	Design and Use	S3, S4	PV panels and PVT panels	R2								✓	✕			
20. Enabling the Use of Natural Lighting/Ventilation	Design and Use	S3, S4	Windows are accessible and can ease the use of natural lighting and ventilation	R2								✓	✕	✓	Each office has an openable window	
21. Utilization of Flexible and Integrated Installations (e.g. Integrated MEPs, Plug-and-Play)	Design and Use	S4, S5	Integrated wall partitions that bring together different systems (e.g. acoustical insulations and electric connections)	R1			✕	✕		✕						
22. Utilization of Water Recovery System	Design and Use	S4	Using system that collects and treats the used water to be used for other purposes	R2 and R3									✕			

Legend: R0- R2 = Smarter product use and manufacture; R3- R7 = Extend life of product and its parts; R8- R9 = Useful application of materials

Note: Green = promoted CBA determinants and R-ladder measures; Orange = newly added solutions to the project or expanded strategies/determinants
Source: Authors' own work



Note: Green = promoted CBA determinants and R-ladder measures; Orange = newly added solutions to the project or expanded strategies/determinants
Source: Authors' own work

Author Contribution M.B.H. and A.G. conceptualized the study. A.G., H.R., and V.G. supervised the work. M.B.H. conducted fieldwork, while all authors contributed to the participatory part and data analysis. M.B.H. wrote the main manuscript and prepared the figures, while all authors reviewed and edited the manuscript.

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Declarations

Competing interests The authors declare no competing interests.

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