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Towards promoting circular building adaptability in adaptive reuse projects: a co-developed framework

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Abstract

Purpose – Circular building adaptability (CBA) in adaptive reuse – building transformation – projects can facilitate a resource-efficient and futureproof redevelopment of the built environment. However, there has been a lack of practical tools that guide practitioners on how to foster CBA in adaptive reuse. Therefore, this study aims to collaboratively develop a guiding framework for CBA in adaptive reuse (CBA-AR) projects in general. The CBA-AR framework is a descriptive and content-oriented synthesis mapping a series of strategies to the CBA determinants alongside their enablers and inhibitors.

Design/methodology/approach – A participatory research-oriented approach was followed. First, an archival research was conducted to develop the CBA-AR framework based on literature review and case studies. Second, two co-creation workshops, triangulated with structured interviews, were conducted to validate and expand the framework.

Findings – The first version of the CBA-AR framework comprises 30 CBA strategies. It also brings seven enablers and six inhibitors together with the 30 CBA strategies. The outcomes of the participatory approach contributed to refining and expanding the framework. The final of the CBA-AR framework version comprises CBA 33 strategies. This version brings 10 enablers and 7 inhibitors together with the 33 strategies.

Practical implications – This framework can be used as a guiding and reporting instrument by designers and property developers while transforming vacant or obsolete properties in the Netherlands. Policy makers can refer to this framework and amend adaptive reuse legislation.

Originality/value – The CBA-AR framework can introduce a transformative change in theory and practice, as it is based on theoretical, empirical and participatory research.

Keywords Adaptability, Adaptive reuse, Built environment, Circularity, Co-creation, Participatory research

Paper type Research paper

1. Introduction

The building sector in Europe is perceived as a major contributor to different problems, including climate change, waste generation and high energy consumption. It has been estimated that the existing building stock in Europe consumes about 40% of the operational energy while producing 36% of the total greenhouse gas emissions which are associated with construction, use, renovation and demolition activities (European Commission, 2020).

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Accordingly, it constitutes an arena for operationalizing new concepts and transformative frameworks in reality to cope with these dilemmas, such as speeding up the transition to circular economy (CE) (Zimmann *et al.*, 2016). In the building sector, adaptive reuse, also known as building transformation, is a multidimensional means to eliminate waste, cope with underutilized property and speed up the transition to CE (Foster, 2020). From an urban regeneration perspective, adaptive reuse is also effective for the redevelopment and revitalization of abandoned areas (Aigwi *et al.*, 2022). Population growth, market dynamics and technological advancement are ongoing triggers for building adaptation (Ross, 2017). In the Netherlands for instance, many canal houses have been adapted and reused multiple times because of various causes of obsolescence (Remøy, 2014). Thus, building adaptation is inevitable and needs to be facilitated in a sustainable and long-lasting way (Beadle *et al.*, 2008; Capolongo *et al.*, 2016; Rockow *et al.*, 2021). This can be fulfilled by promoting circular building adaptability (CBA) in building adaptation projects (Hamida *et al.*, 2023a).

Hamida *et al.* (2023b) defined CBA as "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". For instance, using demountable building products can simultaneously promote building adaptability and circularity (Geldermans, 2016). By bringing together CBA and adaptive reuse, long-lasting utility of the built environment can be promoted while minimizing waste generation (Hamida *et al.*, 2023a), as the CE model could prioritize economic and environmental considerations over the societal ones due to the availability of different definitions and models of CE (Kirchherr *et al.*, 2017). Relevant studies have conceptualized how circularity can be aligned with adaptive reuse (Foster, 2020; Girard and Vecco, 2021; Hamida *et al.*, 2023b; van Laar *et al.*, 2024) or explored the current application of circularity- and adaptability-related strategies in adaptive reuse projects (Hamida *et al.*, 2023a, b; Kaya *et al.*, 2021; Rockow *et al.*, 2021). It is worth noting that CE in adaptive reuse is still emerging, in which lack of knowledge about it in the industry and shortcomings in existing frameworks are among the inhibiting factors to its implementation in Europe (Pintossi *et al.*, 2023). For instance, an exploratory study by Kaya *et al.* (2021) pointed out that few building stakeholders in the Netherlands recognize the alignment of adaptive reuse with CE. In this regard, different decision-making and evaluation-oriented tools have been developed for circular adaptive reuse of heritage buildings (Gravagnuolo *et al.*, 2017, 2024; Kaya *et al.*, 2021). However, there is currently no a guiding and design-oriented framework that can practically provide designers and developers with knowledge on the applicable circularity- and adaptability-oriented strategies in adaptive reuse projects (Hamida *et al.*, 2023c).

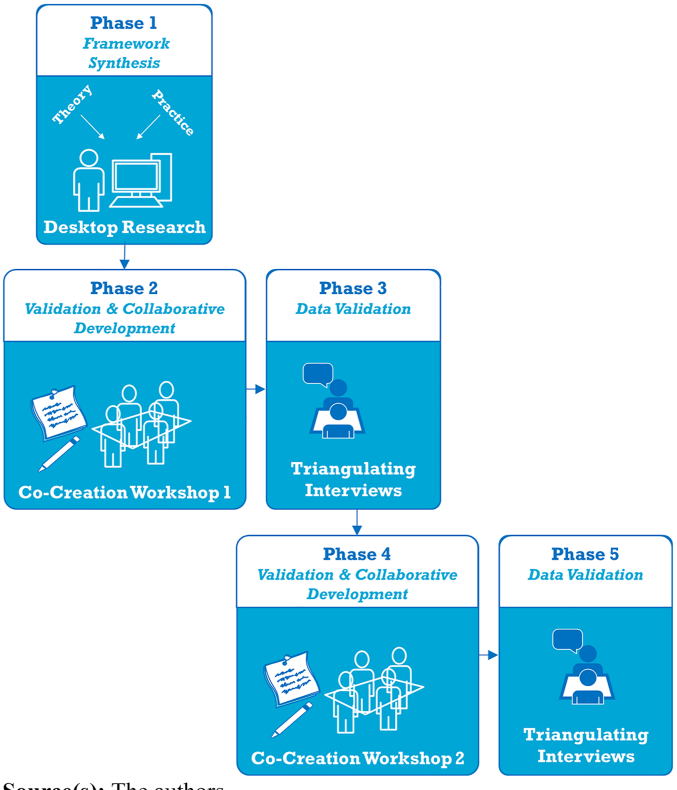
Accordingly, this study aims to develop and collaboratively validate a guiding framework for CBA in adaptive reuse (CBA-AR) projects in general within the context of the Netherlands. A participatory research approach was followed in this paper (see section 2). By virtue of various national initiatives and policies aiming at facilitating the transition to CE in the Netherlands, it is worth mentioning that the Dutch building industry has become a pioneering sector in terms of adopting circularity in practice (Cramer, 2020; Tserng *et al.*, 2021). This study bridges a gap between theory and practice by providing designers, property developers and policy makers with applicable strategies for CBA in adaptive reuse along with the factors that either facilitate or impede the implementation of those strategies. In the building and real estate sectors, designers and property developers can use the CBA-AR framework as a checklist and a reporting tool for promoting circularity in the reuse of existing buildings. Researchers can use the components of this framework in the further development of decision-making tools. Policy makers can amend existing adaptive reuse regulations considering the components of the proposed CBA-AR framework in this study. Thereby, this study ultimately contributes to paving the way for a resource-efficient and future-proof redevelopment of the built-environment.

2. Research methods

2.1 Overview and background of the research methods

This study adopted a participatory research-oriented approach, using co-creation workshops as a primary data collection method. The workshops were preceded by archival research and triangulated with structured interviews. Figure 1 illustrates the flowchart of this study. Participatory research is a convergence approach that actively brings research and practice together by involving participants that are acquainted with a process or phenomenon of interest in the research conduct (Bergold and Stefan, 2012). This approach can facilitate collaborative creation of knowledge – known as co-creation of knowledge (Rock *et al.*, 2018). The concept of co-creation has emerged and is used across different fields with different meanings. Overall, this concept tends to focus on how individuals can collaborate with each other, usually in a form of consortium, to create meanings or meet certain needs whereas the organizer of the collaboration facilitates this collaboration and leverage its outcomes without a total dominance (Ind and Coates, 2013). Research workshops are among the applicable participatory research methods for co-creating knowledge or objects (Thoring *et al.*, 2020). Research workshops can also be also employed for developing, applying and testing solutions (Fisher, 2004).

Workshops represent a useful method to test and validate practice-oriented frameworks for new or emerging practices in the built environment. For instance, van Stijn and Gruis (2020) used a series of student workshops as a means to test a theory-based design tool for



Source(s): The authors

Figure 1.
The flowchart of this study

circular building components. In addition, Aigwi *et al.* (2022) organized a workshop with various stakeholders involved adaptive reuse of historical buildings in in Auckland, New Zealand, to test and validate the applicability of a decision-making framework for the adaptive reuse of underutilized heritage buildings.

In this study, two co-creation workshops were facilitated with building and real estate practitioners in the Netherlands to collaboratively validate and expand a theory- and practice-based framework for CBA-AR (see section 3). The framework acted as a theme of discussion for the collaborative and creative interactions among the participants. The methodological framework by Storvang *et al.* (2018) for diagnosing, planning, facilitating and analyzing research workshops was followed in this study, considering the three main roles of respectively the researcher, facilitator and participants (Table 1).

2.2 Data collection

2.2.1 Archival research. Archival research was conducted to develop the first version of the CBA-AR framework based on the knowledge gained from literature review and case studies (Hamida *et al.*, 2023a, b). Archival research comprises a wide range of activities facilitating the review and exploration of past documents created by organizations or individuals (Ventresca and Mohr, 2002). In this study, knowledge about the CBA strategies and their

Phase	Role	Task/consideration
Diagnosing phase	Researcher*	Developing the CBA-AR framework based on knowledge gained from theory and practice
	Facilitator	Defining and contacting based on his/her research field
	Participants	The participants, who are practitioners who have been involved in implementing circularity and adaptability related strategies in adaptive reuse, was preliminary defined by the researcher
Planning phase	Researcher*	Designing the protocol of the workshop: *content* (invitation, framework, presentation and questions), *boundary object* (material and tools: sheets and standard colours of sticky notes) and *activities* (required tasks from participants) of each workshop
	Facilitator*	Reviewing and revising the workshop protocol
	Participants	The considered participants were contacted to set up a date of the workshop
Facilitating phase	Researcher*	Moderating the workshop, by presenting the program of the workshop, introducing the framework and managing the activities with the facilitator
	Facilitator*	Co-moderating the workshop by observing and documenting the outcomes and interactions among the participants
	Participants*	Validating and collaboratively expanding the components of the framework • *Workshop 1*: Validating and collaboratively expanding the CBA strategies • *Workshop 2*: Validating and collaboratively expanding the enabling and inhibiting factors as well as evaluating the CBA strategies in terms of their effectiveness, economic feasibility and applicability
Analyzing phase	Researcher* Facilitator* Participants*	Reporting, analyzing, validating and interpreting the findings deductively. A technical report of the findings was compiled Reflecting on the outcomes of the workshop

Note(s): *Active role in the phase
Source(s): Authors' own creation

Table 1.
The role of researcher, facilitator and participants in the diagnosing, planning, facilitating and analyzing two co-creation workshops

enabling and inhibiting factors were extracted and brought together as key components of the framework. The first version of the framework, which is a theory- and practice-based synthesis, comprised 30 CBA strategies as well as 7 enabling and 6 inhibiting factors (see section 3).

2.2.2 Co-creation workshops. Two co-creation workshops were facilitated on 19-April 2023 and 18-October, respectively. To facilitate a co-creation session without a dominance of a certain practitioner (Ind and Coates, 2013), the two workshops were hosted and organized at the Faculty of Architecture and the Built Environment, TU Delft, Delft, the Netherlands. The workshops were used as a participatory research method to collaboratively validate and expand the components of the developed theory- and practice-based CBA-AR framework. Table 1 presents the roles of researcher, facilitator and participants during the diagnosing, planning, facilitating and analysing phases.

The first workshop focused on validating and collaboratively expanding the CBA strategies. The second workshop had a threefold focus: 1) validating the defined influence of the previously defined enabling and inhibiting factors on the CBA strategies; 2) collaboratively expanding the defined enabling and inhibiting factors and 3) evaluating the CBA strategies in terms of their effectiveness in promoting CBA, economic feasibility and applicability in practice using a 5-point rating system (Table 2). Collective weighting is a useful technique to arrive at a consensus on the priority and importance of certain measures within a series of possible measures for a certain building practice, particularly when such a practice is a multidisciplinary process and involve different experts with various perspectives. For instance, Capolongo *et al.* (2016) utilized this technique in a focus group discussion to prioritize the importance of design parameters for incorporating flexibility in healthcare buildings.

In both workshops, experts on circularity, adaptability and adaptive reuse were invited from the Dutch building and real estate sectors. The invitees' experience in these three domains was a key criterion for their selection as participants. The invited participants were experts from different professions in the building industry and real estate market, due to the diversity and verity of involved stakeholders and professionals in adaptive reuse projects and circularity built environment (CBE). Section 4 provides further information about a profile of the involved participants. In both workshops, the framework was explained before the creative session.

2.3 Data analysis and validation

The outcomes of the two workshops were deductively reported and analysed, using the so-called theory-driven analysis. In qualitative research, this approach entails borrowing an existing conceptual model or theory to guide the coding and analysis of data (Saunders *et al.*, 2007). As the CBA-AR is the essence of this paper, the components of interests – the CBA strategies and their enabling and inhibiting factors – served as a coding scheme and guide

	Evaluation criterion		
Scale	Effectiveness in promoting CBA	Applicability in practice	Economic feasibility
4–5	Extremely effective	Extremely applicable	Entirely feasible
3–3.9	Very effective	Very applicable	Quite feasible
2–2.9	Effective	Applicable	Feasible
1–1.9	Somewhat effective	Somewhat applicable	Barely feasible
0–0.9	Not effective	Not applicable	Not feasible

Source(s): Authors' own creation

Table 2. The adopted 5-points rating scheme

for the analysis of the outcomes of both workshops. The adopted scale in the 5-points evaluation rating system was used in interpreting the results of the assessment of the applicability, effectiveness and feasibility of the CBA strategies (Table 3), thereby prioritizing the strategies in this regard. To arrive at an overall scoring and rating of the strategies, the average of the received three scores to each strategy was calculated as an overall and general indicator of the acceptability of the strategy. This technique is possible to report an indicative and collective score for scores of related domains in which these domains are independent from each other. However, this technique could overlook differences among the domains, but still it is beneficial as an indicative measure (Pommerich, 2006).

After each workshop, a technical report of the outcomes was compiled and shared with the participants for their reference and reflection. To validate the results of both workshops, three triangulating interviews with expertise on building circularity, adaptability and adaptive reuse were conducted to triangulate the outcomes of the workshop. Triangulation is a validation technique for qualitative data, which can be applied by leveraging other sources and investigators to accurately verify the findings, thereby giving a reasonable interpretation (Creswell, 2013). Structured interviews with other experts were conducted and recorded online as a triangulation method. The length of these interviews ranged between 1 and 1h 35min. In the validation of the outcomes of the first workshop, two consultants and one senior researchers were interviewed. The interviewees were asked to validate the practicality and clarity of the added strategies by the participants of the co-creation workshop. In the validation of the outcomes of the second workshops, the interviewees were asked to reflect on the indicated influence of the enabling and inhibiting factors on the CBA strategies as well as reflect on the validity and clarity of the newly added factors.

Table 3.
Description of the CBA determinants

Determinant	Brief description
Configuration flexibility	The capacity to reconfigure the layout of spaces without utilising external resources and producing waste
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
Asset multi-usability	The capacity to offer a multiplicity of the use of building assets, so that maximising the efficiency of their utilisation
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
Functional convertibility	The capacity to y to repurpose the function of a building or part of it, so that promoting its longevity while keeping its value
Material reversibility	The capacity to efficiently provide, utilise and reuse the materials in the building within a reversible value chain
Building maintainability	The capacity to prolong the utility of the building assets and sustain their performance
Resource recovery	The capacity to regenerate the building resources in a manner that reduces the use of new materials and energy consumption
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
Asset refit-ability	The capacity to efficiently provide state-of-the-art building assets and technologies, while avoiding waste generation or over-invested solutions

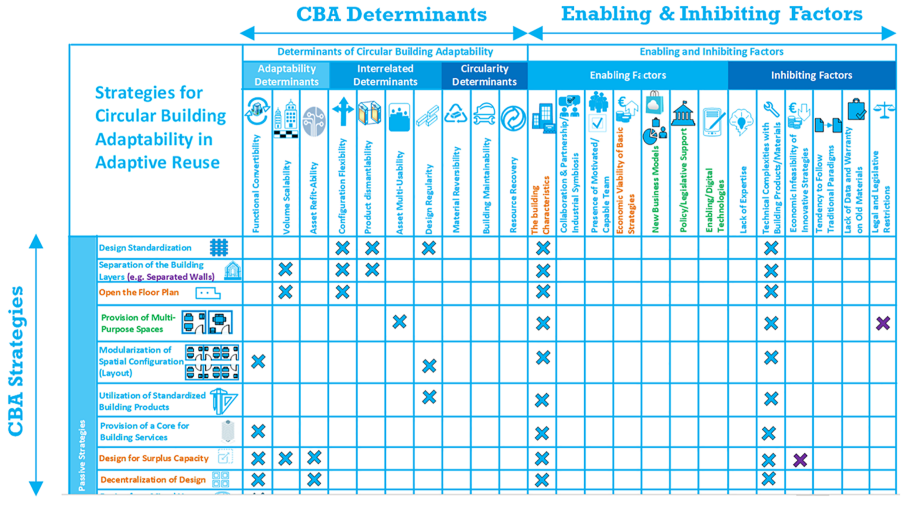
Source(s): Table courtesy of Hamida *et al.* (2023a)

3. A theory-and practice-based CBA-AR framework

The CBA-AR framework is a knowledge-based synthesis that brings together three components, namely CBA determinants (see subsection 3.1), CBA-strategies (see subsection 3.2) and the factors that enable or impede those strategies (see subsection 3.3). Figure 2 illustrates the typica layout of the CBA-AR framework. Cambridge Dictionary broadly defines framework as *"a system of rules, ideas, or beliefs that is used to plan or decide something"* (Cambridge University Press & Assessment, 2021). A conceptual framework acts as a concept-based construct that together links and interprets a certain approach, phenomenon or philosophy based on knowledge gained from discipline-oriented theories and empirical data (Jabareen, 2009).

This study presents a content-wise conceptual framework that was developed to map the explored CBA strategies by Hamida *et al.* (2023a) for circular and adaptable adaptive reuse against their enablers and inhibitors. In this framework, the strategies are mapped to the defined ten determinants of CBA by Hamida *et al.* (2023b), as these determinants were defined based on an integrative literature review of relevant studies to circularity and adaptability in buildings, including Akhimien *et al.* (2021), Arge (2005), Brand (1994) and Eberhardt *et al.* (2022). Keeping in mind the basic rationale of this study – adaptive reuse projects need to be circular and adaptable, these determinants systematically and coherently provide a guiding scheme for this study as they bring the principles of building adaptability and circularity together (see subsection 3.1). For instance, Ollár (2024) adopted these determinants in identifying strategies for designing circular and adaptable multi-residential buildings in Sweden. Regarding the enabling and inhibiting factors, the exploratory study of Hamida *et al.* (2023a) followed a theory- and practice-oriented approach to specifically explore and reveal the enabling and inhibiting factors to the CBA strategies in demonstration adaptive reuse projects in the Netherlands.

The CBA-AR framework would help practitioners in the building industry and real estate market to convert vacant and obsolete properties in a circular and adaptable manner by bringing together the practical solutions that can promote the CBA qualities with the factors that could facilitate and hinder these solutions. In addition, policy makers can amend existing legislation on the basis of the components of the CBA-AR framework. For instance,



Source(s): The authors

Figure 2.
The typical layout of the CBA-AR framework

Shooshtarian *et al.* (2024) explored and mapped challenges and motivations of applying recycled construction products along with their possible strategies in Australian projects in order to inform policy makers and building practitioner about such kind emerging practices; thereby facilitating the application of CE in practice. Following is a brief description of the three components of the framework.

3.1 The 10 determinants of CBA

In this framework, the determinants are the key pillars of the CBA-AR framework as they represent qualities that need to be manifest to promote circularity and adaptability in adaptive reuse. Hamida *et al.* (2023b) defined 10 determinants of CBA, namely "configuration flexibility", "product dismantlability", "asset multi-usability", "design regularity", "functional convertibility", "material reversibility", "building maintainability", "resource recovery", "volume scalability" and "asset refit-ability". Table 3 provides a brief description of each of these determinants (Hamida *et al.*, 2023a).

3.2 The CBA strategies

The CBA strategies represent solutions or actions that promote the determinants of CBA. The CBA strategies are grouped under three categories, namely passive, active and operational strategies. Passive strategies comprise solutions that can promote CBA through the building design, while active strategies encompass solutions that foster CBA through the building configuration and user intervention. Operational strategies are process-oriented solutions that promote CBA. The first version of the CBA-AR framework was developed based on findings from previously conducted literature review and case studies (Hamida *et al.*, 2023a, b).This version of the CBA-AR framework comprised 30 strategies, including 14 passive, 5 active and 11operational strategies.

3.3 The enabling and inhibiting factors to the CBA strategies

The enabling and inhibiting factors are influences on the applicability of the CBA strategies. The enabling factors are the influences that facilitate implementing the CBA strategies while the inhibiting factors are the influences that impede them. These factors were incorporated into the CBA-AR framework as aspects to consider by practitioners when implementing CBA strategies, as capturing knowledge about enablers and barriers to a certain building practice could provide practitioners and organizations with a guide to implement or evaluate the effectiveness of such practice (Okere, 2017).

Based on a theory- and practice-oriented approach, Hamida *et al.* (2023a) came about 7 enabling factors to the CBA strategies, namely the building characteristics, collaboration and partnership (industrial symbiosis), presence of a motivated and capable team, economic viability of basic circular strategies, new business models, legislative support and digital technologies. The authors also came about 6 inhibiting factors, namely lack of expertise, technical complexities with building products and material, economic infeasibility of innovative/advanced strategies, tendency of organizations and individuals to follow traditional paradigms, lack of data and warranty on old material and legal and legislative restrictions. Table 4 briefly describes these enabling and inhibiting factors. The aforementioned 7 enablers and 6 inhibitors were incorporated in the first version of the CBA-AR framework.

As adaptive reuse projects involve various building practitioners and stakeholders (Foster, 2020; Hamida and Hassanain, 2022; Wilkinson, 2014), the main users of this framework are practitioners from the building industry and real estate market, namely designers, contractors, developers, investors and facilities managers. Regulators and policy-makers can use this framework in amending or developing legislation for adaptive reuse.

Enabling factors	
The building characteristics	Availability of flexible size, configuration, and physical and spatial features of the building
Collaboration and partnership (industrial symbiosis)	The presence of a collaboration and partnership among the actors and stakeholders of the adaptive reuse project
Presence of a motivated and capable team	The existence of a shared aim among the engineering team for promoting circularity and adaptability in adaptive reuse
Economic viability of basic circular strategies	Low cost of reusing old building products and affordability of using second hand building products
New business models	Adoption of new business models for promoting reversibility of assets in the closed- reversible value chain
Legislative support	Application of supportive policies and regulations that facilitate the development of adaptable buildings and circular solutions
Digital technologies	Utilization of technologies enabling for using smart building operation, material passports and renewable energy systems
Inhibiting factors	
Lack of expertise	Lack of knowledgeable and skilled practitioners in CBE
Technical complexities with building products/material	Poor construction, maladaptive design and building deterioration
Economic infeasibility of innovative strategies	High cost of restoring deteriorated building elements, reprocessing discarded materials and repurposing old building products
Tendency of organizations and individuals to follow traditional paradigms	Tendency of organisations and practitioners tend to stick to the linear economy paradigm instead of CE
Lack of data and warranty on old material	Lack of records on the used building materials and their performance
Legal and legislative restrictions	Rigidity of existing regulations in terms of applying circular solutions

Source(s): Table courtesy of Hamida *et al.* (2023a)

Table 4. Brief description of the enabling and inhibiting factors to the CBA strategies

The practical contribution of the CBA-AR framework lies in its usability as an informative and guiding tool such as a checklist by practitioners from the building and real estate sectors. Furthermore, the CBA-AR framework can be utilized by professional organizations as an instrument for reporting the promotion of sustainability in adaptive reuse, as it aligns with the EU Taxonomy Compass for the transition to CE without a significant harm to water, climate mitigation, climate change adaptation, pollution prevention and biodiversity (EU Taxonomy Navigator, 2020). In particular, the CBA-AR framework can guide practitioners to design for key aspects mentioned in the EU Taxonomy Navigator (2020), namely design for resource efficiency, adaptability, flexibility and disassembly with the aim of enabling for reusability and recyclability of materials.

4. Results

This section presents findings of collaboratively developing a guiding framework for CBA in adaptive reuse projects based on a participatory approach that involved building and real estate practitioners who have experience with building circularity, adaptable design and adaptive reuse projects in the Netherlands. In the first co-creation workshop, six experts participated, including three architects, a project manager, a researcher and a senior property developer. In the second workshops, nine experts joined the workshop, including three architects, two consultants, a project manager, a real estate developer, a researcher and an R&D manager at a real estate development firm.

4.1 Overview

Figure 3 presents the first version of the framework which was developed based on archival research. Figure 4 presents the revised version of the framework based on the outcomes of the first co-workshop and three structured interviews. Figure 5 presents the final version of the framework based on the outcomes of the second workshops and the another 3 structured

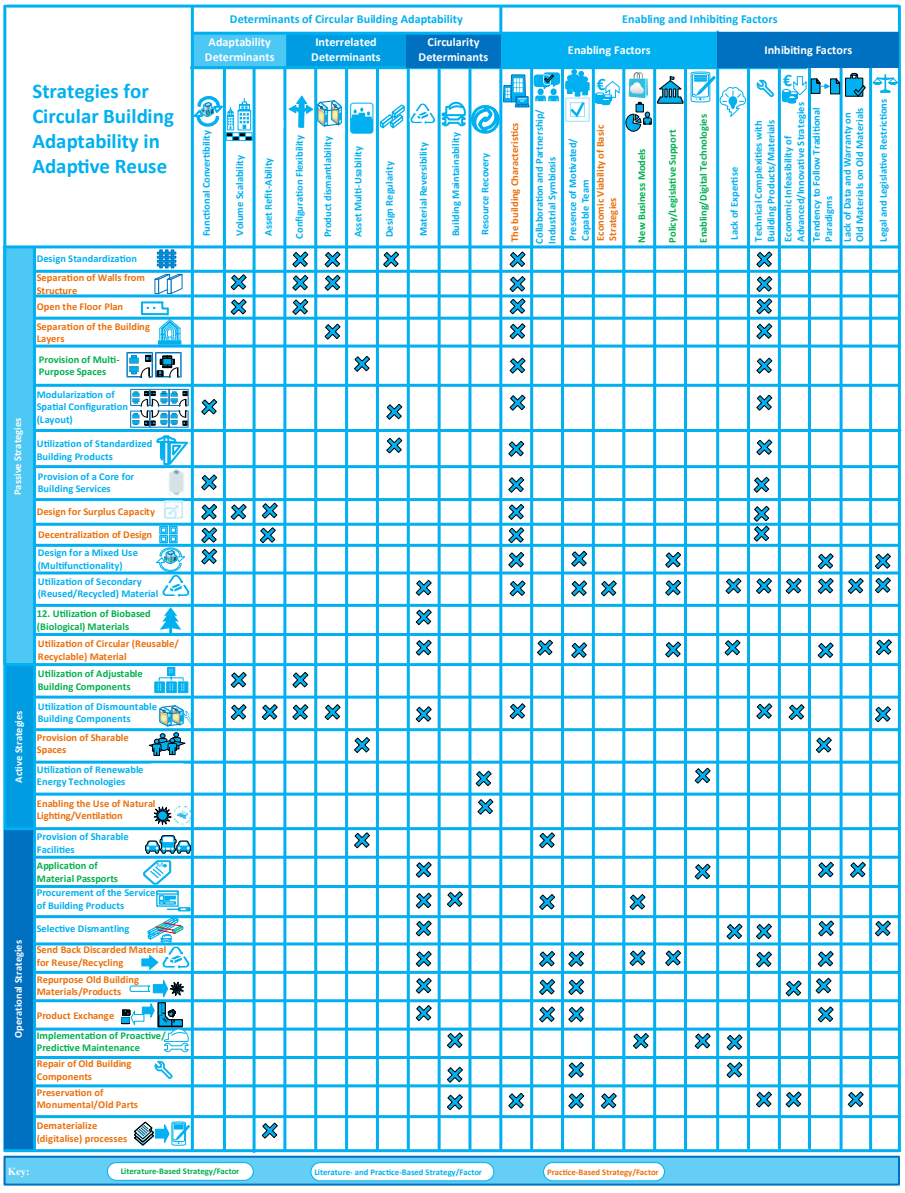
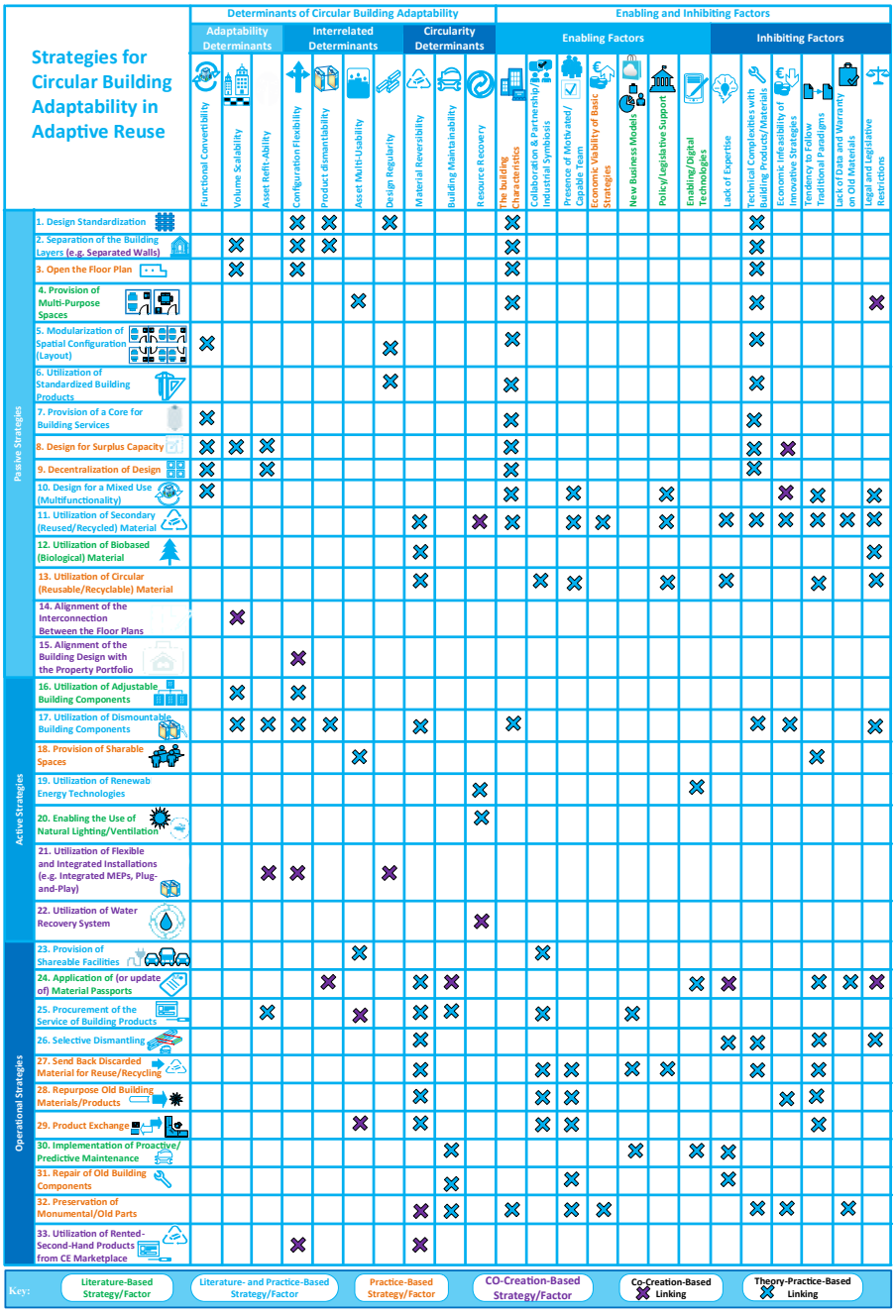


Figure 3.
Components of the first version of the CBA-AR framework

Source(s): The authors



Source(s): The authors

Figure 4.
The revised version of the CBA-AR framework based on the outcomes of the first co-creation workshops and three structured interviews

Figure 5. The finalized version of the CBA-AR framework based on the outcomes of the second co-creation workshops and three structured interviews

Marks: "X" = Theory-Practice-Based Linking; "✖" = Co-Creation-Based Linking; "~~X~~" = Excluded Connection by Participants

Strategies for Circular Building Adaptability in Adaptive Reuse	Determinants of Circular Building Adaptability										Enabling and Inhibiting Factors																	Evaluation of the Strategies			
	Adaptability Determinants			Interrelated Determinants				Circularity Determinants			Enabling Factors										Inhibiting Factors										
Passive Strategies	Functional Convertibility	Volume Scalability	Asset Refit-Ability	Configuration Flexibility	Product dismantlability	Asset Multi-Usability	Design Regularity	Material Reversibility	Building Maintainability	Resource Recovery	The building Characteristics	Collaboration & Partnership/Industrial Symbiosis	Presence of Motivated/Capable Team	Economic Feasibility of Basic Strategies	New Business Models	Policy/Legislative Support	Enabling/Digital Technologies	Location of the Project	Quality and Performance Certification	Social Acceptance	Lack of Expertise	Technical Complexities with Building Products/Materials	Economic Infeasibility of Innovative Strategies	Tendency to Follow Traditional Paradigms	Lack of Data and Warranty on Old Materials	Legal and Legislative Restrictions	Fragmentation of the Building Industry	Effectiveness of the Strategy in Promoting CBA	Applicability in Practice (e.g. Constructability)	Economic Feasibility	Over all Score (Average)
1. Design Standardization				X	X		X				X	✖					✖					X					✖	4	3	5	4
2. Separation of the Building Layers (e.g. Separated Walls)		X		X	X						X											X	✖				✖	5	3	4	4
3. Open the Floor Plan		X		X							X			✖								~~X~~	✖			✖		4	3	3	3.3
4. Provision of Multi-Purpose Spaces						X					X			✖	✖							X	✖			✖		4.5	3	4.5	4
5. Modularization of Spatial Configuration (Layout)	X						X				X	✖		✖			✖					~~X~~	✖			✖		4.5	3	4	3.8
6. Utilization of Standardized Building Products							X	✖			X			✖								X						3	4	4.5	3.8
7. Provision of a Core for Building Services	X										X											X	✖					3	3	3	3
8. Design for Surplus Capacity	X	X	X								X				✖			✖				X	✖			✖		4	4	3	3.6
9. Compartmentalization of Design	X		X								X											X	✖			✖		4	3	2	3
10. Design for a Mixed Use (Multifunctionality)	X										X		X	✖		X		✖			✖	✖	✖	X		X		5	3	2	3.3
11. Utilization of Secondary (Reused/Recycled) Materials								X		✖	X		X	X		X			✖	✖	~~X~~	X	X	X	X	X	✖	5	2	1	2.6
12. Utilization of Biobased (Biological) Materials								X		✖	✖		✖		✖				✖	✖	✖		✖			X		4	3.5	2	3.1
13. Utilization of Circular (Reusable/Recyclable) Materials								X			✖	X	X		✖	X			✖	✖	X		✖	X		X		5	3.5	2	3.5
14. Alignment of the Interconnection Between the Floor Plans		✖									✖														✖			3	3	4	3.3
15. Alignment of the Building Design with the Real Estate Strategy				✖							✖						✖											4	4	5	4.3

Key: Literature-Based Strategy/Factor; Literature- and Practice-Based Strategy/Factor; Practice-Based Strategy/Factor; CO-Creation-Based Strategy/Factor; Co-Creation-Based Linking; Theory-Practice-Based Linking; Excluded Connection by Participants; Revised Text in Workshop 2

(continued)

Strategies for Circular Building Adaptability in Adaptive Reuse	Determinants of Circular Building Adaptability: Adaptability Determinants			Interrelated Determinants			Circularity Determinants			Enabling and Inhibiting Factors: Enabling Factors										Inhibiting Factors							Evaluation of the Strategies			
Active Strategies	Functional Convertibility	Volume Scalability	Asset Refit-Ability	Configuration Flexibility	Product dismantlability	Asset Multi-Usability	Design Regularity	Material Reversibility	Building Maintainability	Resource Recovery	The building Characteristics	Collaboration & Partnership/ Industrial Symbiosis	Presence of Motivated/ Capable Team	Economic Feasibility of Basic Strategies	New Business Models	Policy/Legislative Support	Enabling/Digital Technologies	Location of the Project	Quality and Performance Certification	Social Acceptance	Lack of Expertise	Technical Complexities with Building Products/Materials	Economic Infeasibility of Innovative Strategies	Tendency to Follow Traditional Paradigms	Lack of Data and Warranty on Old Materials	Legal and Legislative Restrictions	Fragmentation of the Building Industry	Effectiveness of the Strategy in Promoting CBA	Applicability in Practice (e.g. Constructability)	Economic Feasibility	Over all Score (Average)
16. Utilization of Adjustable Building Components		✕		✕							✖											✖	✖				✖	4	4.5	3	3.8
17. Utilization of Dismountable Building Components		✕	✕	✕	✕			✕			✕	✖	✖									✕	✕			✕	✖	5	4.5	4.5	4.6
18. Provision of Shareable Spaces						✕					✖				✖			✖		✖				✕		✖		3	3	5	3.6
19. Utilization of Renewab Energy Technologies										✕	✖		✖				✕	✖	✖	✖			✖					3	5	5	4.3
20. Enabling the Use of Natural Lighting/Ventilation										✕	✖								✖				✖					4	3	4	3.6
21. Utilization of Flexible and Integrated Installations (e.g. Integrated MEPs, Plug-and-Play)			✖	✖			✖															✖	✖				✖	4	5	5	4.6
22. Utilization of Water Recovery System										✖									✖			✖	✖				✖	5	3	4	4

Key: Literature-Based Strategy/Factor; Literature- and Practice-Based Strategy/Factor; Practice-Based Strategy/Factor; CO-Creation-Based Strategy/Factor; ✖ Co-Creation-Based Linking; ✕ Theory-Practice-Based Linking; Excluded Connection by Participants; Revised Text in Workshop 2

(continued)

Figure 5

Figure 5

Strategies for Circular Building Adaptability in Adaptive Reuse	Determinants of Circular Building Adaptability										Enabling and Inhibiting Factors																			Evaluation of the Strategies			
	Adaptability Determinants			Interrelated Determinants				Circularity Determinants			Enabling Factors										Inhibiting Factors											
	Functional Convertibility	Volume Scalability	Asset Refit-Ability	Configuration Flexibility	Product dismantlability	Asset Multi-Usability	Design Regularity	Material Reversibility	Building Maintainability	Resource Recovery	The building Characteristics	Collaboration & Partnership/ Industrial Symbiosis	Presence of Motivated/ Capable Team	Economic Feasibility of Basic Strategies	New Business Models	Policy/Legislative Support	Enabling/Digital Technologies	Location of the Project	Quality and Performance Certification	Social Acceptance	Lack of Expertise	Technical Complexities with Building Products/Materials	Economic Infeasibility of Innovative Strategies	Tendency to Follow Traditional Paradigms	Lack of Data and Warranty on Old Materials	Legal and Legislative Restrictions	Fragmentation of the Building Industry	Effectiveness of the Strategy in Promoting CBA	Applicability in Practice (e.g. Constructability)	Economic Feasibility	Over all Score (Average)
Operational Strategies																																
23. Provision of Shareable Facilities						X						X			X	X	X	X	X	X			X					5	5	5	5
24. Application of (or update of) Material Passports					X			X	X		X	X	X				X		X		X	X	X	X	X	X	X	5	5	3	4.3
25. Procurement of the Service of Building Products			X			X		X	X			X			X												X	4	2.5	2	2.8
26. Selective Dismantling								X				X	X		X	X					X	X	X	X	X	X		5	2	2.5	3.2
27. Send Back Discarded Material for Reuse/Recycling								X				X	X		X	X			X	X	X	X	X	X	X	X		5	4	3	4
28. Repurpose Old Building Materials/Products								X				X	X		X	X			X	X		X	X	X	X	X	X	5	4	2	3.6
29. Product Exchange						X		X				X	X		X	X	X		X	X		X	X	X	X	X	X	5	2	3	3.3
30. Implementation of Proactive/ Predictive Maintenance									X						X		X				X		X		X		X	4	4.5	3	3.8
31. Repair of Old Building Components									X				X		X	X					X	X	X		X		X	4.5	4	4	4.2
32. Preservation of Monumental/Old Parts								X	X		X		X	X								X	X		X	X		4.5	5	2	3.8
33. Utilization of Rented-Second-Hand Products from CE Marketplace				X				X				X	X		X		X								X	X	X	4.5	2	3.5	3.3

Key: Literature-Based Strategy/Factor; Literature- and Practice-Based Strategy/Factor; Practice-Based Strategy/Factor; CO-Creation-Based Strategy/Factor; Co-Creation-Based Linking; Theory-Practice-Based Linking; Excluded Connection by Participants; Revised Text in Workshop 2

Source(s): The authors

interviews. In overview, the outcomes of the two workshops and the 6 triangulating interviews contributed to adding new strategies, rephrasing existing strategies, excluding a strategy, combining two strategies, linking the enabling and inhibiting factors to many strategies and adding another enabling and inhibiting factors. Furthermore, the outcomes of the evaluation of the CBA strategies in terms of their effectiveness, feasibility and applicability led to an criterion-specific prioritization of the strategies based on the received scores, also an overall prioritization of the strategies based on the average of the three scores. Appendix 1 presents the outcomes of validating and collaboratively expanding the CBA strategies. Appendix 2 and Appendix 3 present outcomes of validating and collaboratively expanding the enabling and inhibiting factors, respectively. Appendix 4 presents outcomes of collaboratively rating the CBA strategies.

4.2 Validation and expansion of the CBA strategies

The first workshop – focused on validating and collaboratively expanding the CBA strategies – contributed to adding 11 strategies to the framework, including 4 passive, 3 active and 4 operational strategies. One operational strategy was excluded from the framework, namely "dematerialize the processes", because of its inapplicability in buildings. The workshop outcomes also contributed to linking some of the strategies to other CBA determinants, also to the previously defined enabling and inhibiting factors. For instance, the participants concluded that the design for a mixed-use can be hindered by its high initial cost. Six of the eleven added strategies in the workshop were excluded by the interviewees, because of their impracticality. For instance, the interviewees excluded a strategy called "connecting buildings through tunnels", due to its limited applicability in buildings. Two strategies were combined by the interviewees, namely "separation of building layers" and "separation of walls from structure", as the concept of separating partitions from structure is inherent in the "shearing layer" concept by Brand (1994). The second operational strategy, "application of material passports", was rephrased as "application of (or update of) material passports". The participants rephrased the nineth strategy "decentralization of design" to "compartmentalization of design". Similarly, the fifteenth strategy was rephrased as "alignment of the building design with the real estate strategy" instead of "alignment of the building design with the property portfolio", as strategy includes the alignment of real estate portfolio, processes and spaces. Accordingly, 33 strategies were adopted, including 15 passive, 7 active and 11 operational strategies (Figures 4 and 5).

4.3 Validation and expansion of the enabling factors

The results of the second workshop indicated that all the enabling factors are valid. The interconnections between the enabling factors and the CBA strategies have been expanded (Figure 5). Three interconnections were excluded in the second workshop, yet these exclusions were excluded by the interviewees. The formulation of one enabling factor was refined, namely "economic viability of basic strategies".

4.3.1 Refinement of the enabling factors and their influence on the CBA strategies. Out of 8 previously mapped relationships between the third enabling factor "*presence of motivated/capable team"* and 8 CBA strategies, the participants excluded two relationships. The participants excluded that there is an influence of the presence of a motivated/capable team on facilitating the design for a mixed-use as well as repair of old building components, although these relationships were observed in case studies by Hamida *et al.* (2023a). Furthermore, the participants excluded that the support from legislation or policies can be an enabler for the design for a mixed use. All of these exclusions were excluded by the interviewees, in which an interviewee indicated that the capability of the redevelopment team lays the ground for both, designing for a mixed-use and repairing old building

components. In addition, two interviewees indicated that designing a building transformation for a mixed-use is impossible without a support from the legislative support in terms of the zoning polices. The fourth enabling "economic viability of basic strategies" factor was rephrased to "economic feasibility of basic strategies".

4.3.2 Expansion of the enabling factors. Three enabling factors were added to the framework and mapped to many CBA strategies. The newly added enabling factors are "location of the project", "certification" and "social acceptance" (Figure 5). Following are the outcomes of mapping the newly added enabling factors to the CBA strategies:

(1) *Location of the project:* The participants perceived the location of the project as an enabler for 5 CBA strategies, namely design for surplus capacity, design for a mixed use, provision of shareable spaces, utilization of renewable energy technologies and provision of shareable facilities.

(2) *Quality and performance certification:* The participants considered sustainability certification and rating systems, such as BREEAM, as an essential enabler for 11 CBA strategies by means of evaluation. The 11 strategies are: utilization of secondary materials, utilization of circular (reusable/recyclable) materials, utilization of biobased materials, utilization of renewable energy technologies, enabling the use of natural lighting/ventilation, utilization of water recovery system, provision of shareable facilities, application of (or update of) material passports, send back discarded materials for reuse/recycling, repurpose old building materials/products and product exchange.

(3) *Social acceptance:* The participants arrived at a conclusion that social acceptance, as a society-related factor, plays a significant role in the implementation of 9 out of 33 CBA strategies, including utilization of secondary materials, utilization of circular (reusable/recyclable) materials, utilization of biobased materials, provision of shareable spaces, utilization of renewable energy technologies, provision of shareable facilities, send back discarded materials for reuse/recycling, repurpose old building materials/products and product exchange.

According to the expanded relationships between the enabling factors and the CBA strategies, the results show that "building characteristics", "presence of motivated/capable team" and "new business models" have a direct bearing on facilitating the CBA strategies. These factors were connected to 22, 14 and 14 CBA strategies, respectively (Figure 5). However, one of the interviewees who validated the findings indicated that technologies and digitalization are enabling factors for the circularity-oriented strategies, while new business models should illustrate cost-benefit aspects of implementing certain strategies.

4.4 Validation and expansion of the inhibiting factors

The outcomes of the second workshop indicate that the previously identified 6 inhibiting factors are valid (Figure 5). Out of the 6 inhibiting factors, the interconnections between 5 inhibiting factors and the CBA strategies have been expanded in the second workshop. In the second workshop, 7 interconnections have been excluded, yet only 3 exclusions were adopted based on the outcomes of the triangulating interviews.

4.4.1 Refinement of the inhibiting factors and their influence on the CBA strategies. In the second workshop, the potential effect of the lack of expertise on hindering 4 CBA strategies was excluded, namely: utilization of secondary materials, utilization of circular materials, selective dismantling and repair of old building components. The participants also excluded the influence of the second inhibiting factor "technical complexities with building products/materials" on hindering 3 CBA strategies, namely open the floor plan, provision

of multi-purpose spaces and modularization of spatial configuration (Figure 5). The participants supported these three exclusions with the argument that these three strategies are technically complex, but can not be greatly hindered by the technical complexities of building products/materials. However, the interviewees took 4 of these exclusions away. The interviewees supported that lack of expertise, as an experience-related factor, can hinder the utilization of circular materials, selective dismantling and repair of old building components. An interviewee argued that dealing with building components in a circular manners requires a technical knowledge. Furthermore, two interviewees concluded that physical limitations with the design of an existing building and the complexity of its composition could impede the possibility to provide multipurpose spaces within the building.

4.4.2 Expansion of the inhibiting factors. During the second workshop, two inhibiting factors were added to the framework and not mapped to any CBA strategy. The two added inhibiting factors are "fragmentation of the building industry" and "lack of ambition". The participants were after contacted the workshop to map both factors to the CBA strategies, so two participants mapped both factors to the CBA strategies. However, the second added inhibitor, "lack of ambition, was excluded by the interviews, owing to its generality and interrelationship with first inhibitor – lack of expertise. The participants considered the fragmentation of the building industry, in terms of stakeholders and process, as a hey inhibitor to many CBA strategies. As an inhibiting factor, "market fragmentation" was linked to 14 CBA strategies (Figure 5), namely design standardization, separation of the building layers, utilization of secondary materials, utilization of adjustable building components, utilization of dismountable building components, utilization of flexible and integrated installations, utilization of water recovery system, application of (or update of) material passports, procurement of the service of building products, repurpose old building materials/products, product exchange, implementation of proactive/predictive maintenance, repair old building components and utilization of rented-second-hand products from CE marketplaces.

According to the expanded relationships, "technical complexities with building products and material", "economic infeasibility of innovative/advanced strategies" and "legal and legislative restrictions" are apparently key inhibitors to the CBA strategies. The results indicate that these three factors could hinder 20, 26 and 18 strategies, respectively. The participants indicate that there is a direct relationship between the possibility to apply material passports in adaptive reuse projects and the technical complexities with building products, due to the difficulty of adding information about the technicalities of materials to material passports. Two of the interviews who triangulated the findings have perceived lack of data as another key inhibitor to the strategies that require dealing with reuse of materials and building products.

4.5 Evaluation of the CBA strategies

The evaluation of the strategies contributed to getting a better grasp on the effectiveness, economic feasibility and applicability of the strategies.

Regarding the effectiveness of the strategies in promoting CBA, the results of the evaluation indicate that the effectiveness of the 33 CBA strategies is "extremely effective" as shown in Figure 5 and in accordance with the adopted interpretation metrics in Table 3. The applicability of the strategies in practice varied, as the results indicated that it ranges between "applicable" and "extremely applicable". However, the majority of the strategies have been perceived either "very applicable" or "extremely applicable", as shown in Figure 5. The results points out that 5 strategies have been perceived as "applicable", 14 "very applicable" and 14 "extremely applicable", respectively. The evaluation of the CBA

strategies in terms of their economic feasibility indicates that the majority of them are economically feasible. As shown in Figure 3 and according to the adopted interpretation metrics in Table 3, only one strategy has been perceived as "barely feasible", while the other 32 strategies have been considered as "feasible", "quite feasible" or "entirely feasible". Out of the 32 economically feasible CBA strategies, 8 strategies have been perceived as "feasible", 9 "quite feasible" and 15 "entirely feasible", respectively.

Based on the average of the received rating scores, six strategies can be considered as promising strategies for circular and adaptable building transformation. These strategy are: "alignment of the building design with the real estate strategy", "utilization of dismountable building components", "utilization of renewable energy technologies", "utilization of flexible and integrated installations", "application of material passports" and "provision of shareable facilities". However, the results indicate that procuring the service of building products as well as utilizing second-hand materials can be seen as the least promising strategies for circular and adaptable building transformation.

5. Discussion

Due to the unavailability of knowledge-based guiding tools for promoting CBA in adaptive reuse projects, this study focused on co-developing as well as collaboratively validating and expanding a content-wise framework for CBA-AR. The CBA-AR framework is a descriptive and content-wise synthesis that brings together three components, namely CBA determinants, the CBA strategies and the enabling and inhibiting factors to those strategies. A participatory research-driven approach was followed in this paper. All the involved participants and interviewees are practitioners who have a prior experience with building circularity, adaptable design and adaptive reuse projects in the Netherlands.

5.1 Discussion of the main findings

Considering the aim of this study, the findings indicate that the majority of the CBA strategies are valid. The followed approach contributed to paraphrasing some strategies, excluding a strategy, combining two strategies, expanding the interrelationships between the strategies and the CBA determinants, as well as expanding and refining the enabling and inhibiting factors including relationship with the CBA strategies. According to the findings, "utilization of dismountable building components" and "procurement of the service of building products" are apparently the most contributing strategies, because they can promote four CBA determinants. This is justifiable, as dismantlability in building components facilitates the their disassembly and reuse in the future (Akhimien *et al.*, 2021; Eberhardt *et al.*, 2022). Similarly, procuring the service of building paves the way for maintaining, replacing and reusing the procured products instead of discarding them (Iyer-Raniga, 2019; Tserng *et al.*, 2021; Webb *et al.*, 1997). The outcomes of evaluating the CBA strategies indicate that "alignment of the building design with the real estate strategy", "utilization of dismountable building components", "utilization of renewable energy technologies", "utilization of flexible and integrated installations", "application of material passports" and "provision of shareable facilities" are the most promising strategies in the CBA-AR framework. This is in line with the components of the conceptualized framework by Foster (2020) for CE in adaptive reuse.

The results indicate that most of the previously demonstrated relationships between the CBA strategies and their enabling and inhibiting factors are relevant and valid. The findings point out that "the building characteristics", "presence of motivated and capable team" and "new business models" play a pivotal role in enabling for implementing the CBA strategies, while "technical complexities with building products and material", "economic infeasibility

of innovative/advanced strategies" and "legal and legislative restrictions" can greatly hinder them. These findings corroborate with observations indicated by Kanters (2020) and Dewagoda *et al.* (2022) which point out that the infrastructure of buildings along with the adoption of new business models facilitate CE in buildings. Regarding the three most significant inhibitors, the results of this study agree with the findings of Ababio and Lu (2023), AlJaber *et al.* (2023) and Giorgi *et al.* (2020) which indicate that economic, political and technical challenges are main barriers to the application of CE in buildings. The raised technical issues by the participants in regards to the low performance and quality of materials are in line with the empirical observations by Shooshtarian *et al.* (2024).

5.2 Reflection on the implications of the study

It is worth noting that that there has been a possibility to refine and expand the three components of the CBA-AR framework along with acquiring further insights into practical aspects. These outcomes were delivered by the virtue of following such a participatory and iterative approach by using a series of two co-creation workshops as a primary research method. The generalizability of using the CBA-AR framework as a guiding tool by practitioners is possible for different reasons. First, the incorporated strategies into the framework were expanded and validated by practitioners who have practiced with circularity and adaptive reuse in the Dutch building industry and real estate market which are seen as forerunners in operationalizing CE in practice (Cramer, 2020; Tserng *et al.*, 2021). Second, the content of the framework is not only a theory- and concept-based synthesis, as the case of the conceptualized framework by Foster (2020), but rather a synthesis that is based on an integrative outcome of coherently brining findings of theoretical, empirical and participatory research together. Third, the framework does not only link a series of strategies to certain qualities of CBA in adaptive reuse, but rather it coherently connects three components together, namely: strategies, determinants and enabling and inhibiting factors. These three components can inform practitioners on what needs to be fostered for a circular and adaptable building transformation, how to promote that and what are the aspects that could facilitate or impede relevant CBA strategies. Furthermore, the incorporated rating of the CBA strategies into the CBA-AR framework provides practitioners with an initial prioritization of the applicability, effectiveness and feasibility of the CBA strategies. The demonstrated relationships between the strategies and the CBA determinants can guide practitioners, policy makers and researchers in promoting CBA in the Netherlands. Technically, designers and property developers can use the CBA-AR framework as a checklist, evaluation tool and an instrument to report sustainable and circular practices in adaptive reuse projects. Scholars can use the components of this framework in developing decision-making tools and assess the impact of the CBA strategies, while policy makers can refer to them in amending existing legislation and regulations of adaptive reuse.

5.3 Indication of the limitations of this study and possibilities for future research

The CBA-AR framework is still descriptive and has not been tested yet in terms of its usability and effectiveness in practice, which can be a practical limitation of the applicability of this guiding tool in practice. Further, policy experts were not involved in the co-development process along with the building and property experts who participated in the co-development and validation of the framework These limitations can be further studied and addressed by using an action research-oriented approach. Action research is a useful, iterative and self-reflective practice-oriented approach that can be followed to reflect a change in the real world as well as test a theoretical hypothesis in real world settings (Kemmis *et al.*, 2014). In this regard, the CBA-AR framework can be tested and refined in action through a collaborative and iterative process between professionals and scholars

during the design of an adaptive reuse for circularity and adaptability. The outcomes of such a collaborative and iterative process can further contribute to enhance the design of the framework to facilitate its use in practice.

6. Conclusion and recommendations

The built environment is confronted with multiple challenges related to resource scarcity, climate change, market volatility, technological advances and high energy use. Adaptive reuse is an indispensable form of building alterations and it is a coping strategy for the aforementioned challenges. In light of the call for promoting circularity in the built environment, adaptive reuse is seen as a promising solution that aligns with the principles of CE. As an inevitable process, adaptive reuse should also foster the adaptability to accommodate future changes. However, there has not been a developed framework describing how circularity and adaptability can be brought together in adaptive reuse projects.

This study focused on collaboratively developing a guiding framework that describes how circularity and adaptability can be brought together and fostered in adaptive reuse projects in general, considering contextual factors that can facilitate or impede the implementation of these strategies. In this regard, the CBA-AR framework is a knowledge-based synthesis that connects a series of strategies to the CBA determinants together, as well as the enabling and inhibiting factors to those strategies. A participatory research-oriented approach was followed in this paper. An archival research was carried out first to develop the first version of the framework based on the knowledge gained from literature review and case studies. Two co-creation workshops were organized with experts from the Dutch building industry and real estate market to collaboratively validate the components of the framework. The outcomes of each workshop was validated through structured interviews.

The followed participatory approach in this study contributed to collaboratively refining, combining and expanding the components of the CBA-AR framework – the CBA strategies and their enabling and inhibiting factors – as well as their interrelationships. The refined and expanded version of the CBA-AR framework consist of 33 strategies – including 15 passive, 7 active and 11 operational strategies – along with 10 enabling and 7 inhibiting factors. Overall, the findings indicate that "alignment of the building design with the real estate strategy", "utilization of dismountable building components", "utilization of renewable energy technologies", "utilization of flexible and integrated installations", "application of material passports" and "provision of shareable facilities" are the most promising CBA strategies. Furthermore, "the building characteristics", "presence of motivated and capable team" and "new business models" the key enablers, while "technical complexities with building products and material", "economic infeasibility of innovative/advanced strategies" and "legal and legislative restrictions" are the key inhibitors to the CBA strategies.

These observations can guide practitioners, policy makers and scholars in promoting CBA in adaptive reuse. Designers and property developers can use the CBA-AR framework as a checklist and a tool for reporting circular activities in the reuse of existing buildings. Researchers can use the components of this framework further in the development of decision-making tools. Policy makers can adapt the components of the CBA-AR framework in amending existing regulations.

Based on these findings, the following recommendations are put forward:

(1) Designers and property developers of adaptive reuse projects need to facilitate future changes in an efficient manner while reducing waste by utilizing dismountable building products and installing flexible and integrated building installations.

(2) Property developers of adaptive reuse projects need to maintain an updated building information as well as apply and update material passports as a record of the utilized

building assets and their performance, thereby facilitating the reuse of the building assets afterwards.

(3) New business models should adopted for circularity-oriented strategies, in which the cost-benefit aspects should be illustrated.

(4) Researchers need to explore ways of sharing knowledge about the CBA strategies and their adoption in practice.

(5) Future research can focus on testing and reflecting on the effectiveness and usability of the CBA-AR framework in action by following a collaborative and iterative approach that brings professionals and scholars together during the design of an adaptive reuse for circularity and adaptability.

Ultimately, the presented CBA-AR framework complements other frameworks available in the relevant literature, by the virtue of its descriptive content which coherently brings three components together on the basis of acquiring and expanding knowledge from the relevant theory and practice as well as an iterative co-creation process. The CBA-AR framework is a descriptive synthesis that has not been tested yet in the real world, which can limits its useability in practice. Moreover, the CBA-AR framework was co-developed with experts from the building industry and real estate market, in which policy experts were not involved in this process. However, it is worth noting that the content of the CBA-AR framework can set the stage for fostering CBA in future adaptive reuse projects in the Netherlands by the means of knowledge sharing, amendments of current regulations, development of decision-making instruments and actionable studies. Further research can focus on testing the applicability and effectiveness of using the CBA-AR framework in real practice, by the means of action research which brings knowledge from theory and practice together in the real world.

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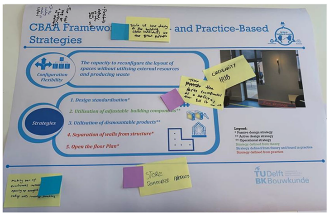
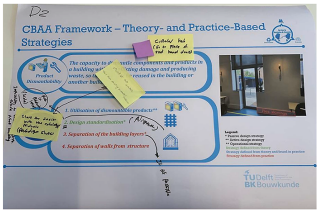
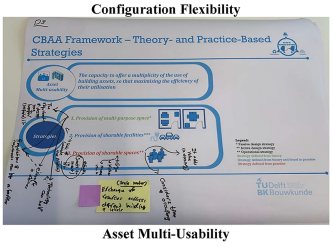
Appendix 1
Outcomes of validating and collaboratively expanding the CBA strategies



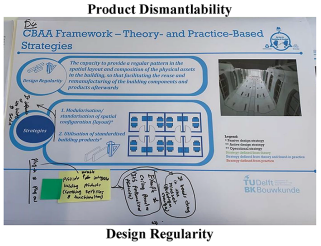
Configuration Flexibility



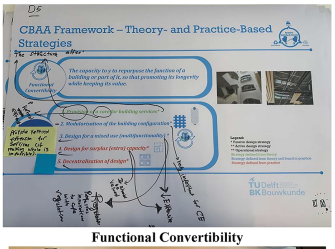
Product Dismantlability



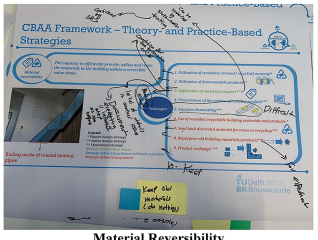
Asset Multi-Usability



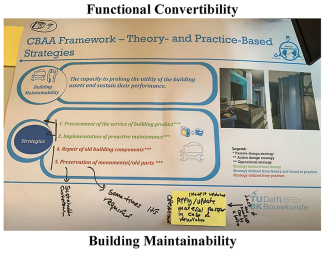
Design Regularity



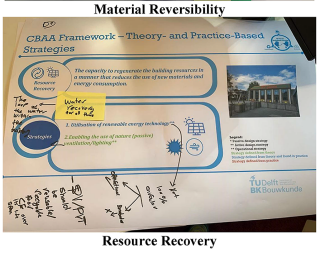
Functional Convertibility



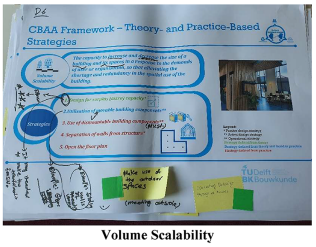
Material Reversibility



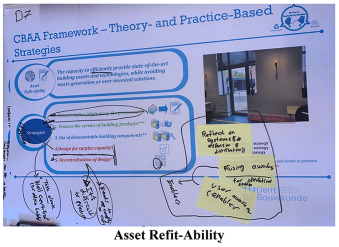
Building Maintainability



Resource Recovery



Volume Scalability

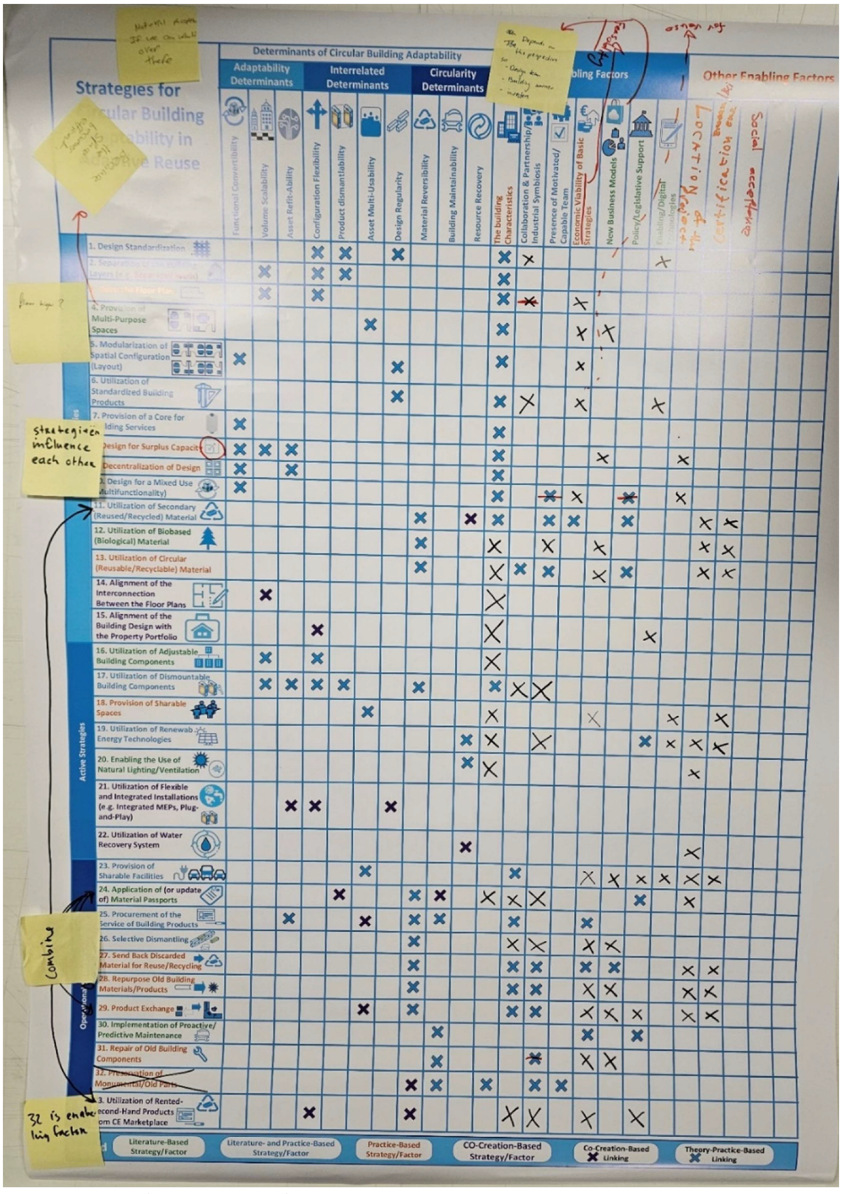


Asset Refit-Ability

Source(s): Authors' own work

Appendix 2

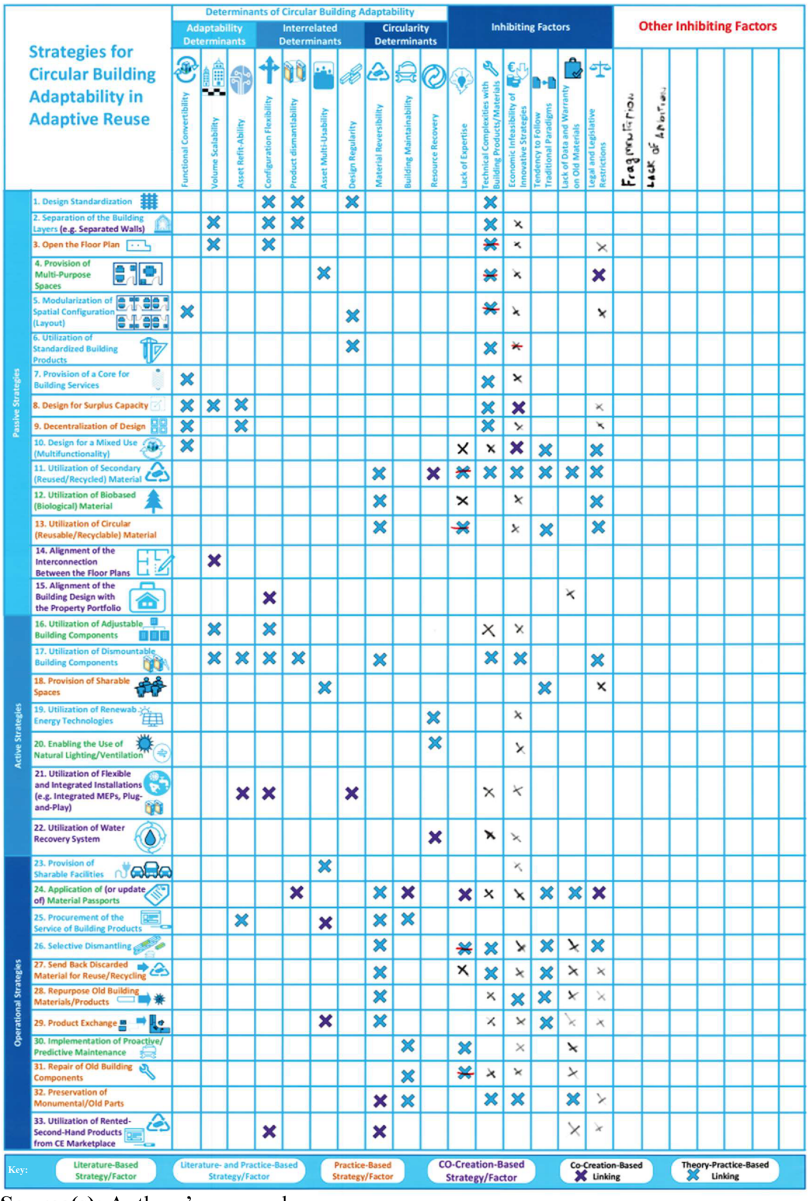
Outcomes of validating and collaboratively expanding the enabling factors



Source(s): Authors' own work

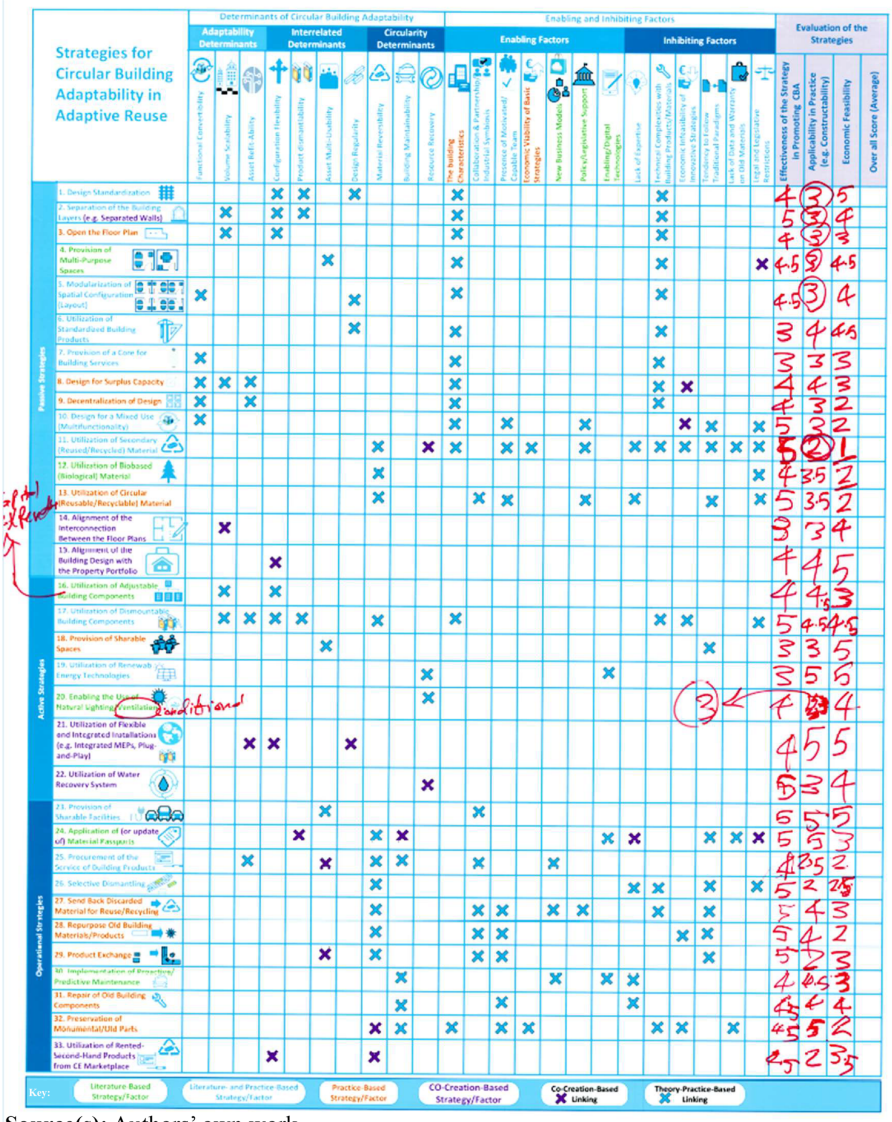
Appendix 3

Outcomes of validating and collaboratively expanding the inhibiting factors



Source(s): Authors' own work

Appendix 4
Outcomes of validating and collaboratively rating the CBA strategies



Source(s): Authors' own work