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From vision to action: An integrative approach for circular adaptive reuse

Circularity in adaptive reuse helps tackle material shortages, environmental damage, and ageing properties, while enhancing asset value. However, bridging the gap between visionary reuse scenarios of existing real estate and design strategies remains challenging. Integrating scenario tools with adaptive reuse frameworks can address this issue. This paper presents an approach to systematically define promising circular real estate scenarios and translate them into actionable strategies.

Brian van Laar, Mohammad B. Hamida and Angela Greco

1. Introduction

Adaptive reuse—or building transformation—has emerged as a key strategy in the transition toward a circular built environment (Tam & Hao, 2019; Remøy, 2010). By reducing the demand for new construction, conserving materials, and extending the lifespan of existing structures, adaptive reuse mitigates environmental impacts while also generating economic and social benefits, such as preserving cultural heritage and enhancing asset value (Foster, 2020).

Despite its multifaceted cultural, societal, and environmental advantages, the implementation of adaptive reuse to enhance circularity continues to face significant technical, legal, and design challenges. These difficulties can be attributed to the intrinsic complexity of decision-making processes, which must balance diverse and often competing criteria (van Laar et al., 2024).

To address this complexity and facilitate more effective adaptive reuse, scholars have primarily focused on two complementary but often disconnected streams of work. The first involves the development of design strategies and frameworks aimed at guiding circular interventions—such as adaptable design, resource efficiency, and the use of low-impact biomaterials—which have demonstrated strong potential to improve environmental performance (Pomponi & Moncaster, 2017; Hamida et al., 2024). An example is the Circular Building Adaptability for Adaptive Reuse (CBA-AR) framework, which integrates principles of circularity and adaptability to offer context-sensitive strategies (Hamida et al., 2024). However, the practical application of such frameworks is still hampered by knowledge gaps and the difficulty of tailoring strategies to specific economic, functional, and technical conditions (Greco et al., 2024).

The second stream focuses on future-oriented scenario tools, which support stakeholders in exploring long-term consequences and navigating uncertainty in adaptive reuse decisions. These tools are especially valuable in the early stages of planning, where they facilitate collaborative envisioning of different futures. For instance, Cross-Impact Balance (CIB) analysis enables the identification of consistent and plausible scenarios by assessing interrelations among key factors (Weimer-Jehle, 2023; van Laar et al., 2025). While both design frameworks and scenario-building methods contribute critical insights, their development in parallel has limited their combined potential. Current tools tend to focus either on crafting visionary reuse scenarios or on providing practical, context-specific strategies—but rarely both. This separation creates a persistent gap between foresight and implementation, making it difficult for stakeholders to transform aspirational ideas into actionable plans.To bridge this gap, we explore the synergies between the CIB methodology,

which enables the co-creation of resilient long-term pathways, and the CBA-AR framework, which provides concrete guidance for adaptive reuse, to offer a more holistic and future-proof approach to circular real estate reuse.

The aim of this paper is to propose and demonstrate an integrated approach that combines scenario development tools with practical circular design strategies, enabling design and real estate professionals to define and visualize desirable adaptive reuse scenarios alongside applicable strategies that promote a circular built environment.

2. Background

2.1 Circular Building Adaptability (CBA) and its adaptive reuse framework

Circular building adaptability (CBA) is a conceptual framework that combines the principles of adaptable and circular design to create sustainable, resource-efficient building strategies (Hamida et al., 2023). It integrates ten key determinants that contribute to ensuring that buildings can adapt to changing needs over time while reducing waste and building generative capacity. These are: "configuration flexibility", "product dismantlability", "asset multi-usability", "design regularity", "functional convertibility", "material reversibility", "building maintainability", "resource recovery", "volume scalability", and "asset refit-ability". These determinants are operationalized through passive (design-based), active (design- and user-based), and operational (process-based) strategies such as using modular design, providing adjustable products, and applying material passports, respectively. Building on these concepts, the CBA framework has been expanded in a strategic design framework for adaptive reuse (CBA-AR), a tool for mapping each determinant to 33 strategies alongside their enablers (e.g., collaboration and technical innovation) and inhibitors (e.g., lack of expertise or regulatory support) (Hamida et al., 2024). Practitioners can use the CBA as a checklist or guide during adaptive reuse projects to implement circular design principles, ensuring that buildings remain adaptable, functional, and sustainable across their lifecycles.

2.2 Cross-Impact Balance Analysis for scenario development

Cross-Impact Balance (CIB) analysis is a structured method for analysing complex systems and developing plausible scenarios by examining the interdependencies between system components (Weimer Jehle, 2023). CIB is founded on descriptors, variants, and the cross-impact matrix. Descriptors represent the key factors of the system studied, such as regulatory frameworks, market dynamics, or resource availability. The cross-impact matrix is the core analytical tool in CIB. It quantifies how variants influence other variants, revealing interdependencies and feedback loops within the system. Once the matrix is constructed, the analysis identifies consistent combinations of variants, where no contradictions exist in how the variants interact. These consistent combinations are then assembled into scenarios, each representing a logically coherent and plausible future.

CIB systematically explores how changes in one part of the system influences others, making it particularly valuable in fields like urban planning, climate adaptation, and adaptive reuse projects. Its structured approach ensures transparency and allows for stakeholder involvement, making it both robust and participatory.

3. Research Methodology

3.1. Overview and background of the research methodology

This study followed an iterative theory- and practice-oriented research methodology, using literature review and desktop research to develop an integrated methodological approach based on a conceptual framework. Technically, a conceptual framework is a constructed network that brings together interrelated concepts to comprehensively explain a phenomenon or

phenomena of interest (Jabareen, 2009). In mixed methods research, conceptual frameworks can be conceptualized, borrowed, or adopted in a research based on certain theories in relevant fields and act as predicting, determining or informing, or they might be expanded through a data collection process. The creation of frameworks constitutes an important research tool that can aid new discoveries by exposing limitations and enablers of knowledge-driven insights (Sharma et al., 2022).

Accordingly, in this paper, our methodological approach is a processes-oriented framework that brings together certain processes, tools and concepts to aid design and real estate professionals to turn their vision of circular adaptive reuse into a defined set of concrete strategies that can be implemented. The development of this approach is based on knowledge gained from adaptive reuse and circular economy related literature combined with desktop research and interviews.

3.2 Methods

3.2.1 Literature review

A brief literature review of circular adaptive reuse was carried out, covering academic literature (Foster, 2020; Hamida et al., 2022; Vafaie et al., 2023; van Laar et al., 2024, Fusco Girard & Vecco, 2021; Gravagnuolo et al., 2024; Hamida et al., 2023; Ikiz Kaya et al., 2021), and grey literature sources. The focus was on methods for circular adaptive reuse and requirements for a methodological approach. The sources were selected in a purposive way. The included themes were applied as a coding scheme to process the requirements, methods, and approaches for circular adaptive reuse. Literature on approaches and frameworks for circular economy in the built environment and circular adaptive reuse were reviewed to initially define steps in the approach while grey literature and methods-based literature were reviewed to define useable tools to be incorporated into the methodological approach.

3.2.2 Desktop research

Based on the reviewed literature, a set of functional requirements are put forward that serve as prerequisites for the integrative methodological approach (section 4). Desktop research was conducted to bring together the scenario development- and strategies-oriented tools and concepts in a stepwise structure. The CIB- and CBA-AR-related literature identified existing tools, while process related literature contributed to synthesizing the steps of the methodological approach. The definition and visualization of the approach were interactively carried out, including rephrasing and merging different steps to avoid redundancy in the process. The approach was then tested in a hypothetical case to validate its potential use. A specific vacant monumental project in the Netherlands was considered as a hypothetical case. Accordingly, the methodological approach was developed during the research while guidelines were put forward for users.

4. Requirements for an integrative methodological approach

The literature review indicates that current decision-support tools for adaptive reuse face significant challenges and lack mechanisms to connect high-level foresight with adaptable, project-specific strategies. Many existing tools prioritize either broad functional outcomes or specific design details, which can limit their ability to provide comprehensive, future-proof solutions for adaptive reuse projects (van Laar et al., 2024). Furthermore, there is often a gap between the visionary nature of scenario planning and the practical steps needed to implement circularity principles effectively.

To address these challenges, we apply a methodological approach combining scenario development and circular strategy based on literature:

1. **Clear definition of steps:** Providing practitioners with stepwise approaches is useful for facilitating emerging innovations and practices

in the built environment (Arfa et al., 2022; Foster, 2020; Geldermans, 2016; Stijn & Gruis, 2019).

2. **Consistency and Plausibility:** Scenarios must be internally consistent and plausible, ensuring that future-oriented projections are logically cohesive and applicable (Weimer-Jehle, 2023). The CIB methodology provides a structured approach to scenario development by assessing interdependencies among scenario elements, supporting realistic and stable projections (Weimer-Jehle, 2006).
3. **Normative Scenarios Aligned with Project Goals:** The scenarios are driven by the specific goals and objectives of the adaptive reuse project. This ensures that envisioned future pathways correspond with the broader project sustainability, community, and financial aims, enabling design and real estate professionals to envision and collaboratively pursue desirable outcomes. By anchoring strategy selection to these high-level project goals, the approach maintains coherence between long-term vision and practical actions.
4. **Adaptability to Evolving Project Conditions:** Given the uncertainty inherent in adaptive reuse, the methodology must allow for flexibility in strategy selection and application to accommodate changing environmental, social, or regulatory conditions. This adaptability enables project-specific tailoring of CBA strategies, ensuring that chosen actions remain relevant and effective under various potential future scenarios.

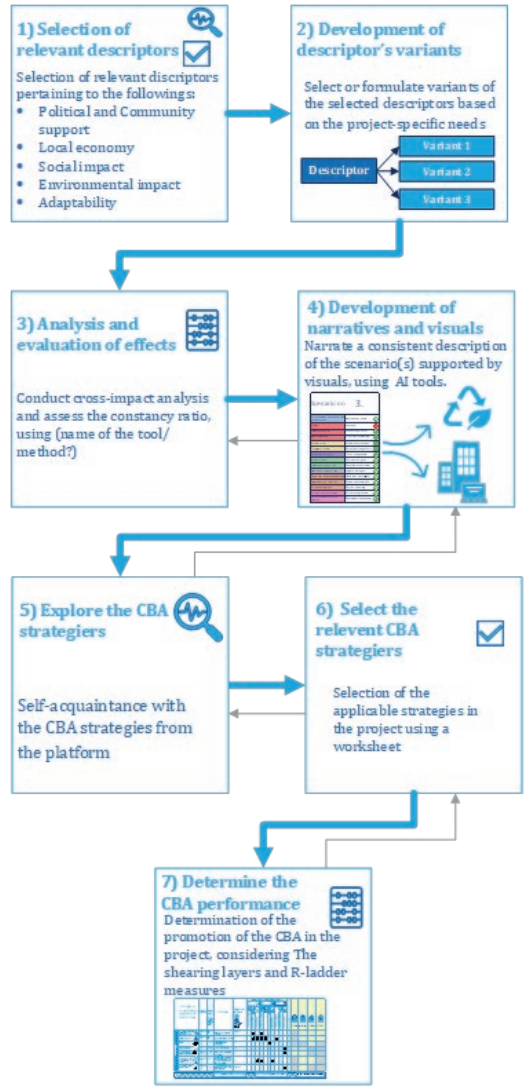
Together, these requirements provide a foundation for an integrated and robust methodological approach that can be further developed and implemented in practice, offering decision-makers a balanced, forward-looking, and methodological approach to circular adaptive reuse.

5. Results

5.1 Overview of the content of the methodological approach

Based on the literature review and desktop research, we developed a stepwise methodological approach of 7 steps (*Figure 1*). This methodological approach brings together

FIGURE 1 ▸ AN INTEGRATIVE METHODOLOGICAL APPROACH FOR DEFINING SUITABLE ADAPTIVE REUSE SCENARIOS AND THEIR PRACTICAL STRATEGIES



three elements, namely informative activities (steps), concepts (circularity and adaptive reuse), and tools (CIB, AI, and CBA-AR worksheet). First, the steps of the approach are detailed, followed by a demonstration of its application to a hypothetical case, illustrating how it fulfils the functional requirements.

The initial definition of the seven steps has been inspired by the model by (Arfa et al., 2022), in which the six subphases of the preparation phase begin with an analysis and evaluation of values and feasibilities of feeding design decisions and outcomes. This has been adapted to accommodate the scenario development process steps from Weimer-Jehle, (2023), enriched with narrative and visualisation techniques by van Laar et al. (2025), and the practical CBA-AR framework (Hamida et al., 2024).

The first four steps are adapted from the scenario development methodology by (Weimer-Jehle, 2023), specifically focusing on Cross-Impact Balance (CIB) analysis to create internally consistent, future-oriented scenarios. The final three steps are derived from the CBA-AR framework (Hamida et al., 2024). The first four steps are visionary, while the last three steps are more practical.

5.1. Description of the steps composing the methodological approach

Step 1: Identification of Relevant Descriptors

This step focuses on identifying descriptors that capture the key uncertainties and influences within the adaptive reuse context. Descriptors (see 2.2) are the central themes that influence the scenario space (Weimer-Jehle, 2023). This step is essential for establishing a scenario framework that is both context-specific and broad enough to encompass various possible futures, aligning with the emphasis on the scenario factors such as economic, environmental, social, and functional.

Step 2: Development of Descriptor Variants

Following the CIB methodology, descriptor variants are crafted to represent a range of plausible outcomes for each descriptor. Variants are defined as: "potential future alternatives" (Weimer-Jehle, 2023). This step is informed by the principle of future openness, where descriptors must cover all potential states without overlap, allowing for a complete exploration of future possibilities. Creating distinct variants ensures that scenarios reflect the diverse conditions that might impact adaptive reuse projects.

Step 3: Cross-Impact Analysis and Consistency Check

This step applies the CIB analysis to evaluate the interdependencies among descriptor variants. By assessing these, this step generates scenarios that are internally consistent, discarding those that are contradictory or logically incoherent. This analytical process is critical for ensuring the reliability and robustness of each scenario, as inconsistencies could undermine stakeholder confidence and strategic decision-making crucial in adaptive reuse projects.

Step 4: Scenario Narratives and Visualizations

This step transforms consistent scenarios into accessible narratives and visuals to facilitate stakeholder understanding and dialogue on adaptive reuse priorities. Generative AI tools can be used to produce vivid visualizations and detailed descriptions, incorporating data from CIB analysis and insights from workshops. Unlike traditional methods like artist impressions, AI provides speed, consistency, and adaptability, enabling efficient content creation tailored to diverse audiences (Epstein et al., 2023). This enhances the storytelling process, making complex scenarios more relatable and applicable for stakeholders.

Step 5: Exploration of CBA Strategies

The CBA-AR framework highlights the importance of familiarizing users with various CBA strategies, categorized as passive, active, and operational. This step provides design and real estate professionals with the opportunity to explore available strategies. By grounding

scenario planning in practical strategies, this step aligns visionary scenarios with applicable actions, bridging the gap between theoretical analysis and practical application.

Step 6: Selection of Relevant CBA Strategies
This step employs the CBA-AR as a worksheet framework, allowing users to map selected CBA strategies to specific scenario outcomes, by ensuring that strategy selection is informed by the scenario objectives and project-specific descriptors identified in the initial steps.

Step 7: Assessment of CBA Performance
In the final step the effectiveness and impact of the chosen CBA strategies is evaluated using performance metrics relevant to circular economy goals. This assessment provides insight into the outcomes aligned with circular principles.

5.2. Application to Hypothetical Case

The following section discusses how the methodological approach is applied to a hypothetical transformation project and examines how it fulfils the functional requirements.

Step 1: Identification of Relevant Descriptors
11 descriptors were selected for the scenario development process, namely: Political & Community support, Cost, market Potential, Social Impact, Building Technology, Indoor Environmental Quality, Rules and Regulations, Flexibility and Adaptability, Durability and Quality, Historic and Cultural value, aligning with the recommended range of 9-15 (Weimer-Jehle, 2023). These descriptors were derived from the criteria and objectives outlined by van Laar et al., (2024), related to the project's objectives, creating normative scenarios aligned with project goals.

Step 2: Development of Descriptor Variants
Each descriptor has three ordinal variants: a strong variant where the objective is fully achieved, a medium variant where the objective is partially achieved, and a weak variant where the objective is not achieved.

Step 3: Cross-Impact Analysis and Consistency Check
A cross-impact matrix was used to evaluate the interdependencies among descriptor variants, ensuring logical coherence and consistency in scenarios that were in line with the first functional requirement. Each variant's direct effects on others are rated from -3 to +3, representing negative, neutral, or positive impacts. Scenarios with high inconsistency (e.g., a negative impact

FIGURE 2 ▸ PRODUCED CONSISTENT SCENARIOS FOR OUR HYPOTHETICAL EXAMPLE

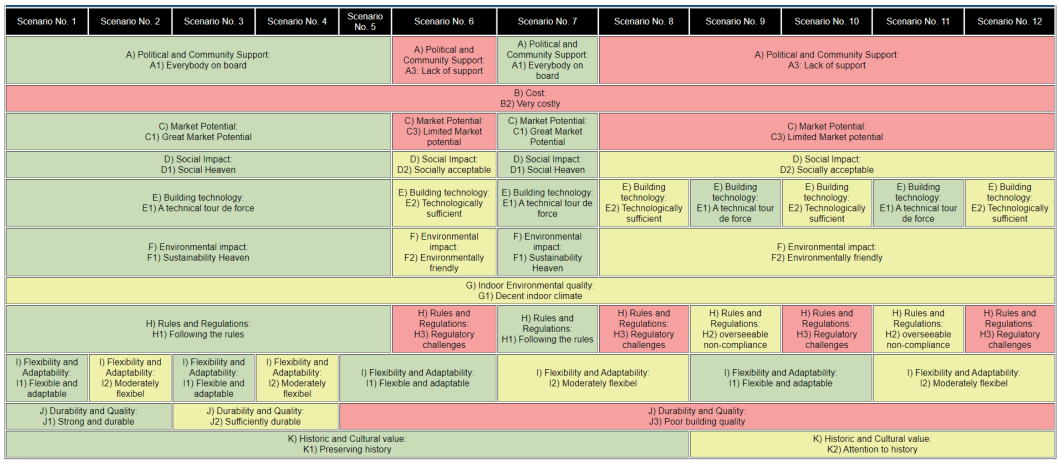


Figure developed with scenario wizard, adapted from van Laar et al., 2025

sum) are discarded, marginal inconsistencies up to a value of 1 are accepted (Weimer-Jehle, 2023). The ScenarioWizard[1] software was used to generate a set of consistent scenarios for robust analysis. *Figure 2* displays a consistent scenario.

Step 4: Development of narratives and visuals

Narratives and visualizations were created using generative ChatGPT-4 to compile structured narratives from the descriptor variants, while DALL-E generated visual representations based on these storylines. Henceforth, a comprehensive scenario scorecard summarizes a selected scenario for the hypothetical case.

Step 5: Explore the CBA performance

In this step, a detailed exploration of the passive, active, and operational CBA strategies was carried out by browsing the CBA-AR framework and its platform (CBA-AR)[2].

Step 6: Select relevant CBA strategies

After reviewing the strategies, the CBA-AR framework was adapted to select applicable strategies. *Figure 3* presents the results of using the CBA-AR worksheet for the passive strategies, where the yellow fields are the ones that must be filled out. The green fields show the CBA determinants and R-ladder measures. Strategy selection was aligned with the project objectives, guided by the descriptor variants of the chosen scenario, which aligns with functional requirements 3 and 4.

Step 7: Determine the CBA performance

The CBA (section 2.1) performance was assessed by identifying how many of the 10 CBA determinants were addressed and to what extent they aligned with the shearing layers model (Brand, 1995). The circularity level was evaluated based on the strategies' relevance to the R-ladder model (Potting et al., 2017). In the hypothetical example, 8 of 10 determinants were covered.

FIGURE 3 ▸ A WORKSHEET SELECTING THE CBA STRATEGIES AND ASSESSING THE CBA PERFORMANCE

	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			Interrelated Determinants			Circularity Determinants				YES/ NO	S3. Skin	S4. Services	S5. Space	S6. Stuff
						Functional Convertability	Volume Scalability	Asset Refit-Ability	Configuration Flexibility	Product Demountability	Asset Multi-Usability	Design Regularity	Material Reversibility	Building Maintainability	Resource Recovery					
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 (café, 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

Adapted from Hamida et al., 2024

6. Conclusion and discussion

This paper aims to provide design and real estate professionals with an approach to coherently define promising scenarios and strategies for circular adaptive reuse. The approach links future-oriented scenarios with applicable strategies that are co-designed by designers and developers.

This paper has established a seven-step methodological approach. The first four steps are vision- and future-oriented activities, while the last three steps are practical and solution-oriented. This approach allows the alignment of project-specific scenarios with practical strategies, ensuring that decisions are grounded in future-oriented sustainability goals. The research underscores the importance of linking scenarios with strategies to align reuse goals with circular principles. Further research on consistent scenario-strategy connections would make these processes repeatable across project types, facilitating earlier decision-making. Future studies could explore how to systematically map scenario descriptors to relevant design strategies. Developing semi-quantitative tools or decision-support mechanisms may also help practitioners balance subjective judgments with more standardized criteria. Additionally, iterative testing in real-world projects would support refinement of the methodology, improving its usability and ensuring that circularity goals are not only envisioned but effectively implemented.

In the scenario development process, the descriptors and variants are crucial for deciding which circular building adaptability (CBA) strategies can be applied. Decisions in this phase directly impact which strategies are feasible. For instance, if project stakeholders prioritize a “strong” variant for the "Historic and Cultural Value" descriptor over others, preserving historical integrity becomes a central theme. This choice supports strategies like retaining monumental parts but may limit strategies such as integrating renewable energy technologies, as installing solar panels on a heritage-protected roof could compromise historical authenticity. By combining value-driven scenario development with strategic planning, practitioners can ensure that chosen strategies align with project goals, minimizing the need for costly adjustments later. A key challenge noted is that practitioners must consider legal, cultural, environmental, and technical factors to select relevant descriptors. Future research could address this subjectivity by developing semi-quantitative tools to standardize descriptor selection and balancing subjective insights.

The presented approach in this paper has two limitations associated with its use and outputs. First, it is an informing, visualizing, and guiding tool that aids design and property professionals in aligning circular vision with applicable strategies, but it does not generate a design. Second, the AI outcomes are based on the user input, and could be misaligned with the actual project situation – ‘garbage in – garbage out’.

In sum, this study provides a scenario-based approach for embedding circularity into adaptive reuse projects. Future research could refine the approach for an even more effective process that enhances both the sustainability and adaptability of our built environment.

About the authors

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FOOTNOTES

1 https://www.cross-impact.org/english/CIB_e_ScW.htm
2 https://cba-ar.com/

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