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From metrics to decisions: aligning evaluation methods with decision problems in adaptive reuse

Irina Sergeevna Shcherbakova[1], Mª Gracia López Patiño[2], Antoni López-Martínez[3]
[1]Universitat Politècnica de València, Spain, [2]Department of Architectural Constructions, Universitat Politècnica de València, Spain, [3]Department of Applied Mathematics, Universitat Politècnica de València, Spain.

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Abstract

Sustainability-oriented adaptive reuse projects are increasingly evaluated through multi-criteria and indicator-based frameworks supporting policy and planning decisions. However, these methods generate different types of analytical results often treated as interchangeable metrics. Based on a targeted review of peer-reviewed studies published between 2019 and 2024, this paper proposes a framework distinguishing five validity types: ranking, feasibility, quality-profile, operational, and explanatory validity. A comparative matrix links methods to decision questions, data requirements, and validity control mechanisms. The framework is a diagnostic tool for matching analytical methods to decision needs, not a new assessment technique. Misalignment between decision problems and evaluation methods may weaken interpretative consistency. The framework clarifies when different methods are appropriate, supporting more coherent decision-making in adaptive reuse practice.

Keywords: *Adaptive Reuse; Sustainability Assessment; Decision Support.*

1. Introduction

Adaptive reuse has become a central strategy in the management of architectural and industrial heritage, as it preserves cultural value, reduces resource consumption associated with new construction, and supports urban regeneration processes (Tu, 2020; Stone, 2023). Due to its interdisciplinary nature, adaptive reuse projects often involve conflicting objectives: conservation constraints must be reconciled with new functional requirements, economic feasibility, anticipated urban impacts, and long-term operational performance (Li et al., 2021; Della Spina, 2021; Hamida & Hassanain, 2020).

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An inappropriate method or an overextended interpretation of its output may distort decisions, even when the computational procedure is formally correct (Li et al., 2021; Nocca et al., 2024; Hamida & Hassanain, 2020). In practice, evaluation results are often used to support and communicate decisions to municipalities, experts, investors, and the public under legal and regulatory requirements, especially in sustainability-oriented governance contexts where prioritization and transparency are required (Maselli et al., 2024; Dabbene et al., 2024; Della Spina, 2021; Lami et al., 2023).

A recurring challenge is that the literature offers many methodological approaches presented as "assessment tools," although they address different decision questions and produce different results (Li et al., 2021; Stone, 2023). For practitioners, the key issue is understanding which method is appropriate at a given project stage, for a specific objective, under available data conditions, and how far the results can be interpreted. In many cases, difficulties arise not from the computational model itself, but from the construction of the evaluation framework, including criteria definition, indicator scaling, and subjective judgments (Fiore et al., 2020; Meng, Zhi, & Pang, 2023; Meng, Pang, & Zhi, 2023; Nocca et al., 2024).

The aim of this study is to systematize this methodological landscape not as a catalogue of methods, but as an applied decision-oriented framework. The paper identifies which approaches correspond to which evaluation questions, what minimal data and formalization conditions are required for valid application, and where the boundaries of interpretation lie (Li et al., 2021; Della Spina, 2021; Hamida & Hassanain, 2020). Unlike reviews focused mainly on methodological completeness, this analysis emphasizes applicability and interpretability by comparing methods according to output type, project stage, and input requirements.

Within sustainability-oriented and ESG-informed governance contexts, adaptive reuse evaluation increasingly contributes to evidence-based policy and resource allocation (Maselli et al., 2024; Dabbene et al., 2024). This reinforces the need for methodological clarity and careful interpretation of analytical outputs. In this paper, "validity" is used in an operational sense: the correspondence between the decision question and the analytical output produced by a method. It does not denote statistical validity in the classical sense, but a functional fit between purpose and result.

This makes the study relevant not only to adaptive reuse research, but also to broader discussions on research methods and analytical decision support, where data, models, and evaluation procedures are expected to inform justified decisions. Adaptive reuse is used here as a domain where the problem of aligning analytical outputs with decision needs becomes particularly visible. This paper contributes a diagnostic framework that helps researchers and practitioners match evaluation methods to decision problems by distinguishing five types of analytical validity. Rather than proposing a new assessment technique, it clarifies which approaches are

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appropriate at which project stage and under what data conditions, thereby reducing the risk of methodological misalignment in sustainability-oriented adaptive reuse assessment.

2. Materials and methods

Sources and Scope. The study is based on a targeted (purposeful) selection of peer-reviewed publications from 2019 to 2024 in which adaptive reuse evaluation methods are explicitly applied as decision-support tools and described with sufficient methodological transparency. Studies lacking explicit formalization of evaluation procedures were excluded. The reviewed studies were identified through focused database searches and selected through relevance-based screening aligned with the analytical objectives of the study. Selection prioritized studies in which the evaluation method, decision-support function, type of analytical output, and data requirements were sufficiently explicit to allow comparison across cases.

The unit of analysis was not the empirical case itself, but the evaluation logic applied in each study: the decision question, the type of output produced, the data required, and the way in which the authors controlled or limited interpretation of the results. The following categories of decision-support approaches were examined:

(1) multi-criteria methods for alternative selection or ranking, including AHP (Analytic Hierarchy Process) and TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) and their variants (Fiore et al., 2020; Haroun et al., 2019; Claver et al., 2020; Meng, Zhi, & Pang, 2023; Meng, Pang, & Zhi, 2023; Nocca et al., 2024; Ragheb, 2021; Maselli et al., 2024);

(2) hybrid frameworks linking ranking procedures to feasibility verification, including integrations with financial evaluation models such as DCF (Discounted Cash Flow) analysis (Della Spina, 2021; Lami et al., 2023);

(3) indicator-informed approaches assessing quality or anticipated impacts through structured performance metrics (Dabbene et al., 2024);

(4) ex-post evaluation based on actual building performance (Post-Occupancy Evaluation, POE) (Hamida & Hassanain, 2020);

(5) empirical studies identifying determinants of perception or evaluation outcomes through regression-based statistical modeling (Tu, 2020; Vardopoulos, 2023).

The study does not reassess case-specific results but examines which type of question each approach addresses, what minimal data conditions are required, and how validity and interpretative correctness are ensured according to the authors.

Analytical logic: "method as an instrument". The comparison is structured around the **practical analytical function** of each method rather than its mathematical formulation. Each

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approach is treated as an instrument designed to answer a specific type of decision question at a particular stage of the project lifecycle.

In accordance with the main purpose, five analytical dimensions were systematically identified: **stage of application** within the project lifecycle (from early strategic framing to ex-post evaluation); **type of validity produced** (ranking, feasibility, quality-profile, operational, or explanatory); **decision question addressed** by the method; **minimal input requirements** necessary for legitimate application; **locus of subjectivity and mechanisms of validity control** explicitly described by the authors. This structure enables comparison across heterogeneous methodological traditions while maintaining analytical consistency.

Data extraction procedure. From each study, descriptions of the applied approach were extracted and organized according to uniform categories: project stage, validity type, decision question, minimal required data and applied methods. The locus of subjectivity and validity-control mechanisms are described separately. Particular attention was given to minimal applicability thresholds — the conditions under which a method can be legitimately applied without overextending its interpretative scope (e.g., avoiding the interpretation of ranking as feasibility proof).

3. Results

The analysis resulted in a comparative typology of adaptive reuse evaluation methods structured along three practical dimensions: project stage, validity type and decision question. These characteristics are summarized in Table 1 together with minimal data requirements, method examples, and source references. The table should therefore be read not as a hierarchy of "better" or "worse" methods, but as a diagnostic map. Its purpose is to help researchers and practitioners check whether the selected analytical method corresponds to the decision problem being addressed and whether the available data are sufficient for the type of conclusion expected from the assessment.

Table 1. Validity-based mapping of adaptive reuse evaluation methods by project stage, decision question, data requirements, and reporting sources

Stage	Validity type	Decision question	Required data	Methods (examples)
Early strategic stage	Ranking validity (factor prioritization)	Which strategic factors should guide further decisions?	SWOT factors + prioritization procedure	A'WOT (Ragheb, 2021)
Ex-ante selection (criteria-based)	Ranking validity	Which alternative is preferable under defined criteria?	Alternatives; criteria hierarchy; expert weights; scaling rules	multicriteria decision tool (Fiore et al., 2020; Haroun et al.,

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Stage	Validity type	Decision question	Required data	Methods (examples)
				2019; Claver et al., 2020)
Ex-ante selection (ideal-solution logic)	Ranking validity	Which option is closest to the ideal solution?	Alternatives × criteria matrix; normalization; weights	TOPSIS (Meng, Zhi & Pang, 2023; Nocca et al., 2024)
Ex-ante (objective weighting)	Ranking validity (reduced weight subjectivity)	How to rank alternatives minimizing subjective weighting?	Quantitative comparable indicator dataset	Entropy–TOPSIS (Meng, Zhi & Pang, 2023)
Ex-ante under uncertainty	Ranking validity (uncertainty-based)	How to rank options when assessments are linguistic or vague?	Linguistic scales; fuzzy transformation rules; evaluation matrix	Fuzzy TOPSIS (Meng, Pang & Zhi, 2023)
Transition to implementation	Feasibility validity (initial verification)	Is the selected option realistically implementable under constraints?	Ranking outcome; constraints; scenario parameters	Hybrid ranking + feasibility verification (Della Spina, 2021)
Implementation / feasibility stage	Feasibility validity (market-validated)	Does the project remain viable under market and financial conditions?	Project parameters; market scenarios; DCF model	Project–market–DCF integration (Lami et al., 2023)
Impact profiling (ex-ante or ex-post)	Quality-profile validity	What is the structured performance profile across indicators?	Defined indicator set; measurement protocol; aggregation rules	Indicator-based assessment (Dabbene et al., 2024)
Post-implementation (in-use evaluation)	Operational validity	How does the reused building perform in practice?	Field inspection; user surveys; usage data	Post-Occupancy Evaluation (Hamida & Hassanain, 2020)
Ex-post explanatory research	Explanatory validity	Which factors statistically explain performance or perception?	Survey datasets; defined variables; statistical model	Statistical determinant models (Vardopoulos, 2023; Tu, 2020)

Control mechanisms vary across validity types: In **AHP-based models**, internal consistency checks (Consistency Ratio) are used to discipline expert judgments (Fiore et al., 2020; Haroun et al., 2019). In **TOPSIS-based approaches**, validity control is embedded in normalization

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procedures, weighting schemes, and, where provided, sensitivity analysis (Meng, Zhi, & Pang, 2023; Nocca et al., 2024). In **entropy-enhanced and fuzzy extensions**, control mechanisms include formalized entropy-weight calculations and fixed linguistic scale definitions that regulate transformation into fuzzy numbers (Meng, Pang, & Zhi, 2023). In **indicator-informed quality assessments**, validity depends on transparent operationalization protocols and clearly defined aggregation rules (Dabbene et al., 2024). In **Post-Occupancy Evaluation (POE)**, standardized inspection frameworks and structured survey instruments ensure empirical grounding and procedural transparency (Hamida & Hassanain, 2020). In feasibility-oriented integrations combining ranking with constraint modeling or DCF-based financial validation, control is achieved through explicit scenario construction and separation between preference ordering and implementation verification (Della Spina, 2021; Lami et al., 2023).

Each method is therefore conceptualized as producing a distinct type of validity claim:

Ranking validity — substantiating preference ordering among alternatives; **Feasibility validity** — substantiating implementability under constraints and market conditions; **Quality-profile validity** — substantiating structured impact or performance profiles; **Operational validity** — substantiating actual in-use performance; **Explanatory validity** — substantiating statistically supported relationships between variables.

Distinguishing between validity types clarifies what different adaptive reuse methods are actually designed to demonstrate. Ranking supports preference selection. Feasibility approaches test whether a project can realistically be implemented. Quality-profile methods structure expected impacts, operational evaluations assess real performance, and explanatory models reveal statistical relationships. These approaches address different decision needs and cannot substitute for one another.

For example, suppose that a municipality or project team has to compare several possible reuse scenarios for an industrial heritage building. At the early selection stage, an AHP- or TOPSIS-based procedure may help rank the alternatives according to defined criteria, expert weights, or an alternatives-by-criteria matrix. However, this ranking would only indicate preference ordering; it would not yet prove that the preferred option is financially or operationally feasible. If the selected option then moves toward implementation, the decision problem changes: constraints, scenarios, market assumptions, or DCF-based verification become necessary. After the building is reused, Post-Occupancy Evaluation may address another question again, namely how the building actually performs in use. This hypothetical sequence illustrates why the same sustainability objective may require different methods at different stages, and why the validity claim attached to each result must remain limited to the question the method is able to answer.

In sustainability-oriented settings, where adaptive reuse informs prioritization and resource allocation, this distinction matters. The proposed classification helps align evaluation methods with the questions they are meant to answer.

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4. Discussion and conclusions

These results highlight that adaptive reuse assessment becomes problematic when methods are treated as interchangeable despite producing different types of analytical results. Evidence from multi-criteria ranking studies (Fiore et al., 2020; Meng, Zhi, & Pang, 2023; Nocca et al., 2024; Ragheb, 2021) shows that such tools are appropriate for structured alternative selection but do not, by themselves, establish implementation feasibility. Hybrid approaches explicitly address this limitation by integrating financial or market verification layers (Della Spina, 2021; Lami et al., 2023). Indicator-informed and post-occupancy approaches respond to different evaluative questions related to quality, performance, and user experience (Dabbene et al., 2024; Hamida & Hassanain, 2020; Vardopoulos, 2023). Recognizing these differences is essential for maintaining interpretative consistency.

From a practical perspective, distinguishing between validity types clarifies when a method is appropriate and when it may be insufficient. This is particularly important for research and analytics contexts in which evaluation outputs are expected to inform transparent decisions. The contribution of the framework is therefore not the calculation of an additional indicator, but the clarification of the analytical status of different outputs: a ranking, a feasibility test, a quality profile, an operational evaluation, or an explanatory model. Ranking methods support structured alternative selection, feasibility requires explicit constraint or financial verification, quality-profile approaches inform impact assessment, and post-occupancy evaluation addresses actual performance. Explanatory statistical models clarify relationships but do not substitute selection-oriented procedures.

Rather than proposing a new evaluation technique, this framework aims to clarify how existing methods relate to different types of decision problems. By making these distinctions explicit, it helps reduce the risk of overextending analytical results in sustainability-oriented adaptive reuse assessment.

While previous review studies have examined adaptive reuse from different perspectives — including research frameworks and assessment methods (Li et al., 2021) and conceptual definitions of adaptive reuse (Stone, 2023) — there is still limited guidance on when and how different evaluation methods should be applied in practice. This study contributes by structuring decision-support approaches according to project stage, decision purpose, and the type of result they generate, thereby clarifying their appropriate use and interpretative limits.

This study is based on the reviewed corpus of recent publications and does not include empirical testing of the proposed framework. The illustrative scenario discussed above is therefore intended only to demonstrate how the framework may guide interpretation, not to validate it empirically. Future research could examine how the validity-based distinction performs when applied to specific case studies.

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