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Evaluating Decision Criteria for Rooftop Rainwater Harvesting Retrofits in Institutional Buildings: A Critical Integrative Review

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ABSTRACT

Selecting rooftop rainwater-harvesting retrofits for existing institutional buildings requires evidence on water performance, affordability, building constraints and operational responsibilities. However, differences in study settings, outcome definitions and assessment boundaries complicate the application of previous findings. This critical integrative review examines the criteria and evidence required to support institutional retrofit decisions. A purposive corpus of 83 full-text publications, selected from 309 Web of Science records, was mapped against 24 predefined criteria across financial, environmental, technological, structural, innovation and social dimensions. The exploratory evidence map contained 203 direct and 390 indirect construct correspondences across 1,992 publication–criterion pairs. Financial and maintenance-related criteria received broader coverage than several thermal, structural and innovation criteria. Direct correspondence nevertheless included different forms of support, ranging from criterion inclusion and design assumptions to modelled and measured outcomes. Financial recovery depended on expenditure boundaries and tariff assumptions, while long-term runoff retention and event-scale discharge control represented distinct outcomes. The review proposes a decision architecture that separates building context and mandatory eligibility requirements from stakeholder preferences and alternative-specific performance. Its contribution is to clarify how previous studies can inform criterion selection, identify overlapping measures and reveal information needed before retrofit comparison. Purposive selection, single-researcher appraisal and heterogeneous evidence limit generalisation. The proposed architecture requires evaluation through building-specific applications.

Keywords: Rooftop Rainwater Harvesting; Institutional Buildings; Multicriteria Decision Analysis (MCDA); Decision Architecture; Sustainable Facilities Management

1.0 INTRODUCTION

Rooftop rainwater harvesting offers a means of supplementing building water supplies by collecting rainfall for uses such as toilet flushing and irrigation. Its contribution depends on matching catchment yield, storage and demand within an affordable and maintainable configuration. At the University of Cape Town, water-balance modelling, ownership costs and multicriteria analysis were combined to investigate harvesting opportunities across campus catchments (Lepota & Armitage, 2025).

Such decisions concern sustainable facilities management, and institutions must consider the water services an intervention can deliver, the resources required to sustain it and its compatibility with existing buildings and organisational priorities. Galarza-Molina et al. (2015) evaluated six university-campus scenarios using hydraulic, financial and institutional-planning criteria, incorporating uncertainty through ELECTRE II and Monte Carlo analysis. Melville-Shreeve et al. (2016) compared household system configurations and demonstrated that preferred options depend on user priorities. At the urban scale, Ndeketeya and Dundu (2023) showed that excluding socioeconomic conditions can overestimate high suitability for harvesting. These studies establish that harvesting decisions extend beyond maximising collection or reducing expenditure. They also illustrate different decision objects, such as identifying promising locations, choosing system configurations and aligning investment with institutional objectives.

However, favourable water-saving estimates or suitability classifications leave important implementation questions. An intervention must fit the building, provide access for installation and maintenance, and operate within the institution's financial and managerial capacity. Melville-Shreeve et al. (2016) explicitly excluded retrofit ability, end-user acceptability and lifetime maintenance requirements from their comparative analysis. Kordana and Słyś (2020), examining broader stormwater-management alternatives, incorporated construction and operational concerns and advocated preliminary selection of technically and financially justified options. Together, these contributions indicate a need to connect performance comparisons with explicit implementation conditions rather than assuming that a preferred modelled option is ready for adoption. Hamidi et al. (2025) combined pilot-scale roof configurations, harvested-water-quality assessment and multicriteria selection, providing a close comparator for roof-related decisions. Nevertheless, findings for particular materials, slopes and intended uses require contextual assessment before application to occupied institutional buildings. Quinn et al. (2021) demonstrated that long-term volumetric retention does not adequately characterise discharge control during significant rainfall events. Consequently, including a runoff criterion, modelling tank retention and demonstrating roof-scale flood attenuation represent different forms of support. Similar distinctions are necessary between the relevance of a criterion, its relative importance and an alternative's measured or modelled performance.

The gap addressed concerns how these complementary findings can be organised into a transparent assessment of rooftop harvesting retrofits in existing institutional buildings. The selected literature already contains campus assessments, roof-selection frameworks and feasibility screening. The remaining analytical task is to clarify which evidence supports each decision, where transfer between settings is defensible and when additional information is required before comparison. This requires examining construct definitions, financial boundaries, dependencies among criteria and differences between conceptual, modelled, measured and secondary evidence. Otherwise, apparently comprehensive scoring can obscure missing performance information or reward the same consequence under several criteria.

This review aims to clarify how existing research can inform the assessment and management of rooftop rainwater-harvesting retrofits in existing institutional buildings, particularly university facilities. Its objectives are to examine the evidence supporting financial, environmental, technical, structural, innovation and social decision criteria; critically assess the meaning, limitations and transferability of that evidence; and propose a decision architecture that distinguishes eligibility requirements, stakeholder preferences and alternative-specific performance when comparing retrofit options.

2.0 RESEARCH METHODOLOGY

This study adopted a critical integrative review approach to examine how published evidence can inform rooftop rainwater-harvesting retrofit decisions in existing institutional buildings. It combined purposive literature selection, deductive criterion mapping and critical comparison of research findings and their application boundaries. The review sought analytical coverage of relevant decision problems rather than an exhaustive inventory of rainwater-harvesting research.

2.1 Corpus Selection and Review Scope

The Web of Science Core Collection was searched on 7 September 2026 using the Topic (TS) field. A focused search combining rainwater-harvesting and decision-support terms returned 309 records, exported in Full Record RIS format. A preliminary scoping search returned 1,301 records and was kept separate. No publication-year, language or document-type restrictions were recorded; individual Core Collection sub-index selections were not documented. The focused search expression was:

TS= (("rainwater harvest*" OR "rain water harvest*" OR "rainwater collect*" OR "rain water collect*" OR "rooftop rainwater" OR "roof rainwater" OR RWHS OR RRWH*) AND (multicriter* OR "multi-criter*" OR "multi criter*" OR MCDM OR MCDA OR AHP OR FAHP OR TOPSIS OR "analytic hierarchy process" OR "analytical hierarchy process" OR "fuzzy analytic hierarchy process" OR "decision support"))

Title and abstract review prioritised 83 publications: 51 addressing buildings, roofs, households, campuses or closely related decisions, and 32 providing methodological or contextual comparisons. All 83 were retrieved and retained. The remaining 226 records were not prioritised for full-text retrieval and were not classified collectively as ineligible. Supplementary Material S1 records these dispositions. Selection was purposive, without independent second screening or a documented numerical prioritisation threshold. The corpus therefore supports a critical synthesis rather than estimates of evidence prevalence across the wider literature. Figure 1 summarises the search, retrieval and mapping stages.

2.2 Deductive Criterion Mapping and Verification

The evidence was organized using a predefined dictionary of 24 criteria across six dimensions: Finance, Environment, Technology, Structure, Innovation and Society. Each dimension contained four criteria. This arrangement served as a fixed analytical structure for examining correspondence and identifying omissions; it does not establish equal dimensional importance or the completeness of the framework. “Appendix A, Table A1” presents the 24 criterion definitions; their codes and the interpretive boundaries applied in the evidence mapping.

The available records establish that the dictionary preceded this mapping exercise but do not fully establish its original development or adaptation history. Hamidi et al. (2025) provide a close published comparator, although several criterion meanings and codes differ. Appendix B, Table B1 compares the review’s criteria with Hamidi et al. (2025, Twenty-one criteria have related constructs, with differences in scope or direction. The comparison identifies conceptual similarities and differences without establishing the dictionary’s derivation.

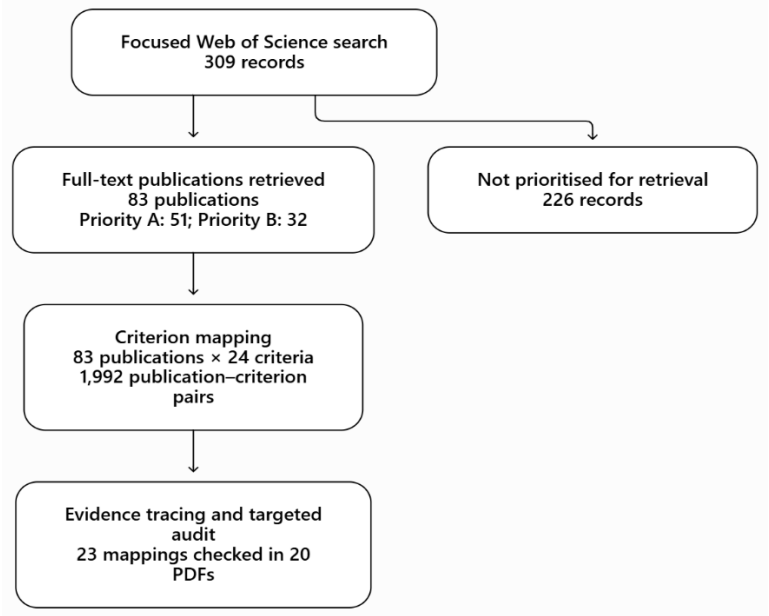


Figure 1. Workflow For Publication Retrieval, Criterion Mapping and Targeted Evidence Audit

Each publication was assessed against all 24 criteria, producing a total of 1,992 publication–criterion pairs. Direct correspondence (D) indicated an explicitly named criterion, equivalent construct, assessed variable or stated design condition. Indirect correspondence (I) indicated a partial relationship, contextual justification or related construct. A zero indicated that correspondence was not identified under the recorded rules; it did not establish that the criterion was absent from the publication or the wider literature. Each publication contributed no more than one entry per criterion.

Direct correspondence describes a relationship with the criterion definition, not methodological quality, demonstrated benefit or suitability for a particular retrofit. A named criterion, a modelled outcome, a primary measurement and a secondary report provide different forms of support. Interpretation therefore considered the physical setting, outcome definition, assessment scale and evidence mode alongside the correspondence code.

All 593 positive mappings are linked to source rationales and contextual notes in Supplementary Material S1. This review did not constitute independent recoding of all 1,992 pairs. No duplicate independent coding or inter-rater agreement assessment was performed. A targeted audit examined 23 previously direct mappings across four criteria: E. coli Content, Runoff Reduction, Urban Heat Island Mitigation and new materials. One entry, W170–EN2, changed from direct to indirect because an economic waterlogging-loss proxy did not establish the specified runoff outcome. The reconciled matrix contains 203 direct, 390 indirect and 1,399 zero entries. Other classifications retain their recorded status, including flagged uncertainties concerning the equivalence of runoff measures. Accordingly, the matrix is treated as an exploratory evidence map rather than a fully revalidated classification.

2.3 Critical Appraisal and Synthesis

The synthesis compared the decision addressed, physical and institutional setting, methods, outcome definitions, findings and transfer limitations of each publication. Narrative appraisal considered whether support arose from conceptual discussion, modelling, primary measurement or secondary reporting; the validation boundaries described in the publication; and the correspondence

between its setting and an occupied-building retrofit. These considerations informed interpretation rather than a numerical quality score. Conceptual frameworks informed criterion relevance and decision structure. Modelled findings were interpreted within their rainfall, demand, cost and operational assumptions. Measurements were considered within their sampling conditions, physical scale and intended use. Secondary publications provided synthesis rather than additional independent observations.

2.4 Development of the Decision Architecture

The critical synthesis informed a proposed decision architecture for institutional rooftop rainwater-harvesting retrofits. Evidence was organised according to five decision roles: context specification, eligibility screening, stakeholder preferences, alternative-specific performance assessment and comparison of feasible alternatives. Mandatory structural, safety, regulatory and intended-use water-quality requirements were distinguished from benefits that could be compared through preference-based scoring. Relationships among financial and operational criteria were examined to identify potential double counting. Information outside the predefined framework, including water-supply reliability, demand and operational energy, informed the requirements for future applications. The architecture represents a synthesis-based proposal; its practical usefulness requires evaluation through building-specific retrofit decisions.

3.0 LITERATURE REVIEW

This section critically reviews research relevant to rooftop rainwater-harvesting retrofits in existing institutional buildings. It examines spatial suitability assessments, system-performance modelling, campus planning and experimental roof-selection studies. The synthesis evaluates what each approach contributes, the limitations affecting transferability and the research gaps that inform the proposed decision architecture.

3.1 Spatial Suitability and Implementation Potential

Geographical information system (GIS) applications of multicriteria analysis identify locations where rainwater-harvesting interventions may be suitable. Toosi et al. (2020) combined physical and socioeconomic information in a catchment-scale assessment, while Ahmad et al. (2024) compared the analytic hierarchy process (AHP) and fuzzy analytic hierarchy process (FAHP) using biophysical spatial layers. These approaches organise heterogeneous information to identify promising locations. However, their terrain, soil, drainage and rainfall indicators address geographical suitability rather than the constructability of interventions on occupied buildings. Adham et al. (2016b) reviewed methods for identifying suitable harvesting locations, while Martínez-Acosta et al. (2019) synthesised agricultural design parameters covering climate, soils, terrain and socioeconomic conditions.

Ahmed et al. (2023) examined 68 site-selection studies and found that 59% of the frameworks relied exclusively on biophysical criteria. Their review identified ecological assessment and stakeholder involvement as areas requiring greater attention. These contributions support broader assessment, but their predominantly catchment and agricultural contexts limit their direct application to roof-specific performance indicators or institutional preferences.

Spatial resolution also differs from the level of detail required for building assessment. Mahmoud and Tang (2015) mapped UK harvesting suitability using soil, land-cover, terrain and

climatic information. Fariz-Salinas et al. (2025) compared 500 × 500 m cells using catchment and social water-use criteria, whereas Mummidivarapu et al. (2026) harmonised urban geospatial layers to a 10 m grid. Nevertheless, finer mapping does not independently establish building-level accuracy. Suitability for ground infiltration and suitability for rooftop collection also concern different physical processes.

Farooq et al. (2022) compared runoff models using flow estimates transferred from a neighbouring gauged catchment. Abebe and Kassa (2025) combined calibrated and validated hydrological modelling with GIS-based FAHP, field surveys and spatial comparison against existing harvesting sites. Yousuf et al. (2026) validated suitability maps against existing harvesting structures using receiver operating characteristic analysis. These procedures provide evidence concerning hydrological simulation or spatial suitability. They do not independently establish structural adequacy, installation feasibility or operational performance for an occupied-building retrofit.

Socioeconomic conditions can substantially alter modelled suitability. In Johannesburg, Ndeketeya and Dundu (2023) found that excluding socioeconomic criteria overestimated the area classified as highly suitable for rainwater harvesting. This finding demonstrates how the choice of criteria affects spatial priorities. However, suitability classifications do not establish observed adoption rates or the causal effects of individual barriers. For institutional applications, financial capacity, management responsibilities and user requirements therefore need assessment alongside physical harvesting potential.

Demand assessment connects harvesting potential with water-service requirements. Shadeed et al. (2019) combined water-poverty and harvesting-suitability maps to identify priority areas for applications. Akter and Ahmed (2021) examined rooftop potential in relation to demand and urban development. Chiu et al. (2020) integrated daily water-balance simulation, life-cycle economic assessment and multicriteria comparison of harvesting, greywater reuse and water-saving devices. Their geographically varying rankings demonstrate that physical potential must be interpreted alongside demand and economic conditions. Consequently, a favourable location does not necessarily provide adequate demand coverage or an economically preferable intervention.

Spatial screening identifies where further investigation is worthwhile. Building-specific assessment must then establish roof condition, structural capacity, drainage connections, installation and maintenance access, and operational responsibility. The managerial value of spatial analysis therefore lies in directing investigation and resources, while retrofit feasibility depends on evidence from the building, the institution and its users.

3.2 System Performance and Campus Planning

System-level assessments examine how harvesting configurations perform under specified rainfall, demand, storage and financial conditions. Melville-Shreeve et al. (2016) compared 13 household configurations using capital cost, water saving, operational energy and stormwater-discharge criteria. Preferred configurations changed with illustrative user priorities, demonstrating that selection depends on the objectives represented in the assessment. These scenarios did not establish population-level agreement about preferences. Retrofit ability, end-user acceptability and lifetime maintenance requirements were also outside the performed evaluation, leaving important implementation questions for subsequent building-specific assessment.

Luo et al. (2026) modelled residential harvesting systems across three Chinese climate zones and found that rainfall and water-use scenarios affected efficiency and reliability differently. Increasing tank capacity could improve collection where sufficient rainfall was available, but could not overcome supply limitations in every setting. Fonseca et al. (2017) similarly developed a sizing tool linking rainfall patterns, catchment characteristics and demand. These studies support context-specific sizing rather than transferring a preferred storage capacity between buildings or climatic regions.

Reliability also depends on the rainfall conditions and demand assumptions used in modelling. Karim et al. (2015) evaluated household tanks in coastal Bangladesh under dry, average and wet conditions. Under the assessed average and dry conditions, increasing catchment area and tank capacity produced limited reliability improvements, with maximum achievable reliability of approximately 70%. This finding illustrates why annual rainfall totals and storage volume alone cannot establish dependable supply. Campus applications therefore require rainfall sequences, occupancy patterns and intended-use demands appropriate to the institution, together with sensitivity analysis of consequential assumptions.

Campus research already integrates performance assessment with institutional planning. Galarza-Molina et al. (2015) developed CRIDE to compare six university harvesting scenarios through hydraulic, financial and institutional-planning criteria. ELECTRE II supported comparison, while Monte Carlo analysis examined uncertainty in assessment inputs. Lepota and Armitage (2025) combined water-balance modelling, ownership costs and alternative weighting scenarios at the University of Cape Town. These contributions establish precedents for institutional decision support. Their findings nevertheless depend on the catchments, system boundaries, financial assumptions and alternatives examined; they do not supply universally applicable retrofit rankings.

Multiobjective modelling provides a further precedent. Rozos et al. (2010) assessed local water-recycling schemes through trade-offs among water-demand reduction, costs and energy under different climatic conditions. Existing research therefore extends beyond single-objective tank optimisation. For institutional retrofits, the remaining task is to connect modelled consequences and financial assessments with building constraints, stakeholder priorities and operational responsibilities. Performance modelling, preference elicitation and eligibility screening provide complementary inputs to that decision. The scope of validation also affects interpretation. Palermo et al. (2020) applied rough-set analysis and TOPSIS to published harvesting cases, generating decision rules and comparative rankings. Such methods structure available information, but their transferability depends on the cases and attributes represented.

Willuweit and O'Sullivan (2013) demonstrated the Dynamic Urban Water Simulation Model's ability to predict water demand and stormwater runoff; this does not independently validate every potential cost, energy or reuse application. Shrestha et al. (2023) reviewed performance evaluation in arid and semi-arid regions, further highlighting the importance of clearly defined assessment measures. For campus planning, model validation and ranking stability must therefore be interpreted in relation to the particular outcomes tested.

3.3 Roof Experiments and Multicriteria Rankings

Hamidi et al. (2025) provide a close roof-selection comparator within the reviewed corpus. They investigated nine pilot configurations combining three roofing materials and three slopes, linking harvested-water-quality experiments with FAHP weighting and the technique for order preference by similarity to ideal solution (TOPSIS). However, alternative scores combined experimental measurements with literature, expert and industry information.

The resulting hierarchy therefore incorporated several forms of evidence rather than experimentally measuring every criterion. Its relevance lies in connecting roof characteristics and water-quality observations with broader selection considerations. The experiment used 2 × 2 m pilot roofs, with sampling covering one rainfall event of approximately six hours and an intended agricultural-irrigation application. These conditions constrain extrapolation to larger roof assemblies, different exposure conditions and other water use. A configuration preferred in that assessment cannot be assumed to be suitable for an occupied university building.

4.0 RESULTS: THEMATIC ANALYSIS

This section presents the findings of the deductive evidence mapping and critical synthesis across six predefined decision dimensions. The matrix contains 203 direct, 390 indirect and 1,399 not-identified correspondences. Table 1 reports criterion-level coverage, and Supplementary Material S1 links every positive mapping to its source. Initial Investment Cost has the largest direct count. Urban Heat Island Mitigation, Wind Resistance and New Materials each have one direct source, Hamidi et al. (2025).

Other codes retain their original construct-correspondence interpretation. They do not imply equal evidence quality or measured performance in occupied-building retrofits. Appendix D (Table D1) presents the publication-level matrix. Every criterion has at least one direct correspondence, but naming a criterion, assuming its adequacy and measuring its consequences represent different evidence. The register distinguishes conceptual justification from transferable performance scores.

Table 1. Publication-level coverage of the predefined rooftop rainwater-harvesting retrofit criteria

Dimension	Code and criterion	Direct	Indirect
Finance	FN1 Operational Cost	24	16
Finance	FN2 Initial Investment Cost	36	17
Finance	FN3 Payback Period	8	8
Finance	FN4 Financial Incentives and Subsidies	9	14
Environment	EN1 E. coli Content	3	46
Environment	EN2 Runoff Reduction	17	38
Environment	EN3 Urban Heat Island Mitigation	1	8
Environment	EN4 Turbidity	5	42
Technology	TC1 Construction Difficulty	8	23
Technology	TC2 Maintenance Convenience	13	36
Technology	TC3 Thermal Insulation Performance	2	3
Technology	TC4 Material Durability	2	9
Structure	ST1 Structural Load	3	3
Structure	ST2 Fire Safety Performance	2	2
Structure	ST3 Wind Resistance	1	1
Structure	ST4 Failure Risk	2	18
Innovation	IN1 New Materials	1	7
Innovation	IN2 Energy-Saving Technology	8	7
Innovation	IN3 Modular Construction	3	1
Innovation	IN4 Digitization	7	14
Society	SO1 Policy and Institutional Support	14	20
Society	SO2 Aesthetic Value	2	13
Society	SO3 Regulatory Compliance	17	15
Society	SO4 Stakeholder/User Acceptance	15	29

Note: D = direct construct correspondence; I = indirect or partial correspondence. Counts represent publications, not criterion importance or demonstrated performance. Of the 1,992 publication–criterion pairs, 203 show direct correspondence, 390 indirect correspondence and 1,399 no identified correspondence. The publication-level matrix appears in Appendix D (Table D1).

4.1 Finance

The financial dimension comprises Operational Cost (FN1), Initial Investment Cost (FN2), Payback Period (FN3), and Financial Incentives and Subsidies (FN4). The evidence matrix records 24, 36, 8 and 9 direct correspondences, respectively. Initial investment therefore has the broadest direct coverage within this dimension. These frequencies describe correspondence within the selected publications rather than financial importance or demonstrated investment performance.

Financial recovery estimates depend on the costs and assumptions included. Imteaz et al. (2011) estimated payback periods of approximately 15–21 years for two large-roof harvesting systems under the assessed tank, climatic and future water-price conditions. Additional maintenance expenditure was not separately quantified because it was expected to be minimal relative to existing irrigation maintenance. The estimates consequently represent projected recovery under specified assumptions rather than observed repayment or a comprehensive assessment of all recurring expenditure. Hargreaves et al. (2019) further showed how built form and roof area per person affect water savings and financial viability, demonstrating that common tariffs alone do not produce comparable outcomes across building configurations. The allocation of expenditure also changes the meaning of financial feasibility. Saha et al. (2024) excluded initial installation investment because the assessed community systems had been donated. Their economic analysis therefore addressed the operation of supported systems rather than recovery of their full installation costs.

Souza et al. (2025) evaluated integrated greywater-treatment and rainwater-harvesting systems and found that two of four proposed scenarios did not achieve positive net present values within the 15-year assessment period, despite broader sustainability benefits. One Brazilian scenario also incorporated a property-tax incentive, illustrating how financial assistance enters project-specific outcomes. Because the systems combined treatment and harvesting functions, their overall benefits cannot be attributed to rainwater harvesting alone.

Economic and service objectives can favour different storage choices. Sampaio and Alves (2017) developed preliminary sizing diagrams that permitted smaller tanks by treating rainwater harvesting as a complementary supply and accepting lower reliability. Their findings illustrate a trade-off between storage expenditure and demand coverage rather than a universally preferable tank size. Dias et al. (2024) estimated potential water-bill savings at industrial sites but excluded capital and operational expenditure from those savings calculations. The reported savings therefore do not establish net financial returns or investment recovery.

Long-term projections introduce additional assumptions. Wurthmann (2020) estimated county-scale installation costs and water and energy savings using specified financing and replacement arrangements. Such projections support planning, but their transfer to institutional retrofits depends on compatible installation conditions and cost boundaries. Rahman (2017) likewise discussed economic assessment alongside wider benefits and life-cycle considerations; this overview provides secondary synthesis rather than additional independent performance evidence. Across the financial evidence, water-bill savings, operational affordability, investment recovery and broader sustainability value represent distinct outcomes. Their interpretation depends on the payer, baseline, assessment period, expenditure boundary and treatment of financial support. Payback also draws on investment costs and subsequent net savings, creating potential overlap when these measures are scored together.

4.2 Environment

Environment comprises E. coli Content (EN1), Runoff Reduction (EN2), Urban Heat Island Mitigation (EN3) and Turbidity (EN4). Direct correspondences numbered three, 17, one and five, respectively. These broad construct counts establish neither the number of material experiments nor wider disciplinary maturity. Quinn et al. (2021) used projected 30-year Sheffield rainfall disaggregated to five-minute intervals. Long-term supply and retention differed from significant-event retention and discharge control. The sample concerned approximately annual events, not every flood return period. Annual retention obscured event performance and controlled versus uncontrolled releases. No configuration dominated all objectives; active releases sometimes exceeded unmodified roof runoff. EN2 therefore requires explicit temporal metrics, boundaries and control assumptions.

Storage, demand and controlled release can reduce downstream discharge without demonstrating a roof-material effect. Roughness and friction coefficients likewise do not directly measure event-volume reduction or peak attenuation. Material scores require roof-scale evidence; system scores must specify storage and control assumptions. Urban runoff studies show how downstream routing changes harvesting benefits. Hamadan simulations distinguished household use followed by return to drainage from garden irrigation. Relative runoff benefits also declined for larger storms (Meshram et al., 2021). The Chittagong assessment combined runoff modelling with spatial screening, assuming that all roofs could collect water and sufficient storage was available (Akter & Ahmed, 2015). These assumptions make end use, drainage connections and storage availability necessary assessment conditions. Neither study measures flow retardation caused by roofing materials.

Related Toledo analyses found building-to-catchment linear extrapolation inadequate for treatment flows and environmental impacts (Tavakol-Davani et al., 2018a). Toilet-flushing and detention comparisons exposed trade-offs among overflow control, treatment and life-cycle burdens (Tavakol-Davani et al., 2018b). Shared authors, modelling and setting preclude treating these as independent replications. Modelled horizons and replacements establish neither measured roof durability nor transferable material scores. Hamidi et al. (2025) included heat-island mitigation without measuring city-scale cooling or validating reflectance as its outcome. Low-carbon building research supports considering thermal behavior (Bai et al., 2021), but reflectance, surface temperature, assembly heat transfer and urban air temperature differ in mechanism and scale. Roof proxies cannot be reported as measured urban heat-island reduction.

4.3 Technology

The technological dimension comprises Construction Difficulty (TC1), Maintenance Convenience (TC2), Thermal Insulation Performance (TC3), and Material Durability (TC4). The evidence matrix records 8, 13, 2 and 2 direct correspondences, respectively. Construction and maintenance therefore receive broader direct coverage than thermal performance and durability within the selected corpus. These criteria address different properties: installation effort, practical inspection and repair, heat transfer through the roof assembly, and functional service life.

Building-related stormwater assessments distinguish construction requirements, maintenance activities and their financial consequences. Hämmerling et al. (2020) and Kordana and Słyś (2020) considered implementation and operational attributes within multicriteria assessments. Their contributions complement configuration studies that evaluate water and energy outcomes while excluding retrofit ability and lifetime maintenance requirements (Melville-Shreeve et al., 2016). For institutional retrofits, these distinctions expose information requirements concerning installation access, drainage routing,

component replacement and continuity of building use. These are building-specific implications of the synthesis rather than measured outcomes from the reviewed household assessments.

Operational assumptions limit what system simulations establish about maintenance. Bouziotas et al. (2019) excluded maintenance frequency, downtime, accidents and other operational variations from their neighbourhood assessment. The authors consequently interpreted the modelled efficiency and autonomy as idealised upper limits. Van de Walle et al. (2022) likewise omitted maintenance from their core closed-water-cycle modelling. Such analyses estimate performance within specified operating assumptions; they do not demonstrate the practical ease or continuity of maintenance after installation. Haider et al. (2019) identified existing-building and retrofit constraints within an urban flood-management assessment, providing additional evidence that technical suitability depends on implementation conditions.

Residential risk assessments provide complementary information about operational tasks. Kaposztasova et al. (2014) and Vranayová et al. (2015) examined risks involving contamination, filters, tanks, pumps and patterns of use, using likelihood–consequence assessment and inspection guidance. These related Slovak applications help identify activities and responsibilities associated with system operation. However, identifying a maintenance task or assigning a risk score does not directly measure accessibility, repair effort or maintenance convenience. Their residential context also limits direct transfer to university facilities. The two direct thermal-performance correspondences arise from different assessment frameworks. Hamidi et al. (2025) included insulation capacity in roof selection, while Bai et al. (2021) incorporated thermal-insulation roofing within a low-carbon community indicator system. These entries establish explicit consideration of the construct, rather than two independent experimental demonstrations of harvesting-retrofit thermal gains. Their interpretation also requires distinguishing material properties from the behaviour of the complete roof assembly.

The two direct durability correspondences similarly concern criterion relevance rather than measured roof service life. Sikder and Salehin (2014) recommended durable water-supply components to reduce recurring repair and replacement, while Song et al. (2022) included durable, weather-resistant and corrosion-resistant materials within green-building disaster assessment. These contributions support attention to durability but do not provide transferable service-life estimates or comparative rankings for harvesting-retrofit roof materials. Recyclability concerns end-of-life recovery and remains distinct from resistance to deterioration during use. Overall, the technological evidence is stronger in identifying construction and operational considerations than in demonstrating roof-specific thermal or durability outcomes.

4.4 Structure

The structural dimension comprises Structural Load (ST1), Fire Safety Performance (ST2), Wind Resistance (ST3), and Failure Risk (ST4). The evidence matrix records 3, 2, 1 and 2 direct correspondences, respectively. These counts include explicit criteria and design conditions; they do not represent equivalent numbers of structural tests or verified retrofit applications. Structural capacity sometimes appears as an assumed condition rather than an assessed outcome. Melville-Shreeve et al. (2016) specified that the modelled household could accommodate header tanks and associated storage. This assumption enabled configuration comparison but did not demonstrate the adequacy of an existing building. Kordana and Słyś (2020) similarly restricted comparison to technically and financially justified alternatives, providing a precedent for feasibility screening.

Hamidi et al. (2025) included structural load, failure risk, fire risk and wind resistance within their roof-selection hierarchy. The publication supplies the only direct correspondence for Wind Resistance in the selected corpus. However, inclusion within a multicriteria hierarchy differs from experimental verification of roof-assembly resistance under specified wind conditions. Song et al. (2022) provide complementary evidence through a green-building disaster-assessment framework that includes fire-protection design and material considerations. Its broader building indicators do not establish comparative fire or wind performance for rainwater-harvesting retrofits.

Resilience terminology also requires contextual interpretation. In the Bangladesh water-supply assessment, cyclone resistance concerned the continued availability of water when other sources were affected by saline inundation (Sikder & Salehin, 2014). This supports consideration of water-service resilience rather than roof resistance to wind loading. Treating these outcomes as interchangeable would transfer evidence between different physical mechanisms. Failure Risk presents a similar boundary problem. The review's ST4 definition concerns leakage or material failure, whereas other publications address water shortage, treatment inadequacy, equipment malfunction or distribution-system integrity.

Liu et al. (2020) assessed risks across water availability, treatment, distribution and storage in small drinking-water systems. Their framework informs overall system-risk assessment but does not independently establish roof-specific failure probabilities. Kee et al. (2022) incorporated water-leakage detection into a smart-home prototype, providing a further connection to physical system integrity. Detection capability, however, does not establish the probability of roof-material failure. Overall, the structural evidence combines assumed capacities, criterion hierarchies, broader building assessments and system-risk applications. Its contribution is principally to identify constraints and clarify relevant failure mechanisms.

4.5 Innovation

The innovation dimension comprises New Materials (IN1), Energy-Saving Technology (IN2), Modular Construction (IN3) and Digitization (IN4). The evidence matrix records 1, 8, 3 and 7 direct correspondences, respectively. Energy integration and digitization therefore receive broader direct coverage than modular construction and new materials within the selected corpus. However, the sources range from conceptual frameworks and design models to implemented prototypes, representing different levels of evidence about practical application. Integrated infrastructure provides one context for innovation. D. Saha and Bhattacharya (2020) proposed a multicriteria framework combining rooftop photovoltaics, rainwater harvesting and electric-vehicle charging. The framework identifies potential relationships involving shared space, infrastructure and costs.

Its alternatives and assessment criteria provide conceptual support for examining integration, but do not demonstrate that a combined system is technically or financially preferable at a particular institution. The anticipated advantages remain conditional on the configuration and application context. Prototype research provides a different form of support. Kee et al. (2022) constructed the UTS smart home using modular containers and integrated photovoltaic generation, rainwater harvesting, sensors and digital water-management functions.

This application demonstrates the incorporation of these technologies within an experimental building. Nevertheless, building-level modularity does not independently establish faster retrofit installation, easier component replacement or long-term operational benefits in existing university facilities.

Bianco et al. (2026) developed a building-scale digital twin combining building information modelling, water-system simulation, forecasting and mixed-reality visualisation. The study supports scenario exploration and reliability assessment, while sensor integration remains a development direction. Its modelled outcomes therefore do not establish field-validated improvements in maintenance response. Similarly, researchers' use of software or fuzzy inference does not itself demonstrate digitization of construction or maintenance activities. Residential evaluations illustrate the importance of distinguishing proposed designs from realised benefits. Hsueh et al. (2021, 2022) combined expert judgements and fuzzy modelling to assess low-carbon residential designs involving energy and rainwater technologies. Hsueh et al. (2021) compared an existing residence with a simulated proposed design rather than two completed operational installations. Bouramdane (2023) likewise ranked smart-city water-management strategies using study-specific judgements informed by literature. These assessments help structure comparisons, but their scores do not constitute measurements of achieved savings, adoption or maintenance performance. Overall, the innovation evidence identifies opportunities for combining technologies, modular building approaches and digital support. Its principal limitation is the uneven connection between proposed functions and demonstrated operational outcomes.

4.6 Society

Society distinguishes non-financial Policy and Institutional Support (SO1), Aesthetic Value (SO2), Regulatory Compliance (SO3) and Stakeholder/User Acceptance (SO4). Financial assistance remains FN4. Management commitment, user preferences and formal admissibility are separate constructs. Social multicriteria analysis in Barcelona found that expressed support for harvesting did not necessarily correspond to the alternatives receiving institutional attention (Domènech et al., 2013). Participatory research in Bangladesh identified maintenance responsibilities, access and caretaker arrangements alongside preferences for water-supply options (Sikder & Salehin, 2014, 2015). The Bangladesh publications appear to share study populations and should not count as independent replications. They show that preferences concern both technologies and the arrangements needed to sustain them.

Portman et al. (2022) found that questionnaire respondents placed health concerns above cost and convenience under hypothetical savings scenarios. Financial attractiveness alone therefore cannot be assumed to determine acceptance. However, convenience sampling and hypothetical scenarios limit conclusions about actual adoption or a universal health-first ranking. University facilities professionals, institutional decision-makers and building users may hold different preferences. Demand-management research distinguishes stated priorities from realized savings. A Sri Lankan household study combined survey-based water-use modelling with a separate AHP comparison of conservation measures (Edirisinghe & Pathirana, 2021). Rainwater use received the highest preference weight among three measures, but this did not measure savings after installation. Awareness also did not consistently predict conservation. For institutional retrofits, preferences, estimated demand and monitored performance require separate interpretation. Household priorities can inform enquiry, but cannot supply campus demand profiles or demonstrate adoption.

Interpreting social priorities requires knowing who participated. Tanzanian research documented local harvesting knowledge that varied across agricultural settings (Mbilinyi et al., 2005). A Turkish blue–green infrastructure prioritization excluded local users and visitors, limiting whose preferences were represented (Demir et al., 2025). A small-island assessment emphasized awareness and capacity building, while using criterion-specific scores and overall alternative weights for different analytical purposes (Chadee et al., 2024).

Awareness scores cannot be interpreted as measured water savings. Transferring social priorities requires an account of participants, decision roles and the meaning of each score. Aesthetics receives less coverage than compliance or acceptance. Stormwater-system assessments nevertheless consider visual and locational consequences for the surrounding built environment (Kordana & Słyś, 2020). On an existing campus, visible tanks, pipework and roof alterations may affect acceptance, which requires site-specific assessment. Institutional capacity, user responses and formal requirements should therefore be assessed separately, with explicit limits on what expert judgement can represent. Figure 2 shows the six dimensions and 24 criteria used to organize the synthesis of construct correspondence, performance evidence and contextual transferability. Connections indicate analytical relationships.

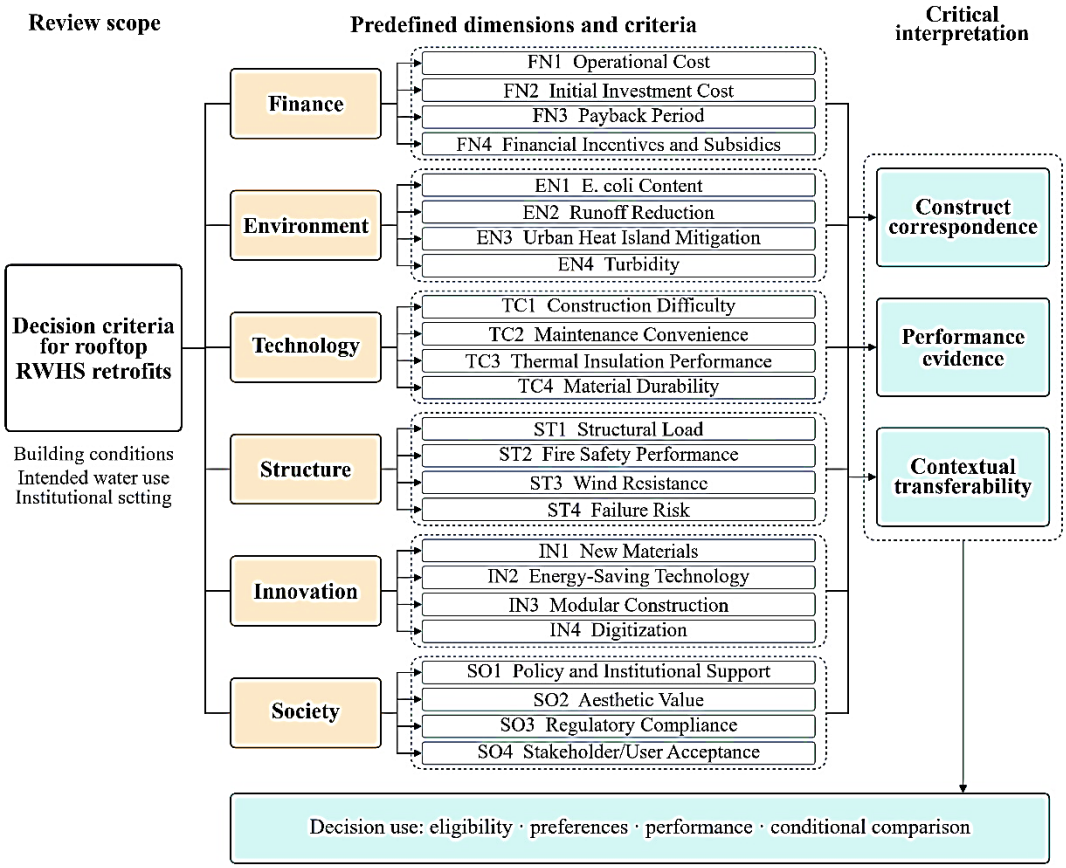


Figure 2. Predefined criterion framework for rooftop rainwater-harvesting retrofits

Appendix C and Table C1 summarizes how selected studies inform retrofit decisions and the conditions limiting transfer of their findings.

5.0 DISCUSSION AND PROPOSED DECISION ARCHITECTURE

The coverage patterns reported in Section 4 require interpretation according to the type and context of the supporting evidence. Direct correspondence establishes a relationship with a criterion definition, but does not necessarily demonstrate measured performance or suitability for an institutional retrofit. The central issue is therefore what each source establishes and whether that evidence can inform the decision under consideration. Previous studies should be considered when determining which criteria are relevant to institutional rooftop rainwater-harvesting retrofits. Their contribution depends on what they assessed, how the evidence was obtained and whether their findings apply to the building under consideration.

Experimental studies may provide measured performance data, modelling studies may estimate outcomes under stated assumptions, and conceptual or review studies may explain why a criterion deserves consideration. Each source therefore requires assessment before its findings are used to assign performance scores to retrofit alternatives.

The evidence map identifies criteria supported by previous studies and those requiring further building-specific investigation. Limited support does not justify excluding a criterion that is important for safety or feasibility. Similarly, support from numerous publications does not automatically justify a higher weight. Criterion weights should reflect institutional objectives and stakeholder preferences, while alternative-specific scores should be based on relevant measurements, justified models or other suitable technical evidence.

5.1 Retrofit Comparison

Retrofit alternatives are compared for the same building and intended water uses, using consistent rainfall, demand, cost and assessment-period assumptions. Each alternative is first checked against applicable structural, fire, wind, regulatory and water-quality requirements. Alternatives that fail these requirements require redesign or exclusion. Where evidence is insufficient, further assessment is required before comparison (Kordana & Słyś, 2020). Eligible alternatives are then compared using defined criteria, such as investment cost, recurring expenditure and maintenance convenience. Stakeholder judgements establish the importance of each criterion, while cost records, measurements, relevant previous studies and justified models provide alternative-specific performance scores (Shah et al., 2024; dos Santos Amorim et al., 2020). Requirements used solely to establish eligibility are excluded from weighted scoring, and the remaining weights are reassessed.

Rooftop storage may occupy less ground space but require additional structural assessment, whereas ground-level storage may improve maintenance access but require available land and additional pipework. These trade-offs require building-specific evidence. Overlapping financial measures also need attention: investment and recurring costs may be scored, with payback reported separately to avoid counting the same financial consequences twice. Table 2 summarises the assessment inputs, and Figure 3 presents the comparison process. The proposed procedure requires evaluation through building-specific applications.

Table 2. Information Roles in the Proposed Retrofit Decision Architecture

Decision role	Required information	Interpretation
Context specification	Building, baseline, intervention boundary, rainfall, demand, roof condition, space and intended uses	Establishes comparable assessment conditions and modelling inputs.
Eligibility screening	Evidence against applicable structural, fire, wind, regulatory and intended-use water-quality requirements	Determines admissibility. Missing evidence prompts further investigation or design revision.
Preference assessment	Judgements from relevant decision-makers, facilities personnel and users, using clearly defined criteria	Establishes contextual priorities rather than physical performance.
Performance assessment	Alternative-specific costs, measurements, modelled outcomes and justified technical information	Establishes consequences, assumptions and uncertainty on defined scales.
Comparison and evaluation	Eligible alternatives, non-redundant criteria, justified aggregation and sensitivity analysis	Supports conditional comparison; practical usefulness requires subsequent evaluation.

A hypothetical illustration shows the consequence of separating these roles. Consider two alternatives for supplying toilet-flushing water: rooftop storage and ground-level storage with treatment.

The rooftop option has lower estimated cost, but its additional loading has not been assessed. The ground-level option has an acceptable location, but evidence that its treatment meets the intended-use requirements is unavailable. The procedure withholds a ranking and requests the missing structural and water-quality evidence. Neither uncertainty is converted into a favourable score. If both alternatives subsequently satisfy eligibility requirements, they can be compared using defined costs, service outcomes and maintenance attributes. To avoid rewarding the same financial consequence repeatedly, one illustrative assessment could score initial and recurring expenditure while reporting payback separately as supporting information. This example demonstrates the proposed decision logic; it does not constitute empirical validation.

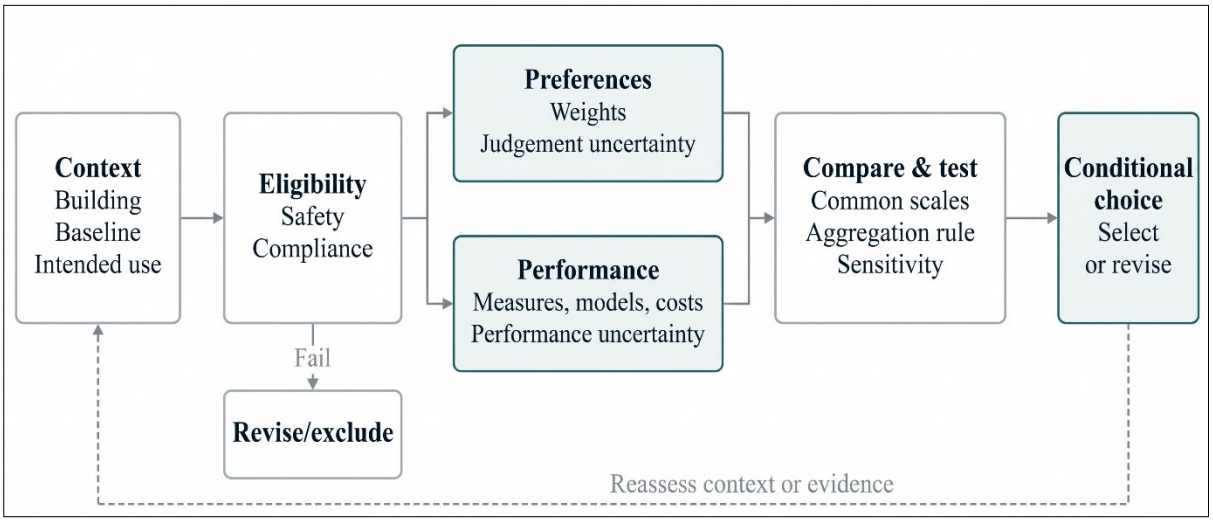


Figure 3. Proposed decision architecture for institutional rooftop rainwater-harvesting retrofits

5.2 Discussion

Capital expenditure, recurring expenditure and payback address distinct financial questions, but payback is calculated from investment and subsequent net savings. Including all three in a weighted assessment may therefore give financial consequences disproportionate influence. Galarza-Molina et al. (2015) examined redundancy within the CRIDE campus assessment, demonstrating the importance of checking whether criteria contribute distinct information. Similar relationships arise between maintenance convenience and operating cost, and between material durability and failure risk.

These criteria are not necessarily redundant: convenient access describes the practical effort of maintenance, whereas operating cost expresses expenditure. Their definitions and performance measures should distinguish these consequences and identify where the same benefit is counted repeatedly. Chi et al. (2021) developed an aggregation method that explicitly accounts for relationships among indicators in sponge-city selection. This provides a methodological example of handling interaction, but does not establish that a complex aggregation method is preferable for institutional retrofits. The appropriate approach depends on the relationships supported by the evidence. Clear definitions, removal of redundant measures and sensitivity analysis should precede the adoption of more complex methods.

The 24 predefined criteria do not capture every input or outcome required for a complete retrofit assessment. Previous studies identify rainfall variability, demand patterns, water-supply reliability and operational energy as important considerations (Liu et al., 2020; Rozos et al., 2010; Vargas et al., 2019). These should retain their specific meanings.

Energy-Saving Technology concerns technological integration, whereas operational energy measures consumption. Similarly, Failure Risk concerns leakage or material damage rather than all causes of water-supply interruption. System boundaries also affect interpretation. Behzadian and Kapelan (2015) examined how the inclusion of different urban-water-system components and sustainability indicators affected strategic assessment.

Duong et al. (2011) and Farooqui et al. (2016) connected water-management options with energy consequences at different implementation scales. Chhipi-Shrestha et al. (2018) further showed that achieving water self-sufficiency does not necessarily ensure lower costs or energy consumption. Water savings, energy use and financial outcomes therefore require separate assessment under consistent system boundaries. For building-specific applications, rainfall and demand should inform performance models, while supply reliability and energy consumption should be reported as defined outcomes. Where these outcomes influence selection, they may become additional comparison criteria with justified definitions and measures. Such extensions should be documented separately from the fixed framework used in this review. Any revised criteria or reused weights must remain consistent with the definitions on which the original assessments were based.

6.0 IMPLICATIONS FOR RETROFIT DECISIONS

The comparison method should reflect the decision objectives, available evidence and information needs of the institution. Sikder and Salehin (2015) obtained the same two leading alternatives using weighted summation, AHP and NAIADE, although lower rankings differed. Conversely, Nnaji and Banigo (2018) obtained different preferred water sources using AHP and TOPSIS. These findings indicate that methodological complexity does not necessarily change the preferred alternative, while differences between methods require examination of their assumptions and inputs.

Fuzzy methods also require a clear justification. Ahmad et al. (2024) compared spatial classifications produced by AHP and FAHP, while Onu et al. (2017) applied fuzzy TOPSIS to water-source selection. Such applications demonstrate approaches to handling judgement and comparison; they do not establish that fuzzy methods consistently produce more accurate decisions. Han et al. (2025), for example, used hypothetical data to demonstrate TOPSIS and fuzzy TOPSIS. Its rankings illustrate the calculation rather than observed technological performance. AHP or FAHP may structure preferences after criterion definitions and decision roles have been established (Buckley, 1985; Saaty, 2008). Reporting should specify the judgement scale, aggregation of individual responses and calculation of final weights. Where numerical judgements are converted into fuzzy ranges, those ranges should be identified as modelling assumptions unless directly elicited from participants. Sensitivity analysis should establish whether these choices materially affect the comparison.

Uncertainty in stakeholder judgements should be assessed separately from uncertainty in estimated performance. Consistency checks examine the internal coherence of pairwise comparisons, whereas agreement concerns differences among participants. Recalculating weights after removing each participant in turn can identify disproportionate individual influence; varying weights can reveal whether the preferred alternative depends on narrowly specified priorities. Performance assessment requires separate tests of rainfall, demand, costs, deterioration and model assumptions. Results should identify the conditions under which an alternative remains preferable and where uncertainty prevents a defensible recommendation. Stable weights alone do not establish reliable performance or feasibility.

7.0 CONCLUSIONS AND RECOMMENDATIONS

This critical integrative review examined 83 publications against 24 predefined criteria to clarify the evidence supporting institutional rooftop rainwater-harvesting retrofit decisions. Financial, operational and institutional considerations received broader coverage than several thermal, structural and innovation criteria. However, publication frequency indicates coverage within the selected literature rather than criterion importance or demonstrated retrofit performance. The synthesis shows that findings from previous studies require interpretation according to their methods, settings and assessment boundaries. Financial recovery depends on expenditure and tariff assumptions; runoff outcomes depend on storage, control arrangements and measurement periods; and stakeholder preferences depend on participants and institutional conditions. These differences limit the direct transfer of published scores or rankings to existing buildings.

The review contributes an evidence map and a proposed decision architecture that separates building context and eligibility requirements from stakeholder preferences and alternative-specific performance. Together, they clarify where previous studies can inform assessment, where criteria overlap and where additional evidence is needed before comparison. The architecture provides a basis for more transparent retrofit appraisal, although its practical effectiveness remains to be evaluated. Institutional assessments should document the building baseline, retrofit alternatives, intended water uses, applicable requirements, evidence sources and operational responsibilities. Alternatives should meet mandatory safety, regulatory and water-quality requirements before weighted comparison. Criterion weights should reflect institutional objectives and stakeholder preferences, while performance scores should draw on relevant measurements, cost records, previous studies and justified models.

8.0 LIMITATIONS AND FUTURE STUDIES

Further research should prioritise existing roof condition and remaining service life, maintenance access and responsibilities, acceptance of non-potable reuse, and assembly-level structural and material performance. Digital and modular options require operational evaluation to establish whether their proposed benefits are realised. Additional evidence searches and documented coding checks would also strengthen the review's coverage and reliability. The focused search and purposive retrieval emphasised decision-support terminology. Relevant evidence may therefore exist among unretrieved records or technical studies outside the search expression. Limited structural, thermal and innovation coverage describes this corpus and should not be interpreted as a general absence of building-engineering evidence. Manual review covered 83 publication summaries rather than independent recoding of all 1,992 publication criterion pairs. The targeted audit examined 23 mappings across four criteria, and no independent duplicate coding was performed. Source excerpts make individual classifications easier to examine, but do not establish coding agreement or the methodological quality of the underlying publications. Appraisal remained narrative. Finally, the deductive analysis was restricted to one predefined criterion framework, whose historical development was not fully documented. Appendices B and C clarify its definitions and relationships with the published comparator but do not establish its original derivation. The proposed decision architecture has not been validated through actual retrofit selection, limiting conclusions about its effectiveness in institutional practice.

Declarations

Competing Interests: The authors declare no competing financial or non-financial interests.
Funding: This research received no external funding.
Data Availability: This review used published literature cited in the reference list. The coded evidence matrix and criterion definitions are provided in the appendices. Additional supporting materials are available from the corresponding author upon reasonable request.
Declaration of Generative AI: Generative AI tools assisted with language editing, manuscript organization, and conceptual restructuring. The authors reviewed and verified the final content and take full responsibility for its accuracy and integrity.
Ethics and informed consent: This review analyzes published literature and involved no new human-participant data collection. Ethical approval and participant consent were not applicable.

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APPENDIX A: Criterion Definitions and Interpretation

The table presents the 24 predefined criteria, their mapping definitions and interpretive boundaries. Changes to criterion meanings require reassessment before existing codes or weights are reused.

Table A1. Definitions and interpretive boundaries of the 24 predefined decision criteria

Code	Criterion	Recorded mapping definition	Interpretive boundary and application requirement
FN1	Operational Cost	Evaluates maintenance, cleaning, and repair costs during the operational phase of the roof scheme.	Specify included recurring items, price year and assessment period. Monetary maintenance consequences belong here; practical access and ease belong in TC2.
FN2	Initial Investment Cost	Assesses construction and installation costs at the investment stage.	State the retrofit and system boundary, including roof work, connections, storage, treatment and installation where applicable.
FN3	Payback Period	Measures how long it takes to recover the initial investment through savings (e.g., through rainwater harvesting).	Distinguish simple from discounted payback and report assumptions or no-payback outcomes. Do not count the same savings again without testing overlap.
FN4	Financial Incentives and Subsidies	Assesses grants, subsidies, tax incentives, or other financial support that reduces initial or life-cycle cost.	Use project-specific eligibility and funding evidence. Show whether support has already reduced costs used in FN2 or FN3.
EN1	E. coli Content	Assesses microbiological suitability of harvested rainwater for the intended non-potable uses.	Use E. coli concentration at a specified sampling and treatment stage. General microbial quality or faecal-coliform evidence is not a species-specific measurement.
EN2	Runoff Reduction	Measures the roof's ability to slow surface runoff during flood events (e.g., friction coefficient considerations).	Identify roof-material or whole-system scope and a baseline. Report retention volume, peak attenuation and delay separately at stated event or continuous scales. A friction coefficient is not an outcome.
EN3	Urban Heat Island Mitigation	Evaluates the roof material's contribution to alleviating the urban heat island effect via reflectance values.	Separate roof reflectance or surface-temperature proxies from measured or modelled urban air-temperature effects. Specify the spatial scale and climate before claiming UHI mitigation.
EN4	Turbidity	Assesses the clarity and treatment implications of harvested rainwater for intended non-potable uses.	Report a defined turbidity measure, sampling point and treatment stage. Turbidity alone does not establish microbiological safety.
TC1	Construction Difficulty	Evaluates challenges in the building phase, including safety risks for workers.	Describe access, labour, equipment and installation sequencing. Mandatory construction-safety conditions require separate checks.
TC2	Maintenance Convenience	Assesses ease of routine inspections, cleaning, and repairs.	Describe access and the practical ease of inspection, cleaning and replacement. Keep service-life evidence in TC4 and expenditure in FN1.
TC3	Thermal Insulation Performance	Assesses how the roof configuration limits heat transfer and supports building energy performance.	Assess thermal behaviour of the relevant roof assembly under specified conditions. Reflectance, acoustic insulation and urban cooling are different constructs.

TC4	Material Durability	Assesses service life and resistance to weathering, corrosion, ultraviolet exposure, and repeated maintenance.	Use functional service-life or deterioration evidence for the relevant exposure and assembly. Recyclability is an end-of-life property, not durability.
ST1	Structural Load	Assesses the roof's impact on the building's structural integrity.	Compare additional dry and saturated loads, including stored water where relevant, with assessed existing-building capacity. Mandatory adequacy is an eligibility condition.
ST2	Fire Safety Performance	Assesses compliance with fire-safety requirements and resistance to ignition, fire spread, and heat-related damage.	Document applicable fire requirements and assembly or material evidence. Clarify score direction when using a source expressed as fire risk.
ST3	Wind Resistance	Measures resilience to wind forces.	Specify wind design conditions, attachments and assembly resistance. General disaster resilience or continued water access is not roof wind resistance.
ST4	Failure Risk	Identifies potential risks of leakage or material failure.	Retain the stated leakage/material-failure scope and define the mode, period and consequence. Water shortage or treatment failure requires a separate system-risk construct.
IN1	New Materials	Assesses the use of innovative materials in manufacturing or maintenance, from the green building lens.	Specify the innovation, intended function, maturity and compatibility. Novelty is not demonstrated benefit; assess claimed environmental or maintenance gains under their corresponding criteria.
IN2	Energy-Saving Technology	Evaluates integration with renewable or energy-saving technologies (solar panels, turbines, etc.).	Separate technical integration from measured or modelled energy savings. Avoid counting the same benefit under insulation, digitisation and energy criteria.
IN3	Modular Construction	Assesses adaptability to modular building techniques and off-site prefabrication.	Document compatibility with fabrication, transport, assembly and replacement. Modular design alone does not demonstrate faster installation or lower costs.
IN4	Digitization	Measures the use of digital technologies in construction and maintenance processes.	Distinguish design tools, construction use and operational monitoring. Researcher use of a model does not establish deployment or maintained sensor-based performance.
SO1	Policy and Institutional Support	Assesses non-financial support from government policies, university plans, and institutional management commitment.	Use documented non-financial policy, plans, responsibilities and management commitment. Keep grants and subsidies in FN4.
SO2	Aesthetic Value	Evaluates visual appearance and design appeal.	Specify the affected stakeholder group and visual context. A general appearance score is not transferable between sites.
SO3	Regulatory Compliance	Assesses alignment with current and potentially evolving building regulations and standards.	Check requirements applicable at the assessment date. Treat mandatory compliance as eligibility and possible future regulatory changes as uncertainty.
SO4	Stakeholder/User Acceptance	Assesses acceptance among campus users, facility managers, and other stakeholders, including perceived operational and maintenance impacts.	Identify users, facilities staff and decision-makers separately. Stated interest, perceived benefits and observed adoption are different outcomes.

APPENDIX B: COMPARISON WITH THE HAMIDI ET AL. CRITERION FRAMEWORK

Table B1 compares the review's criteria with the framework reported by Hamidi et al. (2025), highlighting similarities and differences in scope and interpretation.

Table B1. Correspondence and differences between the review's criteria and the Hamidi et al. (2025) framework

Current criterion	Hamidi et al. counterpart	Relationship and implication
FN1 Operational Cost	FN2 Operational Cost	Cost boundary needs specification; overlaps TC2 and TC4 if the same consequences are counted twice.

FN2 Initial Investment Cost	FN1 Investment Cost	Investment scope should specify retrofit, collection, treatment, storage and installation boundaries.
FN3 Payback Period	No standalone counterpart	Hamidi has no payback indicator; do not present this as inherited from its 24-item set.
FN4 Financial Incentives and Subsidies	FN3 Governmental Incentives	The manuscript includes financial support beyond the source government-incentive concept. Keep distinct from non-financial SO1.
EN1 E. coli Content	EN3 E. coli Content	E. coli is one measured microbial indicator. General microbiological suitability, faecal coliforms and pathogen safety are not interchangeable with species-specific evidence.
EN2 Runoff Reduction	EN1 Reduced Runoff	A friction coefficient is a roof-flow parameter, not a runoff-reduction outcome. Source Table S1 gives no friction coefficient or event metric.
EN3 Urban Heat Island Mitigation	EN4 Mitigating UHI	Source Table S1 includes a heat-mitigation concept but no albedo/reflectance metric or measured urban cooling.
EN4 Turbidity	EN2 Turbidity	Clarity is not a complete operational metric or a guarantee of microbial safety.
TC1 Construction Difficulty	TC1 Construction Complexity	Construction safety is an additional scope element in the current definition; specify whether risk and complexity are assessed separately.
TC2 Maintenance Convenience	TC2 Ease of Maintenance	Source description includes durability, accessibility and maintenance demand. Keep this criterion focused on access and practical ease if TC4 separately judges service life.
TC3 Thermal Insulation Performance	TC4 Insulation Capacity	Source insulation includes external noise and thermal effects. Current TC3 is thermal only.
TC4 Material Durability	No standalone counterpart	Hamidi TC3 is recyclability, not durability. Its maintenance description mentions durable materials, which is not an independent durability criterion or validation.
ST1 Structural Load	ST1 Structural Load	General structural integrity is too broad; distinguish added demand from verified available structural capacity.
ST2 Fire Safety Performance	ST3 Fire Risk	Source judges fire risk (minimise); manuscript judges safety performance. Do not reuse risk scores without direction conversion.
ST3 Wind Resistance	ST4 Wind Resistance	General wind resilience requires design conditions, attachment details and the complete assembly.
ST4 Failure Risk	ST2 Risk of Failure	Avoid double counting deterioration under TC4; define failure mode, exposure period and consequences.
IN1 New Materials	IN1 Use of Innovative Materials	Novelty is not proof of better performance. Benefits require evidence under the corresponding cost, environmental or technical indicator.
IN2 Energy-Saving Technology	IN4 Adaptation of Energy-Efficient Techniques	Source includes renewables, insulation and smart controls. Mere presence of equipment is different from demonstrated energy savings; overlaps TC3/IN4.
IN3 Modular Construction	IN2 Adaptability of Modular Construction Technologies	Modular adaptability is distinct from demonstrated cost or construction-time savings.
IN4 Digitization	IN3 Adaptation of Digital Technologies	Researcher use of a model alone does not show deployment in construction or operations.
SO1 Policy and Institutional Support	No standalone counterpart	Non-financial policy/institutional support is not sourcing regional suitability; financial incentives already map to FN4.

SO2 Aesthetic Value	SO4 Aesthetic Appearance	Visual preference is context- and stakeholder-specific.
SO3 Regulatory Compliance	SO2 Compliance with R&S	Current mandatory compliance should be separate from speculation about possible future rules.
SO4 Stakeholder/User Acceptance	SO1 Client Interest	Client interest is related but not equivalent to measured acceptance among all campus stakeholder groups.

APPENDIX C: DECISION RELEVANCE AND TRANSFERABILITY OF SELECTED STUDIES

Table C1 summarises how selected studies inform retrofit decisions and the conditions limiting transfer of their findings.

Table C1. Decision relevance and transfer limits of selected methodological comparators

Decision object and study	Method	Main finding	Evidence limit	Retrofit judgement supported
Urban suitability Ndeketeya and Dundu (2023)	GIS and multicriteria spatial assessment	Socioeconomic conditions change modelled suitability substantially.	Area classes do not measure adoption or roof constructability.	Identify candidate settings, then obtain building-level supply, demand and space evidence.
Household systems Melville-Shreeve et al. (2016)	Comparison of 13 configurations under illustrative preferences	Preferred configurations depend on objectives and priorities.	Retrofitability and lifetime maintenance were outside the performed evaluation.	Compare explicit configurations; add access, installation and maintenance evidence.
Campus alternatives Galarza-Molina et al. (2015)	ELECTRE II and Monte Carlo analysis of six scenarios	Hydraulic, financial and institutional objectives can be considered together.	Findings depend on the campus alternatives and chosen accounting boundaries.	Specify objectives and test whether financial measures duplicate information.
Pilot roof materials and slopes (Hamidi et al., 2025)	Nine pilot roofs; experiments, literature and expert inputs; FAHP–TOPSIS	Water-quality observations can inform a broader roof-selection hierarchy.	Small roofs, one sampled rain event and mixed sources of criterion scores.	Use material evidence with exposure and intended-use limits; verify occupied-building constraints separately.
Dual-use storage systems Quinn et al. (2021)	Continuous simulation and significant-event metrics	Long-term retention and event discharge control yield different comparisons.	Projected climate and specified tank, demand and release assumptions.	Define the time scale and control rules; do not assign tank benefits directly to roof materials.
Combined decentralised reuse (Souza et al., 2025)	Life-cycle sustainability assessment in Brazil and Germany	Broader sustainability benefits can coexist with negative financial outcomes.	Combined greywater and rainwater effects cannot be separated by attribution alone.	Specify the comparator, payer and cost boundary before transferring financial conclusions.
Community water supply (Sikder & Salehin, 2014, 2015)	Participatory assessment and comparison of decision methods	Preferences interact with maintenance and caretaker arrangements.	Related publications share a setting; community preferences are not campus weights.	Identify responsible actors and elicit context-specific preferences.
Building digital system (Bianco et al., 2026)	Digital twin and scenario-based system modelling	Digital models can explore water-service and reliability consequences.	Field-sensor deployment is described as future work.	Separate design-stage modelling from operationally demonstrated maintenance benefits.

APPENDIX D: Publication-Level Evidence Matrix

Table D1 maps the 83 retained publications against 24 predefined criteria. Criterion definitions appear in Appendix A (Table A1).

Table D1. Direct, indirect and not-identified correspondence across the 24 decision criteria

Notes: D = direct construct correspondence; I = indirect or partial correspondence; 0 = no correspondence identified. Codes indicate correspondence, not methodological quality, measured performance or criterion importance. FN = Finance; EN = Environment; TC = Technology; ST = Structure; IN = Innovation; SO = Society. Rows are ordered by publication year and author label; study IDs distinguish similar author–year labels. Total rows report publication counts for each criterion. The W170–EN2 reclassification from D to I and its rationale are documented in Supplementary Material Table D1.

Source: Table layout informed by Husain et al. (2025, Table 1). https://doi.org/10.1080/15623599.2025.2460354

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Study ID	Reference	Research method	FN1	FN2	FN3	FN4	EN1	EN2	EN3	EN4	TC1	TC2	TC3	TC4	ST1	ST2	ST3	ST4	IN 1	IN 2	IN 3	IN 4	SO1	SO2	SO3	SO4
W231	Bianco et al. (2026)	BIM-integrated water-system modelling	I	I	0	0	0	I	0	I	0	I	0	I	0	0	0	0	0	0	0	I	D	0	0	I
W134	Luo et al. (2026)	YBS water-balance simulation	0	0	0	0	0	D	0	0	0	0	0	0	0	0	0	I	0	0	0	0	0	0	0	I
W056	Mummidivarapu et al. (2026)	AHP spatial overlay	0	0	0	0	I	I	0	I	I	I	0	0	0	0	0	0	0	0	0	0	D	0	0	I
W062	Yousuf et al. (2026)	AHP / FAHP spatial analysis	I	I	0	I	0	I	0	0	I	I	0	0	0	0	0	I	0	0	0	0	D	0	0	D
W130	Abebe & Kassa (2025)	SWAT / FAHP fuzzy overlay	0	0	0	0	0	I	0	0	I	I	0	0	0	0	0	0	0	0	0	0	0	0	0	0
W191	Chen et al. (2025)	Review	D	D	D	D	D	I	0	D	I	D	0	0	D	I	0	0	0	I	0	0	I	0	D	D
W017	Demir et al. (2025)	SWOT / BWM survey	0	0	0	0	I	I	I	I	0	0	0	0	0	0	0	0	0	0	0	0	I	0	D	I
W100	Fariz-Salinas et al. (2025)	Expert-weighted spatial assessment	0	0	D	0	I	I	I	I	D	D	0	0	0	0	0	0	0	0	D	0	I	0	D	I
W080	Hamidi et al. (2025)	Roof experiments / multisource scoring	D	D	0	D	D	D	D	D	D	D	D	I	D	D	D	D	D	D	D	D	0	D	D	D
W221	Han et al. (2025)	Illustrative MCDA	D	D	I	0	I	0	0	I	I	0	0	0	0	0	0	0	0	0	0	I	0	0	I	I
W079	Lepota & Armitage (2025)	YAS simulation / MCA	I	D	0	0	I	D	0	I	I	0	0	I	0	0	0	0	0	0	0	0	0	0	0	0
W063	Souza et al. (2025)	Life-cycle sustainability assessment	D	D	D	D	0	0	0	0	0	I	0	0	0	0	0	0	0	0	0	0	I	0	I	I
W041	Ahmad et al. (2024)	AHP / FAHP spatial overlay	0	0	0	0	0	I	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

W113	Chadee et al. (2024)	Expert AHP / MCA	I	I	0	0	I	I	0	I	I	I	0	0	0	0	0	0	0	0	0	0	D	0	I	D
W174	Dias et al. (2024)	Climate-scenario assessment	I	I	I	0	I	0	I	I	0	0	0	0	0	0	0	0	0	I	0	I	I	0	I	0
W164	Loper et al. (2024)	GIS potential mapping	0	D	0	I	0	I	0	0	0	0	0	0	0	0	0	I	0	0	0	0	I	0	D	0
W213	Saha et al. (2024)	Survey / AHP / economic assessment	D	I	0	I	I	D	0	D	0	I	0	I	0	0	0	I	0	D	0	I	D	0	I	I
W126	Shah et al. (2024)	Weighted decision-support evaluation	D	D	0	I	I	I	0	I	0	D	0	I	0	0	0	I	0	0	0	0	D	0	D	0
W042	Swilla et al. (2024)	Interviews / MCDA	D	D	0	0	I	D	0	I	I	I	I	0	I	0	0	I	0	0	0	0	0	0	0	0
W091	Abdelkader et al. (2023)	Hydrological modelling / acceptance survey	D	D	I	0	0	I	0	0	0	D	0	0	0	0	0	I	0	0	0	0	0	0	0	D
W199	Ahmed et al. (2023)	Literature review	I	0	0	0	I	I	0	D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
W027	Bouramdane (2023)	Judgement-based AHP	0	I	I	0	I	0	0	I	D	I	0	0	0	0	0	I	0	I	0	D	D	0	D	D
W173	Díaz-Vázquez et al. (2023)	GIS / PCA / household surveys	0	D	0	D	0	I	0	0	I	I	0	0	0	0	0	0	0	I	0	0	D	0	0	D
W022	Ndeketeya & Dundu (2023)	GIS–MCDA	0	0	0	0	I	I	0	I	0	0	0	0	0	0	0	0	0	0	0	0	0	I	0	0
W076	Shrestha et al. (2023)	Literature review	0	D	0	0	0	I	0	0	I	I	0	0	0	0	0	0	0	0	0	0	0	I	0	0
W059	RiveraVázquez et al. (2023)	Water sampling / GIS–AHP	I	D	0	0	I	0	0	I	0	I	0	0	0	0	0	0	0	0	0	0	0	0	0	0
W033	Farooq et al. (2022)	SCS-CN / GIS–AHP	0	0	0	0	0	I	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

W107	Hsueh et al. (2022)	Expert-based scenario evaluation	0	0	0	D	0	0	0	0	0	0	I	0	0	0	0	0	I	D	0	I	I	0	D	I
W263	Kee et al. (2022)	Prototype monitoring	I	I	0	I	0	0	0	0	D	0	I	0	I	I	0	D	0	D	D	D	0	0	I	0
W290	Portman et al. (2022)	Survey / AHP	D	D	0	0	I	0	0	I	0	I	0	0	0	0	0	0	0	0	0	0	I	0	D	D
W257	Song et al. (2022)	Expert indicator assessment	0	I	0	0	0	0	0	0	0	I	0	D	I	D	I	I	0	D	I	D	0	0	D	0
W287	Van de Walle et al. (2022)	Water-balance / chloride modelling	0	0	0	0	I	0	0	0	0	I	0	0	0	0	0	I	0	0	0	I	0	0	0	I
W245	Akter & Ahmed (2021)	GIS / hydrological scenario modelling	0	0	0	0	0	I	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	D
W148	Bai et al. (2021)	AHP / fuzzy comprehensive evaluation	0	0	0	0	0	0	0	0	0	0	D	0	0	0	0	0	I	D	0	D	0	0	0	0
W112	Chi et al. (2021)	Aggregation / weighting model comparison	D	D	0	0	I	D	0	I	I	I	0	0	0	0	0	0	0	0	0	0	I	0	0	0
W304	Edirisinghe & Pathirana (2021)	Survey and statistical modelling	0	I	0	I	0	0	0	0	I	D	0	0	0	0	0	I	0	0	0	D	D	0	D	I
W152	Hsueh et al. (2021)	Delphi / AHP fuzzy scenarios	0	0	0	D	0	0	I	0	0	0	0	0	0	0	0	0	0	D	0	0	I	0	I	I
W183	Meshram et al. (2021)	GIS / HEC-HMS simulation	0	0	0	0	I	D	0	I	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
W018	Quinn et al. (2021)	YAS tank simulation	0	0	0	0	0	D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	I
W247	Amorim et al. (2020)	Survey-based comparative assessment	0	D	D	I	0	I	0	0	D	0	0	0	0	0	0	0	0	0	0	0	I	0	D	D

W196	Chiu et al. (2020)	Water-balance / LCCA / MCDA	D	D	0	0	I	I	0	0	0	I	0	0	0	0	0	0	0	0	0	0	D	I	0	I
W045	Hämmerling et al. (2020)	AHP scenario comparison	D	D	I	0	I	I	I	I	D	D	0	0	0	0	0	0	0	0	0	0	0	0	I	I
W305	Kordana & Slys (2020)	SWMM / preference assessment	D	D	0	I	I	D	I	I	D	D	0	0	0	0	0	I	0	0	0	I	I	D	D	I
W273	Liu et al. (2020)	Fuzzy risk assessment	0	0	0	0	I	0	0	I	0	I	0	0	0	0	0	I	0	0	0	0	0	0	0	0
W169	Palermo et al. (2020)	Rough-set analysis / TOPSIS	0	I	0	0	I	I	0	I	0	0	0	0	0	0	0	0	0	0	0	0	I	0	0	0
W170	Saha & Bhattacharya (2020)	Conceptual MCDA	0	D	0	D	0	I	0	0	I	0	0	0	0	0	0	0	0	D	0	0	0	0	0	I
W025	Toosi et al. (2020)	GIS–AHP	0	I	0	0	0	0	0	0	I	I	0	0	0	0	0	0	0	0	0	0	0	I	0	0
W220	Wurthmann (2020)	Scenario-based economic assessment	D	D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	I	0	0	0	0	I	0	0
W293	Zhan et al. (2020)	Water-quality experiments	0	0	0	0	D	0	0	I	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	D
W233	Bouziotas et al. (2019)	UWOT scenario simulation	I	I	0	0	I	D	0	I	0	0	0	0	0	0	0	0	0	0	0	0	I	0	0	I
W239	Haider et al. (2019)	Fuzzy risk–MCDA	D	D	0	0	I	D	0	I	D	I	0	I	0	0	0	0	0	0	0	0	0	0	I	I
W224	Hargreaves et al. (2019)	Coupled spatial–water-use modelling	D	D	D	D	0	I	0	0	0	I	0	0	0	0	0	0	0	0	0	0	I	0	D	I
W087	Martínez-Acosta et al. (2019)	Planning review	0	D	0	0	I	I	0	0	I	0	0	0	0	0	0	0	0	0	0	0	I	0	D	I
W161	Shadeed et al. (2019)	GIS–AHP	0	0	0	0	I	I	0	I	0	I	0	0	0	0	0	0	0	0	0	0	0	0	D	0
W228	Vargas et al. (2019)	Sizing-method comparison	0	D	I	0	0	I	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	I	D

W208	Chhipi-Shrestha et al. (2018)	System dynamics / Monte Carlo	D	D	0	I	I	0	0	I	0	I	0	0	0	0	0	0	I	0	0	0	0	I	0	0
W014	Nnaji & Banigo (2018)	Expert AHP / TOPSIS	0	D	0	0	I	0	0	I	I	D	0	0	0	0	0	0	0	0	0	0	0	0	0	D
W185	Tavakol-Davani et al. (2018b)	SWMM / LCA	0	0	0	0	0	D	0	0	0	I	0	0	0	0	0	0	0	0	0	0	0	0	0	0
W237	Tavakol-Davani et al. (2018a)	SWMM / LCA	0	0	0	0	I	D	0	I	I	I	0	0	0	0	0	0	0	0	0	0	0	0	0	0
W192	Fonseca et al. (2017)	DSS development	0	I	0	I	I	I	0	I	I	0	0	0	0	0	0	0	0	0	0	I	0	0	0	I
W106	Onu et al. (2017)	Fuzzy TOPSIS	0	0	0	0	I	0	0	I	0	0	0	0	0	0	0	0	0	0	0	I	0	I	0	0
W039	Rahman (2017)	Narrative overview	I	0	0	0	I	I	0	I	0	I	0	0	0	0	0	0	0	0	0	I	0	I	I	0
W212	Sampaio & Alves (2017)	Water-balance / economic simulation	D	D	0	0	0	0	0	I	0	I	0	0	0	0	0	0	0	0	0	0	0	0	0	I
W150	Sánchez-Sabau et al. (2017)	Narrative review	I	I	0	I	I	D	0	I	0	D	0	I	0	0	0	0	0	0	0	I	D	I	D	0
W069	Adham et al. (2016b)	Comparative review	0	0	0	0	0	I	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
W187	Adham et al. (2016a)	Survey / AHP	D	D	0	0	0	I	0	0	0	D	0	0	0	0	0	0	0	0	0	0	0	0	0	0
W289	Farooqui et al. (2016)	Water–energy scenario modelling	0	0	0	0	0	D	I	0	0	0	0	0	0	0	0	I	0	I	0	0	I	0	0	I
W007	Melville-Shreeve et al. (2016)	Configuration–performance comparison	I	D	I	I	0	D	0	0	I	I	0	0	D	0	0	0	0	0	0	D	I	0	0	I
W223	Akter & Ahmed (2015)	Hydrological simulation / GIS–AHP	0	0	I	0	I	I	0	I	0	I	0	0	0	0	0	0	0	0	0	0	0	0	0	I
W138	Behzadian & Kapelan (2015)	WaterMet2 simulation / MCDA	D	D	0	0	0	D	0	0	0	0	0	0	0	0	0	0	I	0	0	0	0	I	0	0
W005	Galarza-Molina et al. (2015)	ELECTRE II / Monte Carlo	I	D	D	0	I	I	0	I	I	D	0	0	0	0	0	I	0	0	0	0	D	I	I	I

W219	Karim et al. (2015)	Water-balance simulation	0	0	0	0	I	I	0	I	0	0	0	0	0	0	0	0	I	0	0	0	0	I	0	0
W050	Mahmoud & Tang (2015)	GIS–AHP	0	I	0	I	I	I	I	I	0	0	0	I	0	0	0	0	0	0	0	0	0	0	0	0
W075	Sikder & Salehin (2015)	Household survey / MCDA comparison	D	D	0	0	I	0	0	D	0	I	0	0	0	0	0	0	0	0	0	0	0	0	0	0
W265	Vranayová et al. (2015)	Risk assessment / AHP	I	I	0	0	I	I	0	I	I	I	0	I	0	0	0	0	0	0	0	I	I	I	0	0
W178	Kaposztasova et al. (2014)	Risk assessment / AHP	0	0	0	0	I	I	0	I	0	I	0	0	0	0	0	0	0	0	0	I	0	0	0	0
W016	Sikder & Salehin (2014)	Household survey / weighted-sum ranking	D	D	0	I	I	0	0	I	0	D	0	D	0	0	0	I	0	0	0	0	I	0	0	D
W019	Domènech et al. (2013)	Stakeholder survey / MCDA	D	D	0	D	I	0	0	0	I	I	0	0	0	0	0	0	0	0	0	0	D	0	I	D
W226	Willuweit & O'Sullivan (2013)	Multiscale water-system simulation	0	0	0	0	I	0	0	I	0	0	0	0	0	0	0	0	I	0	0	0	0	0	0	0
W202	Duong et al. (2011)	Participatory AquaCycle simulation	I	I	0	0	I	0	0	I	0	I	0	0	0	0	0	I	0	I	0	0	D	0	I	I
W278	Imteaz et al. (2011)	Water-balance / economic modelling	I	D	D	0	0	0	0	0	0	I	0	0	0	0	0	I	0	0	0	0	0	0	0	I
W172	Rozos et al. (2010)	UWOT / evolutionary optimisation	D	D	D	0	I	0	0	I	0	I	0	0	0	0	0	0	0	I	0	0	0	0	0	0
W181	Mbilinyi et al. (2005)	Participatory mixed-method research	0	0	0	0	0	I	0	0	I	0	0	0	0	0	0	0	0	0	0	I	0	0	I	0
Total D	n = 83 publications		24	36	8	9	3	17	1	5	8	13	2	2	3	2	1	2	1	8	3	7	14	2	17	15

Total I	n = 83 publications		16	17	8	14	46	38	8	42	23	36	3	9	3	2	1	18	7	7	1	13	14	20	13	15
Total 0	n = 83 publications		43	30	67	60	34	28	74	36	52	34	78	72	77	79	81	63	75	68	79	62	49	68	51	39