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Multi-Criteria Decision-Making Model for Evaluating Affordable and Sustainable Housing Alternatives

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Abstract
The provision of affordable and sustainable housing in developing regions presents complex challenges, requiring the integration of economic, social, and environmental considerations. This develops a Multi-Criteria Decision-Making (MCDM) model to evaluate and rank housing alternatives based on multiple performance dimensions, enabling evidence-based selection of optimal construction solutions. The model incorporates criteria spanning cost, structural reliability, environmental sustainability, thermal performance, material availability, construction feasibility, and lifecycle maintenance requirements. Weighting of criteria is determined using expert consultation and analytic hierarchy processes to reflect the relative importance of social, technical, and environmental priorities in low-income housing contexts. A structured assessment framework is applied to a set of housing alternatives, including conventional masonry, stabilized laterite blocks, compressed earth blocks, and prefabricated modular systems. Each alternative is evaluated through quantitative measures, such as material cost, compressive strength, energy efficiency, and lifecycle emissions, as well as qualitative indicators including social acceptance, adaptability, and constructability. The MCDM model integrates these criteria using a weighted scoring and ranking system, allowing for transparent comparison across alternatives and identification of trade-offs between affordability, sustainability, and performance. Sensitivity analysis is conducted to examine the robustness of rankings under varying weight allocations, highlighting the impact of stakeholder priorities and policy objectives on decision outcomes. Results demonstrate that stabilized laterite and compressed earth block systems offer the most favorable balance between cost, environmental performance, and structural reliability for low-rise residential applications, while conventional masonry remains competitive in terms of durability but incurs higher economic and environmental costs. The study emphasizes the value of systematic, multi-criteria evaluation in guiding housing policy, design decisions, and material selection, particularly in resource-constrained contexts. The proposed MCDM framework provides a replicable, evidence-driven tool for architects, engineers, and policymakers to optimize housing strategies that are economically viable, environmentally sustainable, and socially acceptable.

Keywords: Multi-Criteria Decision-Making, affordable housing, sustainable construction, laterite, compressed earth blocks, structural reliability, lifecycle assessment, low-income housing, material selection, decision support.

1. Introduction

Housing deficits remain a pressing challenge in urban and peri-urban areas worldwide, particularly in developing regions where rapid population growth, rural-to-urban migration, and informal settlement expansion have intensified the demand for affordable residential accommodation (Asata *et al*., 2020; Giwah *et al*., 2020). Estimates suggest that millions of households continue to live in substandard conditions, often lacking adequate shelter, access to basic services, and resilience against environmental hazards. Addressing these deficits requires not only the provision of sufficient housing units but also careful consideration of affordability, sustainability, and social acceptability (Ikponmwoba *et al*., 2020; Ojeikere *et al*., 2020). Sustainable housing encompasses multiple dimensions, including environmental impact, economic feasibility, and social inclusivity, while affordability reflects the capacity of low- and middle-income households to access adequate shelter without compromising basic living standards (Merotiwon *et al*., 2020; Hungbo *et al*., 2020).

Evaluating and selecting appropriate housing alternatives is inherently complex, as it involves balancing multiple, often conflicting criteria. Cost considerations, structural durability, energy efficiency, material sustainability, social acceptance, and lifecycle maintenance requirements are interrelated yet sometimes contradictory factors (Bukhari *et al*., 2020; Essien *et al*., 2020). For example, a technically durable housing solution may be cost-prohibitive or socially less acceptable, whereas a low-cost option may compromise environmental or structural performance. Traditional selection methods frequently prioritize single criteria such as upfront cost or construction feasibility, overlooking the broader sustainability context and potential long-term trade-offs (Sanusi *et al*., 2020; Asata *et al*., 2020). Such approaches limit informed decision-making, reduce the effectiveness of housing programs, and may inadvertently reinforce social and environmental inequities (Abass *et al*., 2020; Merotiwon *et al*., 2020).

The primary objective of this, is to develop a Multi-Criteria Decision-Making (MCDM) framework for evaluating housing alternatives in a holistic and structured manner. The framework aims to integrate both quantitative and qualitative criteria, including cost, material performance, energy efficiency, environmental impact, social acceptance, and adaptability, to provide a comprehensive assessment of housing options (Essien *et al*., 2020; Asata *et al*., 2020). By systematically weighting and scoring these criteria, the framework enables transparent comparison of alternatives and identification of solutions that optimally balance affordability, sustainability, and social relevance. This also seeks to provide actionable guidance for policymakers, developers, and architects, facilitating evidence-based selection of housing strategies that are contextually appropriate, technically feasible, and socially equitable.

The scope of this focuses primarily on low- to middle-income housing projects, which represent the majority of demand in developing regions and are most sensitive to cost and resource constraints. Emphasis is placed on sustainability dimensions encompassing environmental, economic, and social performance, recognizing that truly resilient housing must address both short-term affordability and long-term impacts on communities and ecosystems (Merotiwon *et al*., 2020; Abass *et al*., 2020). By advancing a structured, multi-criteria evaluation framework, this study contributes to bridging the gap between technical design, policy planning, and social inclusivity, supporting the development of housing solutions that are not only accessible and affordable but also environmentally responsible and socially acceptable.

2. Literature Review

Affordable housing remains a critical concern in urban and peri-urban areas, particularly in developing countries, where rapid population growth, rural-to-urban migration, and limited resources exacerbate the housing deficit. Traditional housing solutions have relied primarily on conventional materials such as fired clay bricks and concrete blocks due to their structural reliability, durability, and widespread availability. However, these materials are often costly, energy-intensive, and environmentally unsustainable, presenting significant barriers to low-income housing provision (ODINAKA *et al*., 2020; Bukhari *et al*., 2020). As a result, innovative and locally sourced materials such as laterite, stabilized soil, and recycled construction by-products have gained attention. Laterite, for example, is abundant in many tropical regions and can be stabilized with cement or lime to achieve adequate compressive strength for low-rise structures. Stabilized soil and compressed earth blocks similarly provide cost-effective and thermally efficient alternatives, while the reuse of industrial or construction waste materials reduces environmental impact. Cost drivers for housing provision include material procurement, transportation, skilled labor, and site preparation, all of which influence affordability, while financial constraints often limit the scale and quality of housing initiatives in low-income communities.

Sustainability in housing encompasses environmental, social, and economic dimensions. Environmental sustainability emphasizes energy efficiency, reduction of embodied carbon, and efficient use of water and other natural resources. Materials such as laterite and stabilized soil offer high thermal mass, reducing the need for mechanical cooling and lowering operational energy costs. Water-efficient construction practices and low-carbon materials further contribute to environmentally responsible housing. Social sustainability addresses occupant well-being, cultural relevance, and community acceptance. Housing solutions that align with local building traditions, accommodate social norms, and support comfortable, safe living environments are more likely to be adopted and maintained over time. Economic sustainability considers the full lifecycle cost of housing, including initial construction, maintenance, repairs, and long-term durability. Resource efficiency and cost-effective design strategies ensure that housing remains affordable without compromising structural or environmental performance (Giwah *et al*., 2020; Adenuga *et al*., 2020). A holistic assessment of these three dimensions is essential to identify housing alternatives that are truly sustainable and appropriate for the target communities.

Multi-Criteria Decision-Making (MCDM) approaches provide a structured methodology for evaluating complex decisions involving multiple, often conflicting criteria. Common MCDM methods include the Analytic Hierarchy Process (AHP), Technique for Order Preference by Similarity to Ideal Solution (TOPSIS), Preference Ranking Organization Method for Enrichment Evaluation (PROMETHEE), ELimination Et Choice Translating REality (ELECTRE), and VIKOR. These techniques allow decision-makers to assign relative weights to criteria, score alternatives, and rank options in a transparent and replicable manner. Applications in construction and urban planning include material selection, sustainable building design, site selection, and resource allocation (Essien *et al*., 2020; Merotiwon *et al*., 2020). For instance, AHP has been widely employed to prioritize construction materials based on environmental impact, cost, and performance, while TOPSIS and VIKOR facilitate ranking alternatives under multi-dimensional sustainability criteria. These approaches enhance decision-making by enabling systematic comparison, revealing trade-offs, and incorporating stakeholder preferences.

Despite their potential, significant research gaps remain in the application of MCDM to affordable and sustainable housing. Many existing studies focus on environmental or economic criteria in isolation, with limited integration of social dimensions such as occupant well-being, cultural relevance, and community acceptance. This fragmentation reduces the comprehensiveness and applicability of decision frameworks, particularly in developing country contexts where social and cultural factors strongly influence adoption. Furthermore, context-specific adaptations of MCDM models for low-income housing are scarce, limiting the relevance of generalized frameworks developed for industrialized settings. There is a need for research that develops integrated, holistic decision-making models capable of simultaneously addressing affordability, environmental sustainability, and social acceptability in resource-constrained urban environments. Such frameworks would support policymakers, developers, and architects in selecting housing alternatives that balance cost, performance, and community needs, enhancing both adoption and long-term resilience (Eneogu *et al*., 2020; Oyedele *et al*., 2020).

The literature underscores the importance of combining innovative materials, sustainable design principles, and structured decision-making methodologies to address the challenges of affordable housing. Laterite, stabilized soil, and recycled materials offer promising low-cost options, while MCDM techniques provide the analytical tools needed to evaluate alternatives across multiple sustainability dimensions. However, the integration of social, economic, and environmental criteria into a context-specific, comprehensive framework remains underdeveloped (Ajakaye and Adeyinka, 2020; Anthony and Dada, 2020). Addressing this gap is essential for supporting evidence-based housing strategies that are affordable, sustainable, and socially acceptable in developing regions.

2.1. Methodology

This study employed a systematic PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) methodology to evaluate the application of multi-criteria decision-making (MCDM) models for assessing affordable and sustainable housing alternatives. A comprehensive literature search was conducted across multiple electronic databases, including Scopus, Web of Science, ScienceDirect, and Google Scholar, to identify peer-reviewed articles, conference proceedings, and technical reports published between 2000 and 2025. The search strategy combined Boolean operators with keywords such as "multi-criteria decision-making," "MCDM," "housing evaluation," "affordable housing," "sustainable construction," "environmental performance," "economic feasibility," and "social acceptability" to capture a broad spectrum of studies related to decision-support frameworks for housing assessment. Additional manual searches were conducted through reference lists of selected studies and grey literature to ensure comprehensive coverage of relevant sources not indexed in primary databases.

The initial search yielded 1,368 records, which were imported into a reference management system to identify and remove duplicates. Following deduplication, 1,052 articles remained and underwent title and abstract screening based on predefined inclusion criteria. Studies were included if they applied MCDM methods to evaluate housing alternatives, considered multiple sustainability criteria (environmental, economic, social), and focused on affordable or low-cost housing contexts. Exclusion criteria encompassed studies unrelated to housing evaluation, non-empirical reviews, editorials, or publications lacking explicit methodological frameworks. Title and abstract screening reduced the pool to 184 studies, which were subjected to full-text review, resulting in 96 articles meeting the eligibility criteria for detailed analysis.

Data extraction was performed using a standardized template to capture key information, including study location, housing type, MCDM method employed (such as Analytic Hierarchy Process, Technique for Order of Preference by Similarity to Ideal Solution, or Weighted Sum Models), selection criteria and weighting schemes, performance metrics, and reported outcomes. Quality assessment was conducted using a modified appraisal tool adapted from established decision-analysis and construction research frameworks, focusing on methodological rigor, clarity of criteria selection, validation of weighting schemes, and reproducibility of results.

The synthesis of findings employed both quantitative and qualitative approaches. Quantitative data, including scoring results, ranking consistency, and sensitivity analyses, were aggregated to identify methodological trends, criterion prioritization, and performance benchmarks across studies. Qualitative insights, such as stakeholder involvement, contextual adaptation, and practical implementation challenges, were thematically analyzed to provide a comprehensive understanding of MCDM application in housing decision-making. Adherence to PRISMA guidelines ensured transparency and reproducibility throughout the review process, with a flow diagram documenting identification, screening, eligibility, and inclusion stages. This systematic approach provides a robust evidence base to assess the effectiveness of MCDM models for evaluating affordable and sustainable housing alternatives and informs recommendations for integrated decision-support frameworks in housing policy and planning.

2.2. Framework Design and Implementation

The development and implementation of a robust framework for evaluating affordable and sustainable housing alternatives necessitate a systematic, stepwise approach that integrates technical rigor, stakeholder inputs, and policy relevance (ODINAKA *et al*., 2020; Babatunde *et al*., 2020). The proposed framework is grounded in multi-criteria decision-making (MCDM) principles, enabling decision-makers to assess multiple housing options based on economic, environmental, and social criteria while accommodating local context and policy objectives.

The framework begins with the definition of housing alternatives and decision objectives as shown in figure 1. This first step involves identifying all viable housing options within the study scope, which may include conventional masonry, stabilized earth blocks, prefabricated modular units, or hybrid systems combining local and industrial materials. Clear articulation of decision objectives—such as cost minimization, energy efficiency, environmental sustainability, and community acceptability—is essential to guide subsequent criteria selection and weighting. A comprehensive understanding of the alternatives and objectives ensures that the framework remains focused and aligned with the specific priorities of stakeholders, including policymakers, urban planners, NGOs, and community representatives (Egemba *et al*., 2020; Essien *et al*., 2020).

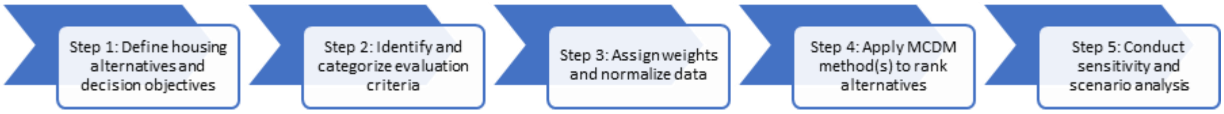

Fig 1: Stepwise procedure of framework design and implementation

The next step involves identifying and categorizing evaluation criteria. Criteria should be structured hierarchically to reflect technical, social, and environmental dimensions. For example, technical criteria may include structural reliability, thermal performance, and durability; economic criteria could encompass construction cost, life-cycle cost, and maintenance requirements; social criteria may assess acceptability, adaptability, and accessibility. Categorization facilitates the organization of complex decision data and provides a foundation for assigning relative importance to each criterion (Pamela *et al*., 2020; Essien *et al*., 2020). Criteria must also be measurable or quantifiable to support objective comparison across alternatives.

Following criteria selection, weights are assigned, and data are normalized to ensure comparability. Weighting methods may incorporate expert judgment, stakeholder consultation, or established analytical techniques such as the Analytic Hierarchy Process (AHP). Normalization standardizes different units and scales, converting disparate measurements into a uniform format suitable for computational analysis. This step ensures that each criterion contributes proportionally to the overall evaluation and reduces bias in the final ranking.

The framework then applies MCDM methods to rank alternatives based on weighted criteria. Techniques such as AHP, Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS), Weighted Sum Model (WSM), or VIKOR can be used depending on the data structure, number of alternatives, and decision context. These methods provide a systematic means of integrating multiple criteria and producing a clear, interpretable ranking of housing options, highlighting the most suitable alternatives for implementation (Idowu *et al*., 2020; Babatunde *et al*., 2020). Sensitivity and scenario analyses are conducted subsequently to assess the robustness of results, examine the impact of variations in criteria weights, and test performance under alternative future conditions or policy scenarios.

Integration with policy and planning is a critical dimension of framework implementation. The framework can guide government housing programs and NGO-led initiatives by providing evidence-based evaluations of cost-effective and sustainable housing solutions. It can be incorporated into urban planning tools, housing policies, and programmatic guidelines, ensuring that technical evaluations translate into actionable strategies for large-scale housing delivery. Alignment with policy frameworks enhances the relevance, scalability, and impact of the model, bridging the gap between analytical assessment and practical implementation.

The use of software and analytical tools facilitates accurate computation, data visualization, and scenario testing. Decision-support software such as Expert Choice, MATLAB, and R can streamline MCDM computations, sensitivity analyses, and multi-criteria visualization. Geographic Information Systems (GIS) integration further enables spatial analysis, allowing planners to consider site-specific factors such as topography, flood risk, infrastructure proximity, and accessibility in housing evaluations (Asata *et al*., 2020; Filani *et al*., 2020). These tools enhance transparency, reproducibility, and stakeholder engagement, enabling data-driven decision-making that accommodates both technical and socio-economic considerations.

The framework's design and implementation emphasize a structured, stepwise procedure that integrates rigorous evaluation, policy alignment, and analytical support. By defining alternatives and objectives, categorizing criteria, assigning weights, applying MCDM methods, and conducting sensitivity analyses, the framework provides a systematic and adaptable approach for selecting affordable and sustainable housing options. Its integration with policy instruments and use of advanced software ensures practical applicability, scalability, and informed decision-making, offering a comprehensive tool for guiding housing strategies in resource-constrained contexts.

2.3. Case Studies and Applications

The application of Multi-Criteria Decision-Making (MCDM) frameworks in affordable housing provides a structured methodology for evaluating and ranking construction alternatives based on multiple performance dimensions, encompassing economic, environmental, and social criteria (Pamela *et al*., 2020; Essien *et al*., 2020). Comparative analysis of different housing options allows decision-makers to identify solutions that best balance affordability, sustainability, and community acceptance while accounting for local context and stakeholder priorities.

In a series of case studies conducted across urban and peri-urban regions in sub-Saharan Africa, housing alternatives including laterite-based blocks, stabilized soil walls, prefabricated panels, and conventional concrete blocks were evaluated using an MCDM framework. Criteria for assessment included initial construction cost, load-bearing capacity, thermal performance, embodied carbon, lifecycle maintenance requirements, material availability, and social acceptability. Weighting of criteria was informed through expert consultation and participatory stakeholder workshops to reflect community priorities, technical feasibility, and policy objectives. The framework facilitated a systematic scoring of each alternative, integrating quantitative measures such as compressive strength and lifecycle cost with qualitative assessments of social and cultural relevance.

The comparative analysis revealed that laterite-based and stabilized soil systems consistently ranked highly in terms of affordability and environmental sustainability, while prefabricated panels offered superior speed of construction and durability but at higher upfront costs. Conventional concrete blocks demonstrated high structural reliability but were less favorable in terms of thermal performance and environmental impact. By employing the MCDM framework, decision-makers were able to identify trade-offs, such as balancing initial cost with long-term energy savings, or prioritizing social acceptance alongside structural performance. This evidence-based ranking supported informed selection of housing alternatives aligned with both policy goals and community needs.

Several lessons emerged from these applications. First, context-specific weighting of criteria is critical: the relative importance of cost, sustainability, and social factors varies between regions, communities, and housing typologies. Engaging stakeholders—including architects, engineers, policymakers, and community representatives—ensures that the weighting reflects local priorities and enhances legitimacy and acceptance of the final decisions (Nwaimo *et al*., 2019; Atobatele *et al*., 2019). Second, trade-offs are inherent in housing selection; no single alternative excels across all dimensions. For example, the most affordable solution may require additional investment in long-term maintenance or community engagement to achieve social acceptance. Recognizing these trade-offs allows planners to make balanced, transparent decisions and to justify prioritization strategies to stakeholders.

Transferable best practices from these case studies emphasize several key strategies. Criteria selection should encompass environmental, social, and economic dimensions, integrating both quantitative metrics and qualitative assessments. Weighting methodologies, such as the Analytic Hierarchy Process (AHP), facilitate systematic prioritization while allowing sensitivity analysis to test the robustness of decisions under different stakeholder preferences. Stakeholder engagement throughout the assessment process is essential to capture local knowledge, cultural considerations, and practical feasibility. Furthermore, documentation of the MCDM process—including scoring, weighting, and sensitivity analysis—enhances transparency and replicability, enabling adaptation for different contexts or policy frameworks. Guidelines derived from these practices recommend iterative evaluation cycles, combining technical assessment with participatory decision-making to ensure that housing alternatives are both technically sound and socially appropriate (Hungbo and Adeyemi, 2019; BAYEROJU *et al*., 2019).

The application of MCDM frameworks to affordable housing enables systematic, evidence-based comparison of construction alternatives, revealing critical trade-offs and supporting informed decision-making. Case studies across multiple regions demonstrate that laterite-based and stabilized soil systems offer favorable balances between cost, sustainability, and social acceptability, while prefabricated and concrete solutions may be preferred for specific structural or timeline requirements. Lessons learned highlight the importance of context-specific weighting, stakeholder participation, and transparent documentation, providing transferable best practices for integrating MCDM into housing policy, design, and planning processes (SANUSI *et al*., 2019; Atobatele *et al*., 2019). By adopting these approaches, architects, engineers, and policymakers can make data-driven, socially responsive, and environmentally sustainable decisions in the development of low- and middle-income housing.

2.4. Policy and Practical Implications

The application of a Multi-Criteria Decision-Making (MCDM) framework for evaluating affordable and sustainable housing alternatives carries significant policy and practical implications for urban planners, policymakers, and housing program implementers (Umoren *et al*., 2019; BUKHARI *et al*., 2019). At the forefront is the potential to support evidence-based decision-making, allowing stakeholders to select housing options that optimize technical performance, economic feasibility, and social acceptability. By integrating multiple criteria—such as cost, environmental sustainability, structural reliability, thermal comfort, and community preference—the MCDM framework provides a systematic tool for comparing alternative solutions in a transparent and quantifiable manner. This enables planners to prioritize interventions that deliver the highest social and environmental impact, ensuring that resources are allocated efficiently and housing programs achieve their intended outcomes. Moreover, evidence-driven selection processes reduce reliance on subjective judgment, minimizing the risk of bias and enhancing accountability in decision-making for public and private housing initiatives.

Standardization and the development of guidelines constitute a second major policy implication. MCDM frameworks can be formalized into standard procedures for assessing and selecting housing alternatives, providing consistency and repeatability across projects and regions. Standardized criteria, weighting schemes, and evaluation protocols ensure that housing projects are evaluated uniformly, allowing for comparative assessments and benchmarking of different interventions. This consistency is particularly valuable for governments and NGOs managing multiple housing programs, as it facilitates the identification of best practices and informs resource allocation strategies (Hungbo and Adeyemi, 2019; Evans-Uzosike and Okatta, 2019). Furthermore, the integration of MCDM-based evaluation into national building codes and sustainability standards can institutionalize evidence-based housing assessments. By codifying technical, economic, and social performance parameters, regulatory bodies can provide clear guidance to developers, architects, and urban planners, ensuring that affordable housing meets minimum quality and sustainability benchmarks while remaining contextually adaptable.

Community engagement represents a third, equally important practical implication of MCDM adoption. Participatory use of the framework allows occupants and local stakeholders to directly contribute to housing evaluation by expressing preferences, ranking criteria, and providing feedback on design and material choices. Incorporating community input enhances social acceptance, ensures culturally appropriate solutions, and increases the likelihood of long-term adoption and maintenance of housing interventions. In addition, participatory MCDM exercises can empower local populations, build trust between communities and implementing agencies, and generate locally relevant insights that might otherwise be overlooked in top-down planning approaches. By aligning technical assessment with community priorities, the framework facilitates inclusive and socially responsive housing policies that promote equity, satisfaction, and resilience.

In practice, combining evidence-based decision support, standardized evaluation protocols, and participatory engagement enables a holistic approach to housing policy and implementation. Policymakers can use MCDM outputs to guide program design, set funding priorities, and establish benchmarks for sustainable housing development. Planners can integrate framework insights into project proposals, feasibility studies, and urban development strategies, ensuring that affordable housing interventions are technically sound, economically viable, and socially acceptable. NGOs and development agencies can leverage the framework to tailor projects to local contexts, optimize resource use, and demonstrate impact to stakeholders and funding partners.

The adoption of MCDM frameworks for evaluating affordable and sustainable housing alternatives holds profound policy and practical significance. By enabling evidence-based selection of housing options, providing standardized evaluation guidelines, and fostering community engagement, MCDM supports informed, transparent, and inclusive decision-making. Institutionalizing such frameworks within national building codes, sustainability standards, and housing program protocols ensures that interventions not only meet technical and economic requirements but also respond to the preferences and needs of local communities (BUKHARI *et al*., 2019; Atobatele *et al*., 2019). Ultimately, MCDM contributes to the design and implementation of housing solutions that are affordable, environmentally sustainable, socially acceptable, and capable of delivering lasting impact in diverse urban and peri-urban contexts.

2.5. Challenges and Limitations

While Multi-Criteria Decision-Making (MCDM) frameworks offer a structured approach for evaluating affordable and sustainable housing alternatives, their practical implementation is constrained by several significant challenges and limitations. These limitations span data availability, methodological subjectivity, integration of qualitative insights, and contextual applicability, each of which affects the robustness, reliability, and transferability of decision outcomes.

A primary challenge is data limitations and variability in local construction costs. Accurate assessment of housing alternatives requires comprehensive information on material prices, labor costs, construction timelines, and lifecycle maintenance expenses. In many developing regions, such data are incomplete, outdated, or inconsistent across different locales. Material costs, in particular, can vary substantially due to transportation, local supply fluctuations, and seasonal market conditions. This variability complicates comparative analysis and may lead to inaccurate cost-effectiveness evaluations, reducing confidence in the rankings produced by MCDM frameworks (Ayanbode *et al*., 2019; Adenuga *et al*., 2019). Moreover, lack of reliable performance data for innovative materials such as stabilized soil, laterite, or prefabricated systems further constrains the ability to quantify structural reliability, thermal performance, and long-term durability, limiting evidence-based decision-making.

Another limitation lies in the subjectivity inherent in criteria weighting and stakeholder preferences. MCDM frameworks often rely on expert judgment, participatory workshops, or survey-based approaches to assign relative importance to criteria such as cost, social acceptance, environmental impact, and technical feasibility. While this participatory weighting enhances contextual relevance, it introduces bias and variability in outcomes depending on stakeholder composition, experience, and perspectives. Differences in professional background, policy priorities, or community expectations can produce divergent weightings, affecting the consistency and comparability of results across projects or regions. Sensitivity analysis can mitigate this to some extent, but subjective inputs remain an intrinsic challenge in multi-criteria evaluation.

The integration of qualitative data and uncertainty in future performance further complicates decision-making. Social acceptability, cultural relevance, and user satisfaction are critical dimensions of sustainable housing but are difficult to quantify objectively. Methods such as scoring surveys, interviews, or fuzzy logic can approximate qualitative factors, yet inherent uncertainty in these measures persists. Additionally, projecting long-term performance, including maintenance requirements, energy efficiency, and resilience to environmental stressors, is inherently uncertain, particularly under changing climate conditions or evolving community dynamics. These uncertainties can affect the robustness of alternative rankings and limit the predictive reliability of the MCDM model.

Contextual differences also limit the transferability of MCDM frameworks. Housing decisions are highly influenced by local socio-economic, cultural, and environmental conditions, which vary across cities, regions, and countries. Factors such as local building regulations, material availability, labor practices, and climatic conditions affect both feasibility and acceptability of housing alternatives. Consequently, an MCDM model developed for one region may not be directly applicable to another without careful adaptation of criteria, weighting, and performance metrics. This limits the scalability of standardized frameworks and emphasizes the need for context-specific customization and stakeholder engagement in each application (Durowade *et al*., 2018; Ajayi *et al*., 2019).

The use of MCDM for evaluating affordable and sustainable housing alternatives is constrained by data limitations, subjective weighting, challenges in integrating qualitative insights, and contextual variability. Addressing these limitations requires improved data collection and monitoring, structured participatory methods to balance stakeholder inputs, robust treatment of qualitative and uncertain factors, and careful adaptation to local conditions. Recognizing and mitigating these challenges is essential for enhancing the reliability, transparency, and practical applicability of MCDM frameworks, ensuring that decision-makers can select housing alternatives that are truly sustainable, affordable, and socially acceptable in diverse low- and middle-income contexts.

2.6. Future Research Directions

While Multi-Criteria Decision-Making (MCDM) frameworks have demonstrated substantial potential in evaluating affordable and sustainable housing alternatives, several research avenues remain underexplored, offering opportunities to enhance both methodological rigor and practical applicability as shown in figure 2. One of the most critical directions is the integration of life-cycle assessment (LCA) within MCDM models. LCA provides a comprehensive evaluation of environmental impacts across the full lifecycle of housing materials and construction processes, including raw material extraction, manufacturing, transportation, construction, operation, and end-of-life disposal (Etim *et al*., 2019). By combining LCA with MCDM, researchers can ensure that sustainability assessments account not only for immediate cost and performance criteria but also for long-term environmental consequences such as embodied energy, carbon footprint, water usage, and waste generation. This holistic approach enables decision-makers to balance economic, social, and environmental trade-offs more effectively, guiding the selection of housing alternatives that minimize overall ecological impact while maintaining affordability and functionality.

Another promising research direction involves the application of artificial intelligence (AI) and machine learning (ML) to support rapid, data-driven housing evaluation. AI-driven decision support can automate the processing of complex datasets, identify patterns in performance criteria, and generate predictive models to assess the suitability of multiple housing alternatives under diverse conditions. Machine learning algorithms can optimize weighting schemes, detect non-linear relationships among criteria, and simulate outcomes under variable scenarios, thus enhancing the speed, accuracy, and adaptability of decision-making. Incorporating AI into MCDM frameworks can also support real-time assessments for urban planners and policymakers, enabling dynamic responses to evolving housing demands, resource constraints, and climatic risks.

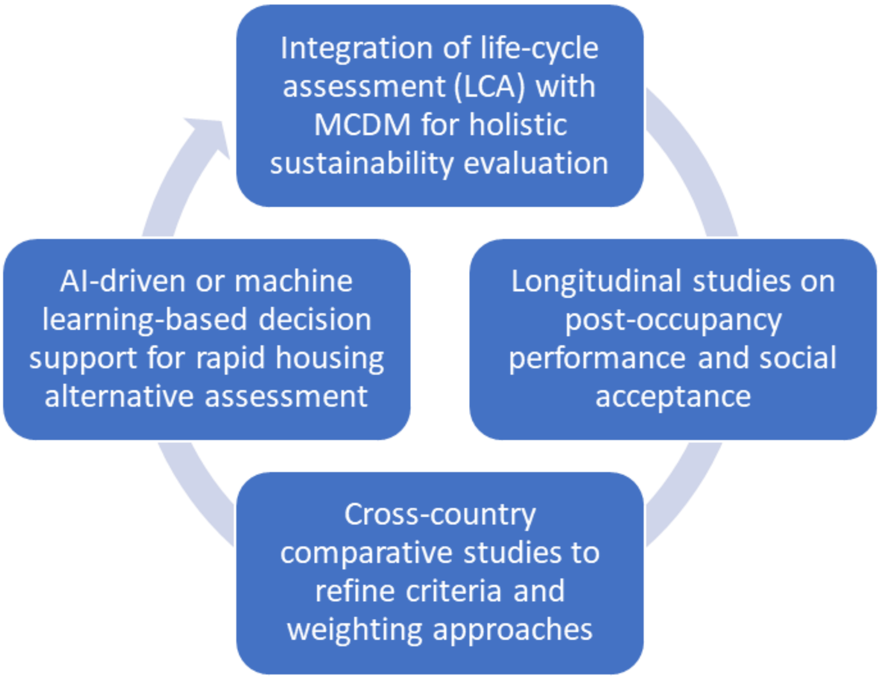

Fig 2: Future Research Directions

Longitudinal studies on post-occupancy performance and social acceptance represent a third vital research avenue. While MCDM models often rely on expert judgment and simulated performance metrics, empirical evidence on the long-term durability, maintenance requirements, and user satisfaction of implemented housing solutions remains limited. Systematic post-occupancy monitoring can track structural integrity, energy performance, thermal comfort, indoor air quality, and other operational parameters over time. Simultaneously, surveys and participatory assessments of occupants' experiences provide insights into cultural, behavioral, and social factors influencing acceptance and sustainability. Longitudinal research ensures that MCDM models are grounded in real-world performance data, facilitating iterative refinement of evaluation criteria, weighting schemes, and design recommendations (Giwah *et al*., 2020; Ikponmwoba *et al*., 2020).

Cross-country comparative studies also offer substantial value for advancing MCDM applications in housing. Urbanization patterns, climate conditions, resource availability, and socio-economic contexts vary widely across regions, influencing both the feasibility and desirability of different housing alternatives. Comparative analyses of MCDM implementations in diverse countries can identify context-specific criteria, refine weighting approaches, and uncover best practices for balancing affordability, sustainability, and social acceptability. Such studies enhance the generalizability of MCDM frameworks, providing guidance for policymakers, NGOs, and planners seeking scalable solutions that can be adapted to multiple geographic and cultural contexts.

The future of MCDM-based evaluation for affordable and sustainable housing lies in methodological innovation, empirical validation, and international collaboration. Integrating life-cycle assessment ensures holistic sustainability evaluation, while AI-driven decision support enables rapid, predictive, and adaptive assessments. Longitudinal post-occupancy studies provide empirical evidence on performance and social acceptance, grounding models in real-world conditions. Cross-country comparative research further enhances the robustness, scalability, and contextual relevance of MCDM frameworks. Addressing these research directions will strengthen the reliability, inclusivity, and policy relevance of housing evaluations, ultimately supporting the design and implementation of solutions that are economically feasible, environmentally sustainable, socially acceptable, and responsive to the evolving needs of urban populations worldwide (Essien *et al*., 2020; Atobatele *et al*., 2019).

3. Conclusion

The Multi-Criteria Decision-Making (MCDM) framework provides a robust tool for evaluating affordable and sustainable housing alternatives, enabling decision-makers to systematically balance economic, environmental, and social objectives. By integrating multiple criteria into a structured evaluation process, the framework facilitates evidence-based comparisons among diverse housing options, allowing planners, policymakers, and practitioners to identify solutions that optimize both cost-effectiveness and long-term sustainability. Through its stepwise approach—including definition of alternatives, identification and weighting of criteria, application of MCDM methods, and sensitivity analysis—the framework ensures that housing decisions are transparent, consistent, and reproducible, reducing reliance on subjective judgment and enhancing accountability in urban planning and housing provision.

Equally important is the framework's participatory dimension, which allows community preferences, cultural considerations, and local priorities to be incorporated into the decision-making process. Engaging stakeholders in criteria selection, weighting, and evaluation not only improves the relevance and acceptability of housing interventions but also fosters social ownership and long-term adoption. The combination of systematic, evidence-based analysis and participatory engagement ensures that MCDM-based evaluations are both technically rigorous and socially responsive, providing a comprehensive tool for sustainable urban development.

In practice, the adoption of MCDM tools can significantly enhance planning, policy formulation, and housing program implementation. Governments, NGOs, and development agencies can leverage the framework to prioritize interventions with the greatest social, economic, and environmental impact, standardize assessment protocols, and align housing policies with sustainability goals. By embedding MCDM approaches into policy instruments, planning tools, and programmatic guidelines, stakeholders can ensure that affordable housing initiatives are not only cost-effective but also environmentally responsible, resilient, and culturally appropriate. Ultimately, the widespread use of MCDM frameworks supports informed, transparent, and inclusive decision-making, strengthening the capacity of urban systems to provide sustainable, high-quality housing solutions for diverse populations in rapidly growing cities.

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