



WALL MATERIAL SELECTION FOR AFFORDABLE HOUSING: INTEGRATED FUZZY AHP AND TOPSIS APPROACHES

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ABSTRACT: The selection of wall material for affordable housing is a multi-attribute decision problem that has to reconcile structural safety, economic circumstances, local implementation conditions, and environmental performance under various regional contexts. This study develops an integrated Fuzzy Analytic Hierarchy Process (FAHP) and Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) framework for the most appropriate wall material for affordable housing in Banjarnegara, Cilacap, and Tasikmalaya regencies, Indonesia. Three mainstream wall alternatives, clay brick, concrete block, and autoclaved aerated concrete (AAC) block, were evaluated using fifteen sub attributes grouped into four attributes: technical, economic, social, and environmental. Expert and practitioner judgments were used to derive the attribute weights using FAHP, and district-specific performance data was utilized in TOPSIS to rank the alternatives. The weight of priority for the technical attribute (0.4739) was stated to be higher than the economic (0.2182), and the social attribute (0.1939), while the environmental attribute received the lowest weight (0.1140). At sub attribute level, structural and seismic safety performance; durability weathering, moisture, and humidity; initial construction cost were the highest impact attributes. TOPSIS placed AAC blocks first in all regencies, followed by clay bricks and concrete blocks.

Keywords: Multi-attribute decision-making, Fuzzy AHP, TOPSIS, Affordable housing, Wall material selection

1. INTRODUCTION

Sustainable housing development relies heavily on selecting wall systems, as early-stage material decisions dictate a building's long-term environmental performance, affordability, and durability. Globally, construction drives the climate crisis, accounting for 32% of global energy consumption and 34% of CO₂ emissions [1]. Consequently, the selection of building materials is not simply a workaday technical specification [2], but a strategic decision that influences embodied carbon and the long term resilience of housing. Wall systems are a significant area of focus because they represent the largest volume of material in most buildings and are structural enclosures, thermal barriers, and load bearing elements. Therefore, the selection protocol must be performed systematically as it has a direct impact on structural mass, indoor comfort, moisture safety and occupant security [3, 4].

The material options are extremely limited due to the severe financial constraints of the affordable housing market in developing regions. In Indonesia, empirical studies show that clay bricks, concrete blocks, and autoclaved aerated concrete (AAC)

blocks are still the most common materials for residential construction and urban housing [5, 6]. One of such modern technology is AAC block that is fast becoming popular and widely adopted in construction practices in Indonesia. The selection amongst these three materials is a complex trade-off of environmental impact, economic viability and engineering performance [6, 7]. The design process is optimized for low income communities by taking into account local socio-technical constraints and the availability and cost-effectiveness of materials [8]. To maximize the benefits of sustainable housing, assessments must go beyond upfront costs to explicitly balance life-cycle expenses and environmental impacts with life-cycle energy analysis, ensuring long-term durability and socio-technical dynamics [9].

The complexity of multi-criteria balancing in project management research has led to the widespread application of Multi-Criteria Decision-Making (MCDM) methods such as VIKOR, COPRAS, AHP, and TOPSIS [10]. These methods present specific advantages that make them appropriate for specific situations, project constraints and different data types [11]. However, deterministic approaches

are generally not suitable for research projects with conflicting objectives, qualitative judgments, and incomplete data. Fuzzy techniques are mainly required to handle subjective expert assessments and the vagueness of human perceptions in the decision process [12]. Therefore, it seems that the combination of FAHP and TOPSIS is the most promising approach to optimize wall material selection in affordable housing projects by balancing the criteria weighting and the robust alternative ranking [12, 13].

The methodological approach is challenging to implement in developing countries like Indonesia, which have limited financial resources and face diverse environmental hazards for affordable housing. Decisions are often very decentralized, as they are driven by homeowners and informal builders with very little technical knowledge, hence materials must be a compromise between performance, affordability, constructability and local acceptance [8]. Housing fragility [14] across Java Island [15, 16] due to severe geographic risks further complicates this environment. For example, Banjarnegara has landslide-prone areas [17], Cilacap is a tropical coastal area that is prone to tsunami [15], and Tasikmalaya is a seismically active area with traditional construction [18]. Therefore, selection of wall materials should be made with changing profiles of these hazards in mind.

But there are three different research gaps in the existing wall material selection MCDM literature despite these urgent requirements. First, while there is much work evaluating advanced wall technologies, little attention is given to the mainstream wall materials that are actually used in affordable housing markets. Second, it is difficult for existing evaluation models to capture the important socio-technical factors unique to developing countries, e.g., supply chain reliability, labor readiness, and cultural acceptance. Third, most studies present a single generalized ranking of materials ignoring differences of structural and environmental priorities across seismic uplands, humid coastal zones, and areas with different market access.

This study proposes an integrated Fuzzy AHP–TOPSIS framework to bridge these gaps for the selection of affordable housing wall in disaster-prone regencies in Indonesia. The framework is capable of dealing with highly uncertain, qualitative, and incomplete linguistic information through the embedding of fuzzy logic. This model assesses common residential materials, synthesizes local socio-technical criteria, and most importantly captures the dynamic nature of changing material priorities in varying geographic and hazard-prone terrains.

The research has three specific objectives: (1) to determine and rank important technical, economic, social, and environmental attributes influencing material selection from the perspective of experts; (2) to systematically evaluate localized performance of clay bricks, concrete blocks, and AAC blocks in three different study regencies; and (3) to provide practical, context-sensitive recommendations to homeowners, builders, and government stakeholders. Overall, this study presents a novel district-level decision support tool that explicitly links regional environmental risks to local construction capacities and socio-economic constraints. The rest of this paper is organized as follows. Section 2 presents the significance of the research; Section 3 presents the research methodology, Section 4 the findings and discussion, and Section 5 concludes with practical implications.

2. RESEARCH SIGNIFICANCE

The significance of this study upholds in its localized, multi-layered perspective on sustainable construction management. It enhances the science of decision-making through a hybrid Fuzzy AHP–TOPSIS framework since it can methodologically connect multi-attribute analysis and regional hazard variations. Effectively, it gives capability to the vulnerable communities by translating complex data into evidence-based recommendations for safer and more affordable housing. The framework may also support the selection of roofing, structural and foundation systems, pavement materials, post-disaster housing components, and other construction products involving uncertain judgments and competing performance requirements.

3. RESEARCH METHODOLOGY

This paper uses a quantitative multi-attribute decision making design (integrating Fuzzy AHP (FAHP) and TOPSIS) to assess and rank affordable housing wall materials in different regional contexts. FAHP ascertains the weights of attributes from consensus decisions made by experts under incompleteness, TOPSIS ranks alternatives corresponding to closeness to an ideal result. There are a six-stage course of action that present broad and region-certain, as follows.

Stage 1: Study areas and case selection

Conducted in three distinct Indonesian regencies, (1) landslide-susceptible of Banjarnegara, (2) tsunami-prone of Cilacap, and (3) seismically active of Tasikmalaya, this comparative case study

investigates the suitability of clay bricks, concrete blocks, and AAC blocks for affordable housing. Each mainstream material involves particular socio-technical trade-offs between cultural acceptance, cost, structural weight, supply reliability, and craftsmanship. This multi-attribute framework thus avoids a flat ranking. Instead, it examines regional environmental hazards, material availability, and local practices to demonstrate how geographic context affects the performance and feasibility of each wall option.

Stage 2: Attribute and field data sources

To address the multi-dimensional nature of affordable housing construction evaluation, attributes were extracted from literature. This framework is structured into technical, economic, social, and environmental dimensions, which recognize that wall selection varies according to mechanical performance criteria, cost factors, availability of supply (raw materials), labour availability, and sustainability considerations. The structure is therefore able to capture the diverse stakeholder preferences while also accommodating qualitative and quantitative decision-making criteria.

Field data collection utilized a triangulation of sources approach through the integration of well-accepted technical standards, an extensive market survey, and stakeholder questionnaires across three districts to avoid biases and enhance transparency. Attributes were categorized into benefit or cost drivers, operationalized by quantified sub-indicators, and transformed via crisp performance scores. Three wall alternatives were assessed against fifteen localized sub attributes to construct individual district-specific TOPSIS decision matrices.

Stage 3: Respondents and questionnaire design

The decision matrix was developed using two groups of respondents for its constitution. First, for the FAHP weighting, thirty purposively selected experts (including 10 academics, 10 engineers, and 10 government officers) provided pairwise judgments by accommodating regulatory, scientific, and practical perspectives. Second, thirty locally based field respondents (homeowners, builders, and suppliers from the three regencies) accompanied the TOPSIS performance assessment with a local market survey. They were also required to understand the wall materials evaluated in this study and to have professional exposure to at least one of the study regions or to comparable Indonesian construction

environments. Data was collected by questionnaire after a pilot study. Fuzzy linguistic scales were used to limit the subjective and uncertain nature of recorded data by realistically translating expert opinion into specific, robust figures and non-biases.

Stage 4: FAHP weighting procedure

The relative importance of attributes was determined using FAHP based on pairwise comparison matrices. Respondents compared each attribute using a linguistic scale corresponding to Saaty's 1–9 preference logic. Each expert compares the relative importance of two attributes using a linguistic scale characterized by triangular fuzzy numbers (TFNs). A triangular fuzzy number is expressed as Eq. (1).

$$\tilde{a}_{ij} = (l_{ij}, m_{ij}, u_{ij}) \quad (1)$$

Where: $\tilde{a}_{ij}$ denotes the fuzzy comparison value between attribute i and j . l_{ij} ; m_{ij} and u_{ij} represent the lower, middle, and upper values of the fuzzy judgment. The reciprocal comparison is expressed as Eq. (2).

$$\tilde{a}_{ji} = \left(\frac{1}{u_{ij}}, \frac{1}{m_{ij}}, \frac{1}{l_{ij}} \right) \quad (2)$$

In this study, 30 expert respondents provided individual pairwise comparison judgments, resulting in 30 separate priority weight vectors. To synthesize these individual weights into a single consensus weight vector, the geometric mean aggregation technique was applied. This method is the standard and mathematically rigorous approach for combining multiple expert judgments in AHP-based studies, as it is the only aggregation method that strictly preserves the reciprocal attribute of pairwise comparison matrices [15, 18]. For multiple experts, individual fuzzy pairwise comparisons are aggregated using the geometric mean, as in Eq. (3).

$$\tilde{a}_{ij}^G = \left[\left(\prod_{k=1}^K l_{ij}^k \right)^{1/K}, \left(\prod_{k=1}^K m_{ij}^k \right)^{1/K}, \left(\prod_{k=1}^K u_{ij}^k \right)^{1/K} \right] \quad (3)$$

Where: K is the number of experts. The fuzzy geometric mean for each attribute is then calculated, followed by the derivation of fuzzy weights. The fuzzy weights (C_i) were subsequently defuzzified using the centroid method (Eq. (4)). and normalized weight (w_i) to obtain the final local weight (Eq. (5)).

$$C_i = \frac{l_i + m_i + u_i}{3} \quad (4)$$

$$w_i = \frac{c_i}{\sum c_i} \quad (5)$$

The global weight of each sub attribute was obtained by multiplying the local sub attribute weight by the corresponding parent attribute weight, as described in Eq. (6).

$$GW_{sa} = W_{pa} \cdot W_{sa} \quad (6)$$

Where: GW_{sa} = global weight of subattribute; W_{pa} = individual parent attribute weight; W_{sa} = individual sub attribute weight.

To confirm the reliability of expert judgments, the consistency of each comparison matrix was assessed using the consistency ratio (CR) using Eq. (7). A CR value less than 0.10 was considered to be logically consistent judgments.

$$CR = \frac{CI}{RI} \quad (7)$$

Where: CI (consistency index) = $\frac{\lambda_{max} - n}{n - 1}$, λ_{max} (principal eigenvalue) = $\frac{1}{n} \sum_{i=1}^n \frac{(Aw)_i}{w_i}$, $(Aw)_i$ is the i element of the vector resulting from the multiplication of the original comparison matrix and the weight vector, and Random Index (RI) denotes the random index conforming to the matrix order n .

Stage 5: TOPSIS ranking procedure

After deriving the attribute weights, the alternative materials were ranked using TOPSIS, based on the theory that the preferred alternative should have the shortest distance from the positive ideal solution and the farthest distance from the negative ideal, as follows. First, construction of the decision matrix indicating the performance of each alternative under each attribute, then normalization of the decision matrix. Let x_{ij} denote the performance of alternative i on attribute j . The decision matrix was first normalized using vector normalization, as mentioned in Eq. (8).

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^m x_{ij}^2}} \quad (8)$$

Second, multiplication of the normalized matrix by the FAHP-derived attribute weights. The weighted normalized value was then obtained as in Eq. (9).

$$v_{ij} = w_j r_{ij} \quad (9)$$

Where: w_j is the global weight produced by FAHP.

Third, determination of the positive and negative ideal solutions. The positive ideal solution (v_j^+) and negative ideal solution (v_j^-) were determined from the best and worst values of each attribute (Eqs. (10-

11)). These were determined by distinguishing between Benefit attributes and Cost attributes.

$$v_j^+ = \begin{cases} \max_i(v_{ij}), & \text{if } j \in J \text{ (Benefit)} \\ \min_i(v_{ij}), & \text{if } j \in J' \text{ (Cost)} \end{cases} \quad (10)$$

$$v_j^- = \begin{cases} \min_i(v_{ij}), & \text{if } j \in J \text{ (Benefit)} \\ \max_i(v_{ij}), & \text{if } j \in J' \text{ (Cost)} \end{cases} \quad (11)$$

Fourth, calculation of the Euclidean distance of each alternative from the ideal solutions. The Euclidean distances (D_i) of each alternative from these ideal solutions were then computed as Eqs. (12) and (13). Finally, the TOPSIS method was employed to calculate the closeness coefficient (CC_i) for ranking the alternatives (Eq. (14)).

$$D_i^+ = \sqrt{\sum_{j=1}^n (v_{ij} - v_j^+)^2} \quad (12)$$

$$D_i^- = \sqrt{\sum_{j=1}^n (v_{ij} - v_j^-)^2} \quad (13)$$

$$CC_i = \frac{D_i^-}{D_i^+ + D_i^-} \quad (14)$$

A larger number of CC_i indicates a more preferable wall material in the corresponding district context. This value can be understood as a "higher is better" value. Theilig et al. [7] have recently compared MADM methodologies and identified TOPSIS as one of the more applicable MADM methodologies for building-part decisions. TOPSIS is effective when paired with fuzzy-derived weights and normalized material-performance data [12].

Stage 6: Sensitivity Analysis and Field-Based Comparison

The robustness of the FAHP–TOPSIS results was evaluated through sensitivity analysis and field-based comparisons. The effect of the final TOPSIS rankings for all three regions was then assessed by using Eqs. (8–14) with the criteria weight (technical, economic, social, and environmental) increases of 10%, 15%, and 29% in the sensitivity analysis. A ranking was considered robust if the preferred alternative was consistent for most of the scenarios. If the ranking changed, it was interpreted as an indication that the material selection was sensitive to specific decision priorities.

In addition, a field comparison was done by a survey of the actual use of wall materials in 130 newly built houses in Banjarnegara, Cilacap, and Tasikmalaya. The survey also gave reasons for the choice of materials such as affordability, local availability, familiarity with workmanship, perceived safety, and community acceptance. This comparison does not imply that the most used material was the

most suitable alternative in technical terms. Instead, it served as a test of empirical plausibility to verify whether the FAHP–TOPSIS ranking was consistent with local construction practices and market realities. The difference between the model recommendation and current field practice was interpreted as an implementation gap between the technically optimal material and the material most commonly adopted by local communities.

4. RESULTS AND DISCUSSIONS

4.1 Attribute Operational Definition

The literature review and preliminary discussion with the experts identified 15 sub attributes, which

were grouped under 4 main attributes as given in Table 1. These attributes were selected to represent the core technical, economic, social, and environmental factors influencing the viability, performance, and sustainability of wall materials in affordable housing projects. To avoid indicators, overlap and to provide consistent interpretation, measurement and conversion into the performance scores needed for the TOPSIS decision matrix, operationalization was used for each sub attribute. All sub attributes were of the benefit–cost orientation. Raw value of sub attributes for “Benefit” indicated that the higher the raw value, the better the performance. For “Cost” sub attributes, a lower raw value represented better performance and was assigned a higher score after inverse conversion.

Table 1. Attributes and operational definitions

Code	Attribute and Sub attribute	Operational Definition	Type
Technical			
T1	Structural and seismic safety performance [14, 17]	Degree to which the wall material reduces seismic force and maintains integrity under lateral loading, cracking, and out-of-plane action.	Benefit
T2	Weathering, moisture, and humidity durability [17]	Capability of the wall material to resist moisture ingress, humidity exposure, weathering, and deterioration in wet/coastal environments.	Cost
T3	Thermal and acoustic comfort [15]	Capacity of the wall material to provide indoor thermal stability and sound insulation for residential comfort.	Benefit
T4	Constructability and workmanship compatibility [15]	Ease with which the material can be transported, cut, assembled, and installed correctly by local workers using available tools and methods.	Benefit
Economic			
E1	Initial construction cost [15, 18]	Direct upfront cost required to procure and install the wall material in affordable housing construction.	Cost
E2	Life-cycle maintenance and repair cost [14, 17]	Expected long-term cost burden associated with maintenance, repair, replacement, or moisture-related deterioration during service life.	Cost
E3	Local availability and supply reliability [15, 18]	Degree to which the material is consistently available in local markets and can be supplied without major delay or uncertainty.	Benefit
E4	Price stability and market volatility [17]	Degree to which material prices remain stable and predictable over time under local market conditions.	Benefit
Social			
S1	Cultural and aesthetic acceptance [15]	Extent to which the material aligns with local housing preferences, visual expectations, and culturally accepted building practices.	Benefit
S2	Availability and readiness of skilled local labour [15, 18]	Extent to which local masons/craftsmen possess adequate familiarity and skill to use the material properly.	Benefit
S3	Perceived occupant safety and confidence [14, 17]	Level of confidence among occupants and local stakeholders that the wall material is safe, reliable, and protective during hazards and daily use.	Benefit
S4	Compliance with local regulations and standards [15, 18]	Degree to which the wall material complies with building codes, standards, and locally acceptable construction requirements.	Benefit
Environmental			
L1	Embodied energy and embodied carbon [15, 17]	Amount of energy consumed and greenhouse gas emissions generated from raw material extraction, manufacturing, and transport to site.	Cost
L2	Material circularity Potential [14, 17, 19]	The potential of the material to be reused, recycled, recovered, or reintegrated into circular construction flows at the end of service life.	Benefit
L3	Local ecological impact and resource extraction pressure [19, 20]	Degree of local environmental damage associated with raw material extraction, land degradation, biomass use, or ecosystem disturbance.	Cost

4.2 FAHP Weighting Results

The results of the FAHP based on Eqs. (1-6) show that the decision model was mainly controlled by the technical attribute with the highest weight of 0.4739. The economic attribute was next with a weight of 0.2182, followed by the social attribute with 0.1939 and the environmental attribute with 0.1140. All pairwise comparison matrices satisfied the consistency requirement, with CRs (Eq. (7)) below the conventional threshold of 0.10, implying the expert judgments were logically consistent and acceptable for further synthesis, as in Table 2. These findings confirm that the selection of wall material for affordable housing in the three study areas is driven more by safety, hazard resilience, and service performance than by affordability alone. Recent studies in MCDM also support this pattern by suggesting that construction material selection needs a hierarchical structure of attributes, consistency checks, and hybrid decision support methods [10, 19–21].

At the sub attribute level, the structural and seismic safety performance (T1) carried the largest global weight (0.2244), followed by weathering, moisture and humidity durability (T2) (0.1558) and initial construction cost (E1) (0.1062). These three sub attributes accounted for 0.4864, or approximately 48.64% of the total decision weight.

This result indicates that nearly half of the decision structure focused on seismic safety, durability for environmental exposure, and initial

affordability. Thus, although the study is about affordable housing, the expert panel did not consider the lowest price as the dominant basis of selection. Only when the material also meets safety and durability requirements, affordability become important. Recent hybrid FAHP–TOPSIS material-selection studies have reported similar findings, balancing cost, performance, and sustainability attributes using expert-based weighting and ideal-solution ranking [10, 21].

The high priority for structural and seismic safety performance (T1) and durability against weathering, moisture, and humidity (T2) is consistent with hazard-specific conditions of the three study areas. Banjarnegara and Tasikmalaya are inland, hilly regions where seismic exposure, wall mass, cracking behaviour, and quality of workmanship are critical concerns. Cilacap, as a southern coastal area, adds stronger challenges on humidity, moisture ingress, and long-term material deterioration.

The dominance of the technical attribute indicates that hazard resilience and functional performance were the primary drivers in the decision-making context. The importance of T1 indicates that the respondents were concerned about the behaviour of the walls during an earthquake since the damage of affordable housing is often affected by factors of the nominal strength of wall units such as wall mass, cracking behaviour, mortar compatibility, workmanship quality and interaction with the surrounding structural system.

Table 2. FAHP weights of attributes and sub attributes

Code	Attributes and Sub attributes	CR	Global Weight	
			Attributes	Sub-Att.
	Technical	0.0795	0.4739	
T1	Structural and seismic safety performance			0.2244
T2	Weathering, moisture, and humidity durability			0.1558
T3	Thermal and acoustic comfort			0.0467
T4	Constructability and workmanship compatibility			0.0469
	Economic	0.0276	0.2182	
E1	Initial construction cost			0.1062
E2	Life-cycle maintenance and repair cost			0.0463
E3	Local availability and supply reliability			0.0455
E4	Price stability and market volatility			0.0202
	Social	0.0359	0.1939	
S1	Cultural and aesthetic acceptance			0.0565
S2	Availability and readiness of skilled local labour			0.0488
S3	Perceived occupant safety and confidence			0.0476
S4	Compliance with local regulations and standards			0.0409
	Environmental	0.0415	0.1140	
L1	Embodied energy and embodied carbon			0.0466
L2	Material circularity potential			0.0303
L3	Local ecological impact and resource extraction pressure			0.0371
	Sum		1.00	1.00

This interpretation is in line with recent studies that emphasize the importance of avoiding decisions on building material and envelope based on a single performance indicator, and including technical performance, uncertainty, environmental exposure and multi-criteria trade-offs [17, 22].

The weight assigned to T2 confirms that durability in moisture was considered one of the main performance variables and not just a secondary maintenance problem. The warm and humid climate of Cilacap and coastal areas in general can impact on service life, decay in and out, indoor comfort, aesthetic appearance, as well as cracking, surface staining, and the ongoing repair burden of repeated wetting-drying cycles from that humidity. The third most important sub attribute, initial construction cost (E1), indicates that affordability is still an important consideration in affordable housing but less so than the safety and durability considerations. Respondents clearly distinguished between short-term affordability and suitability across a product's life cycle as a material with a lower total cost may be less rational if it has poor performance in the face of hazards or excessive long-term maintenance [14, 22].

Although the environmental attribute is the least weighted in terms of overall weight, it still plays a significant role in the decision hierarchy. The embodied energy and embodied carbon weight (L1 = 0.0466) was comparable to some technical and economic sub attributes indicating environmental performance as a complementary sustainability filter rather than the primary determinant of material suitability as mentioned in some previous references [15, 17]. Social factors such as cultural acceptance and local labour readiness should be considered as implementation modifiers since they influence the

practical adoption of material in the local construction practice. The FAHP results generally show a balanced hierarchy and are context sensitive. Technical safety and durability form the main basis for selection, whereas economic feasibility, social acceptance and environmental responsibility contribute to the refinement of the final material decision.

4.3 TOPSIS Ranking Results

The TOPSIS analysis was performed to determine the relative preference of three wall-material alternatives in the three distinct study regencies. The calculation used the global weights derived from FAHP as the weighting input, while the performance scores of each alternative were structured into three district-specific decision matrices. Table 3 presents a sample the original unit of each sub attribute performance for Banjarnegara. In order to conduct TOPSIS analysis, all quantitative and qualitative indicators were first normalized using vector normalization, as in Eq. (8). Qualitative indicators arranged from expert assessment or stakeholder perception. This procedure ensured that the TOPSIS decision matrix contained dimensionless and comparable performance scores, enabling fair evaluation among clay brick, concrete block, and AAC block across all attributes and study regencies.

Based on Eqs. (8-14), the TOPSIS method got a stable rank pattern in the three regencies. The AAC block was ranked first, while the clay brick was ranked second and the concrete block was ranked third, as shown in Table 4.

Table 3. Original-unit data of wall-material alternatives in Banjarnegara, Cilacap, and Tasikmalaya, respectively

Code	Subattributes	Type	Unit	Wall Materials		
				Clay Brick	Concrete Block	AAC Block
T1	Structural and seismic safety performance	Benefit	Suitability index (expert score)	2.8; 3.5; 3.0	2.2; 2.5; 2.2	4.5; 5.0; 4.5
T2	Weathering, moisture, and humidity durability	Cost	Water absorption (%)	17%; 18%; 17%	23%; 16%; 21%	18%; 24%; 18%
T3	Thermal and acoustic comfort	Benefit	Thermal conductivity W/mK	0.72; 0.72; 0.72	0.95; 0.95; 0.95	0.16; 0.16; 0.16
			and sound insulation dB	±45; ±45; ±45	±40; ±40; ±40	±42; ±42; ±42
T4	Constructability and workmanship compatibility	Benefit	Installation productivity m ² /day/team	7; 7; 7	9; 9; 9	9; 11; 9
E1	Initial construction cost	Cost	IDR-thousand/m ²	190; 185; 180	165; 165; 165	255; 225; 240
E2	Life-cycle maintenance and repair cost	Cost	IDR-thousand/m ² /year	20; 24; 20	25; 28; 25	14; 18; 15
E3	Local availability and supply reliability	Benefit	Material lead time days	2; 2; 1	2; 1; 2	6; 3; 4

E4	Price stability and market volatility	Benefit	Price fluctuation (%)	7%; 6%; 6%	6%; 5%; 6%	13%; 8%; 10%
S1	Cultural and aesthetic acceptance	Benefit	Likert score	4.06; 4.50; 4.70	3.08; 3.80; 3.80	3.03; 3.70; 3.60
S2	Availability and readiness of skilled local labour	Benefit	Ready-skilled labour proportion, %	90%; 90%; 92%	86%; 88%; 86%	45%; 65%; 58%
S3	Perceived occupant safety and confidence	Benefit	Likert score	3.06; 3.30; 3.60	3.00; 3.10; 3.00	4.01; 4.00; 4.10
S4	Compliance with local regulations and standards	Benefit	Compliance proportion, %	78%; 82%; 80%	72%; 78%; 72%	85%; 88%; 86%
L1	Embodied energy and embodied carbon	Cost	kg CO ₂ e/m ²	95; 92; 94	78; 76; 78	65; 68; 66
L2	Material circularity potential	Benefit	Reuse/recycling potential	35%; 35%; 35%	30%; 35%; 30%	55%; 55%; 55%
L3	Local ecological impact and resource extraction pressure	Cost	Impact index (expert score)	4.2; 4.10; 4.50	3.2; 3.30; 3.20	2.4; 2.50; 2.50

Table 4. TOPSIS ranking results

Alternatives	D_i^+	D_i^-	CC_i	Rank
Banjarnegara				
Clay brick	0.0889	0.0760	0.4608	2
Concrete block	0.1146	0.0820	0.4171	3
AAC block	0.0798	0.1182	0.5971	1
Cilacap				
Clay brick	0.0663	0.0686	0.5083	2
Concrete block	0.0931	0.0787	0.4581	3
AAC block	0.0778	0.0958	0.5518	1
Tasikmalaya				
Clay brick	0.0729	0.0769	0.5136	2
Concrete block	0.1014	0.0822	0.4475	3
AAC block	0.0793	0.1061	0.5721	1

The AAC block always got the highest preference value in all three regencies. The CC_i value of the AAC block in Banjarnegara was 0.5971, Cilacap was 0.5518, and Tasikmalaya was 0.5721. The second largest was clay brick with CC_i values of 0.4608, 0.5083, and 0.5136, respectively, in all regencies. The third rank was concrete block with CC_i values in the range of 0.4171 to 0.4581. The consistency of this ranking supports the appropriateness of TOPSIS in determining alternatives closest to the ideal solution when several technical, economic, social and environmental attributes are considered simultaneously [12, 14]. In each regency, as shown in Figure 1, there is a clear three-tier structure in which AAC block is always superior to clay brick and concrete block.

The high-performance score assigned to AAC blocks under the structural and seismic safety sub-attribute should be interpreted primarily as a potential advantage associated with its relatively low unit weight. A lighter wall can reduce building dead load and earthquake-induced inertial demand. However, quality of implementation and structural details are important in the assessment of AAC

block-based wall systems. The response of an AAC block wall system also depends on the structural configuration, wall confinement, wall-to-frame and wall-to-roof connections, reinforcement and anchorage, opening arrangement, compatible adhesive mortar, workmanship, and compliance with applicable seismic detailing requirements. Ultimately, the TOPSIS results reflect AAC block's comparative performance under this study's specific criteria, not an absolute guarantee of its earthquake safety.

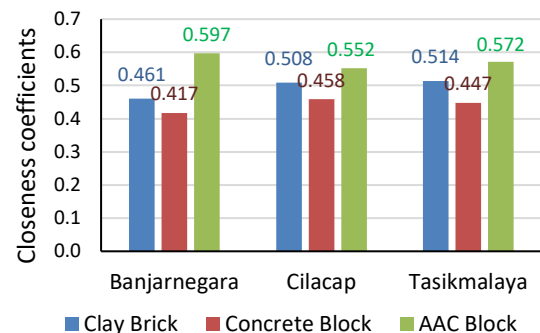


Figure 1. TOPSIS closeness coefficients of wall-material alternatives

The main reason for the superiority of AAC blocks is their sound performance in the highly weighted technical sub attribute, in which the global weights of T1 and T2 were the highest in the FAHP results, and the alternatives with better performance of structural safety, seismic response, and exposure resistance were associated with stronger TOPSIS preference values. The structural and seismic performance characteristics of the AAC block obtained a high score in the three regencies, thereby reducing the distance from the positive ideal solution. However, quality of implementation and structural details are important in the assessment of AAC based wall systems.

The results also provide the contextual differences of the three regencies. The AAC block was ranked first in Banjarnegara, indicating that technical performance and seismic safety considerations were more important than the familiarity with conventional materials. The AAC block also became the highest rank in Cilacap. The higher difference between AAC block and clay brick shows that moisture durability and exposure to coastal conditions were the main reasons for the choice. An underline is especially relevant for the southern coast of Java including Cilacap, which is exposed to tsunamis and other coastal hazards where moisture-related performance is critical for the long-term durability of the building envelope. The highest total score was obtained by AAC block in Tasikmalaya. This is in line with the need to highlight seismic performance in regions prone to local earthquake hazard and ground-condition variability [15, 16, 18].

Clay brick was the second most common material in all regions due to local availability, cultural convenience, and ease of labour. Thus, the choice of materials for affordable housing is frequently determined by local building practices and the trust of the communities. Where local masonry traditions are dominant, factors such as cultural acceptance, availability of skilled labor, occupant perceptions of safety, and availability—rated highest by clay brick—are especially important. This is consistent with the work on material suitability in developing contexts where it has been shown that appropriate material selection may be influenced not only by ease of engineering, but also local capacity, access to markets and cultural acceptance [8]. But that placed clay brick just below the top rank as AAC block was technically superior. Third was concrete block, showing that its price advantage could not compensate for its lower performance on the more highly rated technical and durability characteristics. Finally, the TOPSIS method results in a multi-dimensional compromise among safety, durability, cost, social acceptance and environmental sustainability [10, 12].

The FAHP–TOPSIS analysis shows that the best alternative wall material for affordable housing in the three study regencies is AAC block. AAC is not the cheapest, or most familiar, option but it offers a performance that hits the balance across the four pillars of technical benefit, resilience, serviceability, and sustainability. However, this recommendation of AAC blocks should be moderated in context sensitive by providing the implementation barriers such as availability of adhesive mortar, trained labour, cutting tools, quality control, and market acceptance. This evidence finally advocates the potential of the

integrated FAHP-TOPSIS model as a transparent decision-support tool for the selection of technically high-performing, economically affordable, socially acceptable, and environmentally sound wall materials.

4.4 Practical Implications

The research shows that the choice of wall materials for affordable housing should not be based on conventional or apparent low initial costs. Developers should be incentivized to use materials appropriate to local hazard realities, not the temporary market rates and policymakers should incentivize wall systems that improve structural safety as well as environmental credentials. In the end, affordable housing materials must be resilient in many ways. Stakeholders need to move away from decisions based on cost or sustainability alone, to a balanced approach which is locally appropriate and takes into account real-world hazard and exposure conditions.

4.5 Sensitivity Analysis and Field-Based Comparison

A global sensitivity analysis was conducted to evaluate how changes in criteria (technical, economic, social, and environmental) weights impact the final TOPSIS rankings. The sensitivity analysis conducted for the purpose of evaluating a 10%, 15%, and 29% weight increase followed by normalization via the scale range method. By applying for Eqs. (8–14) to the comprehensive data across all three regions, the analysis determined the TOPSIS closeness coefficients for the three types of wall materials.

The sensitivity outcomes are presented in Figs. (2-4), that the final rank is very stable across all scenarios, while there were small fluctuations in the final values but no ranks reversals. The AAC block consistently occupies first place, followed by clay bricks and concrete blocks in that order.

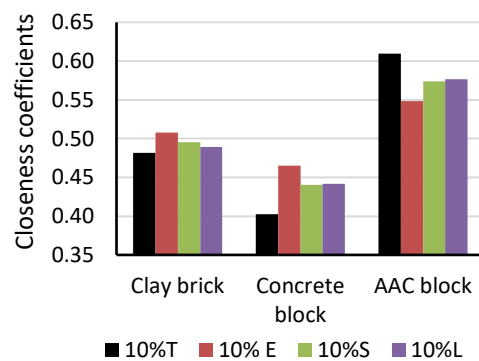


Fig. 2. Sensitivity analysis for 10% additional weight

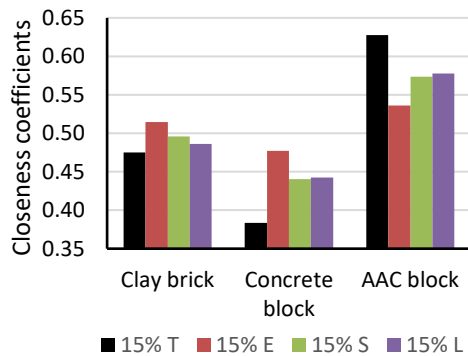


Fig. 3. Sensitivity analysis for 15% additional weight

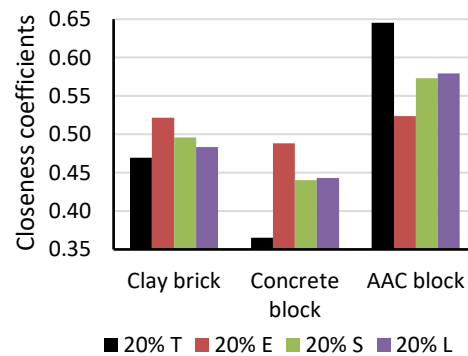


Fig. 4. Sensitivity analysis for 20% additional weight

The top parameter of stability verifies that the FAHP–TOPSIS model is sufficiently stable and highly insensitive to slight changes in weight values. Such type of structural robustness is important for models supporting the selection of construction materials where the priorities of stakeholders are competing often in different dimensions [10, 12].

The AAC block performed well in all the three study regions consistently. This shows that the technical advantages of the AAC block were sufficient to overcome the initial cost disadvantage. It guides the choices to promote not only money efficiency but also safety, functionality, feasibility, and sustainability. This result is more consistent with the present hybrid MCDM literature suggesting that the lowest cost building material in a multi-constituent structured application is often a sub-optimal choice as it generally performs better over a broad range of decision variables [10].

Sensitivity analysis is not the only way to check the plausibility of the results. An empirical verification of the local construction realities was made by comparing recommendations derived from the FAHP–TOPSIS model with those built on the field. A survey of data on the practical side of implementation was conducted in 130 newly built homes. This included availability of materials, labour

availability, cultural acceptability, perceived safety of occupants and market dynamics as ground level indicators. The results show that traditional masonry is the preferred choice of people in the study areas with market shares of 39% for clay brick, 36% for AAC block and 25% for concrete block. The difference is less a contradiction than an essential gap in implementation. The professional stakeholders involved in model development preferred the AAC block with better performance in heavily weighted categories due to their technical knowledge. Individual homeowners were a smaller percentage of survey respondents but were the majority of end users. They preferred clay brick because of its entrenched place in local building culture, local availability and its full backing by existing artisan skills and mature supply chains.

The socio-technical barriers explaining the adoption of clay brick over AAC blocks reveal different regional specifics showing the need to promote the advantages of AAC in affordable housing. Besides hilly and remote Banjarnegara, there is also a paradox where the geological need for lightweight AAC blocks to reduce landslide hazards is still widely used in the form of conventional clay bricks. Research shows AAC blocks are more resistant to aggressive marine climates and coastal moisture than traditional wall materials. But socio-financial conditions still bind builders in Cilacap to the older conventional products. However, the deviation in Tasikmalaya was due to labour practice and historical confidence in builders reverting to traditional clay brick construction ignoring seismic friendly low mass designs. The AAC blocks are a recent invention that is gradually gaining acceptance in the Indonesian masonry market. To scale up its use, reliable supply networks, upskilling of the masonry labor force, localized training on adhesive-mortar applications and strict on-site monitoring are required. The analysis shows that the selection of materials for affordable housing is not so much a technical optimization problem, but an implementation issue that is driven by cost, local technical capability, community acceptance and market readiness [10].

The results should be interpreted within the constraints of the model and dataset, which included only three wall materials and three regencies, and should not be extended without recalibration. Although fuzzy aggregation and consistency testing were used, expert judgments are still partly subjective and costs, labour, workmanship, product quality, and environmental data may vary across time and locations. Given the dependence of MCDM rankings on criteria, weights, hazards, regulations and market conditions, future applications should

update the data, re-evaluate the weights and consider additional wall systems.

5. CONCLUSIONS

This study proposes an integrated FAHP-TOPSIS decision-support framework for wall material selection of affordable housing in three Indonesian regencies with different hazard, market, and construction conditions. The results of FAHP showed that the most dominant factor was the technical attribute with a weight of 0.4739, followed by economic (0.2182), social (0.1939) and environmental (0.1140) attributes. The highest global weight at the sub attribute level was for structural and seismic safety performance (0.2244), followed by weathering, moisture, and humidity durability (0.1558), and initial construction cost (0.1062). The results suggest that safety, durability, and service performance were weighted more heavily than cost alone in the expert and practitioner judgements, although affordability was still found to be a crucial factor in affordable housing.

The TOPSIS result showed that AAC block was the most preferable wall-material alternative with closeness coefficient of 0.5971, 0.5518 and 0.5721 in Banjarnegara, Cilacap and Tasikmalaya, respectively. The sensitivity analysis also showed that the ranking was robust for 10%, 15% and 20% changes in the main attribute weights, which suggests that the recommendation was not dependent on a narrow condition of weighting. However, a comparison in the field showed an implementation gap. The AAC block performed best in the model, but the clay brick is still more supported by local practice, because of cultural acceptance, familiarity of labour, local availability, and established supply chains.

Although the AAC blocks can be recommended as the most suitable wall material for affordable housing in study areas, reliable supply chains, skilled labor, correct application of adhesive mortar, construction supervision, and cost control strategies must support its deployment. The primary contribution of this study is a context-sensitive MADM framework that integrates expert judgment, district-level hazard exposure, local construction practice, socio-economic constraints, and sustainability attentions into a single decision-support model for selecting wall materials that are feasible, resilient, affordable, and suitable for affordable housing areas prone to disasters.

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