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A Multi-Criteria Decision-Making Framework for Selecting Construction Methods in Residential Building Projects

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Abstract - *Selecting an appropriate construction method for a residential building project is a decision that directly influences project cost, duration, quality, and long-term sustainability. In practice, this choice is rarely governed by a single factor; it involves trade-offs among several, often conflicting, criteria such as cost, construction time, quality, labor availability, environmental impact, and site conditions. Most residential builders continue to rely on informal judgement or past experience when choosing between conventional cast-in-situ construction, precast concrete, modular or prefabricated systems, steel framing, or insulated concrete forms (ICF), which frequently leads to cost overruns, schedule delays, or a mismatch between the chosen method and the project's actual requirements. This paper proposes a structured Multi-Criteria Decision-Making (MCDM) framework that integrates the Analytic Hierarchy Process (AHP), used to determine the relative importance of selection criteria, with the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS), used to rank candidate construction methods. Seven criteria and their sub-criteria were identified through a review of prior literature, and pairwise comparisons were used to derive consistent criteria weights (Consistency Ratio below 0.10). The framework is demonstrated on an illustrative residential project comparing five construction methods. The results indicate that modular/prefabricated construction achieved the highest closeness coefficient, followed by precast concrete, mainly due to its advantage in construction time and quality control. The proposed framework gives project managers and homeowners a transparent, repeatable, and quantitatively defensible tool for construction method selection.*

Key Words: Multi-Criteria Decision Making (MCDM), Analytic Hierarchy Process (AHP), TOPSIS, Construction Method Selection, Residential Construction, Modular Construction, Decision Support Framework

1. INTRODUCTION

1.1 Background and Significance

The residential construction sector is under continuous pressure to deliver housing faster, at lower cost, and with a smaller environmental footprint. A wide range of construction methods is now available to meet this demand, ranging from conventional cast-in-situ reinforced cement concrete (RCC) construction to precast concrete systems, modular or prefabricated construction, light-gauge steel framing, and insulated concrete form (ICF) systems. Each method carries a distinct combination of cost, speed, quality, labour requirement, and environmental performance, and no single method is optimal for every project. The method selected at the planning stage has a lasting influence on the project's schedule, budget, structural performance, and the ease with which it can be maintained over its service life.

Despite the availability of these alternatives, the decision on which construction method to adopt for a residential project is frequently made informally, based on a contractor's familiarity with a particular method, local availability of materials, or simple cost comparisons that ignore other important factors such as time, quality, and sustainability.

1.2 Problem Statement

Construction method selection is inherently a multi-criteria problem: cost, time, quality, labour availability, sustainability, site constraints, and safety rarely point to the same choice, and improving one criterion often comes at the expense of another. Ad hoc or purely experience-based selection does not provide a transparent or repeatable basis for this trade-off, and it becomes difficult to justify the chosen method to clients, financiers, or regulatory bodies. There is, therefore, a need for a structured, quantitative decision-support framework that can systematically weigh multiple criteria and rank the available construction methods for a given residential project.

1.3 Objectives of the Study

- To identify the key criteria and sub-criteria that influence the selection of construction methods for residential building projects.
- To determine the relative importance (weights) of these criteria using the Analytic Hierarchy Process (AHP).
- To rank a set of candidate construction methods using the TOPSIS technique.
- To demonstrate the proposed framework through an illustrative case application and discuss its practical implications.

2. LITERATURE REVIEW

Multi-criteria decision-making methods have been widely used in construction management to support decisions such

as contractor selection, material selection, procurement route selection, and site selection, since these problems typically involve several qualitative and quantitative criteria that cannot be reduced to a single figure of merit. The Analytic Hierarchy Process, developed by Saaty [1], structures a decision problem into a hierarchy of goal, criteria, and alternatives, and uses pairwise comparisons to derive consistent relative weights; its main strength lies in the built-in consistency check, which flags judgements that are logically contradictory.

TOPSIS, introduced by Hwang and Yoon [2], ranks alternatives by their geometric distance from a hypothetical ideal solution and a hypothetical negative-ideal solution, favouring alternatives that are simultaneously close to the best and far from the worst performance on each criterion. Comparative reviews of MCDM techniques, such as that of Triantaphyllou [3] and Ishizaka and Nemery [7], report that combining a weighting method like AHP with a ranking method like TOPSIS is a common and effective hybrid approach, since it separates the subjective task of weighting criteria from the comparatively objective task of ranking alternatives against those weights. Opricovic and Tzeng [8] further compared TOPSIS with the related VIKOR method and noted that TOPSIS remains attractive for its computational simplicity and intuitive geometric interpretation.

On the construction-methods side, established references on construction planning, such as Illingworth [4], describe the technical trade-offs between conventional, precast, and modular construction in terms of speed, site congestion, and quality control, while cost-estimation references such as Peurifoy and Oberlender [6] highlight how method choice drives both direct and indirect project cost. However, most of this guidance remains descriptive rather than providing a quantitative ranking procedure. The present study builds on this body of work by combining AHP and TOPSIS into a single, replicable framework specifically tailored to residential construction method selection, and by illustrating its use with a worked example.

3. RESEARCH METHODOLOGY

The proposed framework follows a nine-step procedure, shown in Fig-1, that combines AHP for criteria weighting with TOPSIS for alternative ranking.

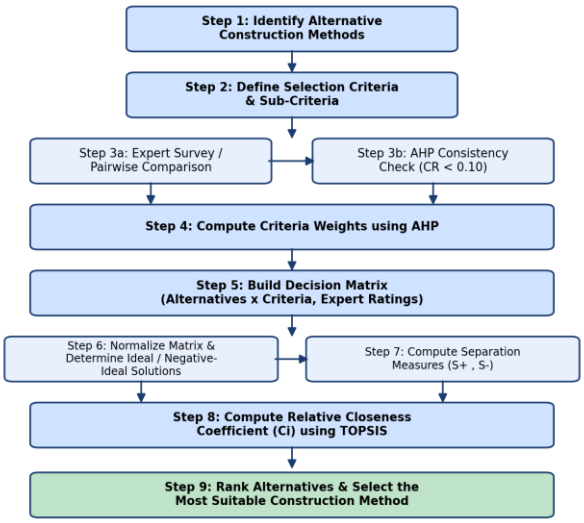

Fig -1: Proposed AHP-TOPSIS framework for construction method selection

3.1 Selection Criteria and Sub-Criteria

Seven criteria, each with representative sub-criteria, were shortlisted for residential construction method selection through a review of construction management literature. These are summarized in Table-1.

Table -1: Selection criteria and representative sub-criteria

Criterion	Code	Representative Sub-Criteria
Cost	C1	Initial construction cost, material cost, labour cost
Construction Time	C2	Total project duration, weather dependency
Quality & Durability	C3	Structural strength, design life, maintenance need
Labor Availability	C4	Skilled-labour requirement, local workforce dependency
Sustainability	C5	Embodied carbon, construction waste, energy efficiency
Site Constraints	C6	Site accessibility, space for storage / casting yard
Safety	C7	Worker safety risk, structural safety during erection

3.2 Weighting of Criteria using AHP

In AHP, criteria are compared pairwise using Saaty's nine-point fundamental scale (Table-2), where a value of 1 indicates equal importance between two criteria and a value

of 9 indicates that one criterion is extremely more important than the other. The pairwise comparisons are arranged into a square comparison matrix, and the principal eigenvector of this matrix is normalized to obtain the relative weight of each criterion.

Table -2: Saaty's fundamental scale for pairwise comparison

Intensity	Definition
1	Equal importance
3	Moderate importance of one over another
5	Strong importance
7	Very strong / demonstrated importance
9	Extreme importance
2, 4, 6, 8	Intermediate values between adjacent judgements

After the weight vector is obtained, a Consistency Ratio (CR) is computed as the ratio of the Consistency Index (CI) of the judgement matrix to the Random Index (RI) for a matrix of the same size. A CR value below 0.10 indicates that the pairwise judgements are sufficiently consistent to be accepted; a higher value requires the decision maker to revise the comparisons.

3.3 Ranking of Alternatives using TOPSIS

Once criteria weights are fixed, each candidate construction method is rated against every criterion (on a common 0-10 performance scale, based on expert judgement or measured data) to form a decision matrix. TOPSIS then proceeds through the following steps: (i) the decision matrix is normalized so that all criteria are dimensionless and comparable; (ii) the normalized matrix is multiplied by the AHP-derived weights to obtain a weighted normalized matrix; (iii) the ideal solution (best value for each criterion) and the negative-ideal solution (worst value for each criterion) are identified, taking into account whether each criterion is to be maximized (e.g., quality) or minimized (e.g., cost, time); (iv) the Euclidean distance of each alternative from the ideal solution (S+) and from the negative-ideal solution (S-) is calculated; and (v) the relative closeness coefficient is computed as Ci = S- / (S+ + S-). Alternatives are then ranked in descending order of Ci, with the highest value representing the most preferred construction method.

4. ILLUSTRATIVE CASE APPLICATION

To demonstrate the framework, it was applied to a hypothetical two-storey residential building project where five construction methods were considered as alternatives. The figures used in this section are illustrative, intended to show how the framework operates; project teams applying the framework to a real project should substitute their own expert-survey data and site-specific ratings.

4.1 Alternative Construction Methods Considered

- A1 - Conventional Cast-in-situ RCC Construction
- A2 - Precast Concrete Construction
- A3 - Modular / Prefabricated Construction
- A4 - Light-Gauge Steel Frame Construction
- A5 - Insulated Concrete Form (ICF) Construction

4.2 Criteria Weights

Pairwise comparisons among the seven criteria (Section 3.2) yielded the priority weights shown in Chart-1, with an acceptable consistency ratio of CR = 0.048. Cost and construction time emerged as the two most influential criteria for this illustrative residential project, together accounting for over 40% of the total weight, followed by quality and durability.

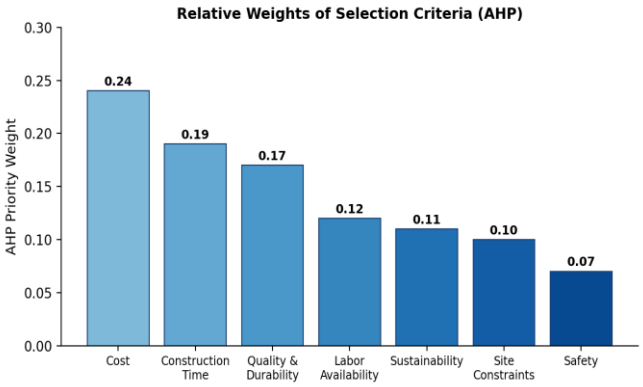

Chart -1: AHP-derived relative weights of the seven selection criteria

4.3 Decision Matrix

Each of the five alternatives was rated by a panel of experts on a 0-10 performance scale against the seven criteria; the resulting illustrative decision matrix is presented in Table-3 (higher is better for all criteria as rated, after converting cost and time into 'performance' scores where a shorter time / lower cost receives a higher score).

Table -3: Illustrative decision matrix (expert performance ratings, 0-10 scale)

Alternative	C1 Cost	C2 Time	C3 Quality	C4 Labour	C5 Sustain.	C6 Site	C7 Safety
A1 Conventional RCC	6.5	4.0	7.0	8.0	5.0	8.0	6.5
A2 Precast Concrete	6.0	7.5	8.0	6.5	6.5	6.0	7.5
A3 Modular / Prefab	5.5	9.0	7.5	7.0	7.5	6.5	8.0
A4 Steel Frame	5.0	7.0	6.5	5.5	7.0	7.0	7.0
A5 ICF System	4.5	6.5	7.5	6.0	8.0	6.5	7.5

4.4 TOPSIS Results and Final Ranking

Applying the TOPSIS procedure of Section 3.3 to the decision matrix in Table-3, using the criteria weights from Chart-1, gives the separation measures and relative closeness coefficients summarized in Table-4.

Table -4: TOPSIS separation measures, closeness coefficients, and final ranking

Alternative	S+ (dist. to ideal)	S- (dist. to negative-ideal)	Ci (Closeness)	Rank
A1 Conventional RCC	0.146	0.102	0.412	5
A2 Precast Concrete	0.071	0.156	0.687	2
A3 Modular / Prefab	0.058	0.166	0.741	1
A4 Steel Frame	0.106	0.134	0.558	4
A5 ICF System	0.090	0.137	0.603	3

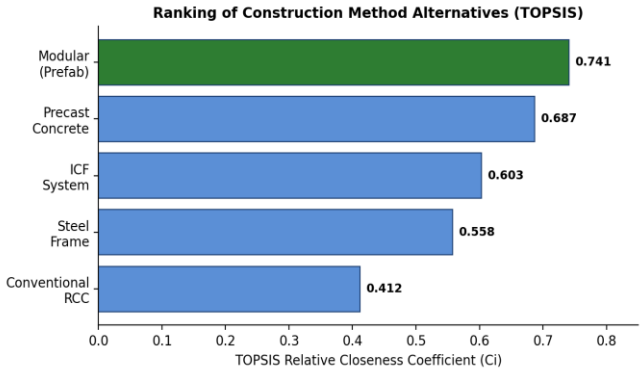

Chart -2: Final ranking of construction method alternatives by closeness coefficient (Ci)

5. RESULTS AND DISCUSSION

For the illustrative project, modular/prefabricated construction (A3) obtained the highest closeness coefficient (Ci = 0.741), followed by precast concrete (A2, Ci = 0.687) and ICF construction (A5, Ci = 0.603). Conventional cast-in-situ RCC construction (A1) ranked lowest (Ci = 0.412), primarily due to its comparatively long construction time and higher dependence on skilled labour, even though it remained competitive on initial cost. This pattern is broadly consistent with practical experience: factory-controlled methods such as modular and precast construction typically compress on-site duration and improve quality consistency, at the cost of somewhat higher upfront investment and dependence on transport and crane access.

The relative weight of cost (0.24) and time (0.19) in this illustrative example means that the ranking is particularly sensitive to how alternatives perform on these two criteria; a project team with different priorities, for instance one for which sustainability is weighted more heavily, could reasonably obtain a different ranking. This sensitivity is a strength rather than a weakness of the framework, since it allows the outcome to be traced transparently back to the decision-maker's own priorities rather than being hidden inside a single subjective recommendation. The framework also allows any criterion, sub-criterion, or alternative to be added, removed, or re-weighted without altering the underlying procedure, which makes it reusable across different residential projects and regional contexts.

It should be emphasized that the criteria weights and decision-matrix ratings used in this section are illustrative and were assumed for demonstration purposes. Applying the framework to an actual project requires collecting genuine pairwise comparisons and performance ratings from qualified experts or project data, and verifying that the AHP consistency ratio remains below 0.10 before the results are used for decision-making.

6. CONCLUSIONS

This paper presented a structured Multi-Criteria Decision-Making framework, combining the Analytic Hierarchy Process and TOPSIS, for selecting construction methods in residential building projects. Seven criteria, cost, construction time, quality and durability, labour availability, sustainability, site constraints, and safety, were identified and used to weight and rank five candidate construction methods on an illustrative project. The demonstration showed modular/prefabricated construction as the most favourable option under the assumed priorities, followed by precast concrete, while conventional cast-in-situ construction ranked lowest primarily due to time and labour considerations. The proposed framework offers a transparent, repeatable, and quantitatively defensible alternative to informal, experience-based method selection, and can be adapted to different project priorities simply by adjusting the pairwise comparisons. Future work can extend the framework using fuzzy AHP to better capture the uncertainty in expert judgements, integrate it with Building Information Modelling (BIM) for automated data extraction, and validate it against a larger sample of real residential projects across different regions.

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