

Architectural Concepts For Integrating Human Preferences And Environmental Sustainability Into AI-Driven Architectural Design

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Abstract: Artificial intelligence (AI) is increasingly influencing architectural design through generative modelling, performance prediction, spatial planning, and workflow automation. However, many current applications address individual tasks or emphasize visual novelty, while practical design decisions must balance human needs, climate responsiveness, affordability, accessibility, regulatory constraints, and environmental performance. This paper proposes a Human-Centered and Sustainability-Aware AI Architectural Design Framework (HCS-AADF) that combines these considerations within an iterative design-support workflow. The framework accepts user requirements, site and climate information, budget limits, and applicable design constraints; analyses the project context; generates alternative layouts or massing concepts; evaluates alternatives against multiple criteria; explains trade-offs; and returns shortlisted options to an architect for review. Human feedback can be used to refine subsequent iterations. A conceptual multi-criteria scoring model and an evaluation protocol are specified to support future implementation and testing. The paper synthesizes three supplied research directions—AI architectures informed by human drives and emotions, the adoption and capabilities of AI software tools in architecture, and systematic reviews of AI applications in architectural design—along with relevant recent literature on generative design and sustainable building optimization. The proposed contribution is an integrated, transparent workflow rather than a claim of experimentally proven performance. Expected benefits include more traceable design comparisons, earlier consideration of sustainability, and improved collaboration between architects and AI systems. The framework also identifies risks involving data quality, bias, explainability, regulatory verification, and over-reliance on generated outputs. Experimental validation with representative building projects and expert review is proposed as the next step.

Keywords: Artificial intelligence; architectural design; human-centered design; generative design; sustainable buildings; multi-criteria decision analysis; explainable AI; design optimization

I. INTRODUCTION

Precision Software Architectural design is a complex decision-making activity that combines functional requirements, spatial relationships, site conditions, environmental performance, construction cost, cultural context, and aesthetic intent. Conventional computer-aided design tools support drafting and modelling, while contemporary AI systems can assist with concept generation, prediction, image synthesis, parametric exploration, and repetitive documentation tasks. These capabilities expand the number of alternatives that a design team can explore, but they do not automatically guarantee that a generated design is safe, buildable, inclusive, affordable, or environmentally appropriate. Recent literature describes AI applications in spatial planning, parametric modelling, generative design, building-performance analysis, and related areas. Albukhari's systematic review discusses the potential of AI to improve automation,



creativity, and sustainability while noting ethical concerns and the risk of losing architectural identity Cortiços, Zheng, and Duarte examine architectural AI software tools and their coverage across design workflows, emphasizing that tool effectiveness depends on capability, viability assessment, integration, and regulatory needs Jang, Roh, and Lee report that generative AI research has concentrated heavily on early-stage design and image-based data, while evaluation practices remain uneven . These findings suggest a need for workflows that connect design generation to explicit, measurable criteria and human oversight. This paper proposes an integrated framework that treats AI as a design-support partner rather than an autonomous replacement for an architect. Its central idea is to combine user-centered requirements, site and climate context, multi-criteria evaluation, explainable trade-offs, and expert feedback in one repeatable process. The framework is conceptual and intended to guide implementation

II. PROBLEM STATEMENT

AI-assisted architectural tools can generate many visual or geometric alternatives quickly, but the alternatives may not be evaluated consistently against user needs, energy performance, cost, accessibility, local regulations, and construction feasibility. Separate tools may also produce fragmented workflows in which site analysis, concept generation, simulation, and documentation do not share a common decision record. A visually convincing output can therefore be mistaken for a validated design. The problem addressed in this paper is the absence, in many AI-assisted concept workflows, of a transparent and human-supervised process that connects contextual inputs to multi-criteria assessment and iterative improvement

III. AIM AND OBJECTIVE

The aim is to propose a human-centered and sustainability-aware framework for AI-assisted architectural design. The objectives are:

- (1) identify key inputs that influence early architectural decisions
- (2) define a workflow for generating and evaluating alternative concepts
- (3) establish a transparent multi-criteria scoring approach;
- (4) include architect review and feedback as explicit stages
- (5) define measurable indicators for future evaluation; and
- (6) document limitations and responsible-use safeguards

IV. RESEARCH QUESTION

RQ1: How can user requirements, site context, climate, budget, and design constraints be combined in an AI-assisted architectural workflow?

RQ2: How can generated alternatives be compared transparently across sustainability, usability, cost, and feasibility criteria?

RQ3: How can human review and feedback improve traceability and reduce the risks of unsuitable AI-generated designs? RQ4: Which metrics can be used to evaluate the framework in a future empirical study?

V. EXISTING SYSTEM

The Existing AI-assisted architectural workflows commonly use separate tools for site analysis, generative image production, parametric modelling, energy simulation, cost estimation, and BIM/CAD documentation. These tools can improve speed and expand the design space, but their outputs may use different data formats, assumptions, and levels of precision. Image-generation systems can create persuasive visual concepts without ensuring dimensional accuracy or code compliance. Performance tools can provide useful estimates, but results depend on model inputs and assumptions. Human experts remain necessary to interpret requirements, verify engineering and legal constraints, and make context-sensitive design decisions.



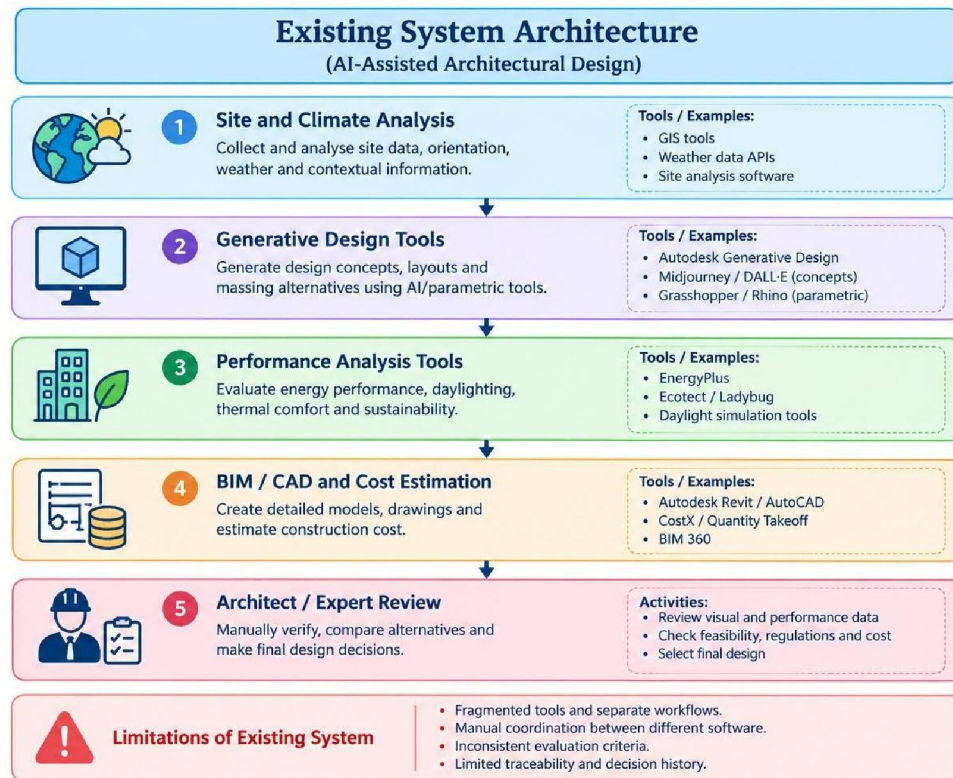


Figure 1. Existing AI-Assisted Architectural Design System

VI. PROPOSED SYSTEM

Figure 1 presents the proposed high-level architecture. Inputs are transformed into a contextual project representation; a design-generation component produces alternatives; evaluation services assess performance; a ranking component explains trade-offs; and human review provides a feedback path. The architecture is modular so that individual tools can be replaced without changing the overall decision workflow. Data provenance should be preserved across stages, including input source, software version, model assumptions, evaluation settings, and reviewer decisions.

• Proposed System: HCS-AADF

The Human-Centered and Sustainability-Aware AI Architectural Design Framework (HCS-AADF) is organized into six stages.

Stage 1 — Input data collection: collect the project brief, intended occupants and activities, area requirements, budget range, site boundaries, orientation, local climate, accessibility needs, and known regulatory constraints. Each input should be labelled as verified, estimated, or missing.

Stage 2 — Context analysis: convert the brief into structured constraints and preferences. Identify spatial relationships, site limitations, climate opportunities, and requirements that need professional confirmation. Missing or conflicting inputs are flagged rather than silently assumed.

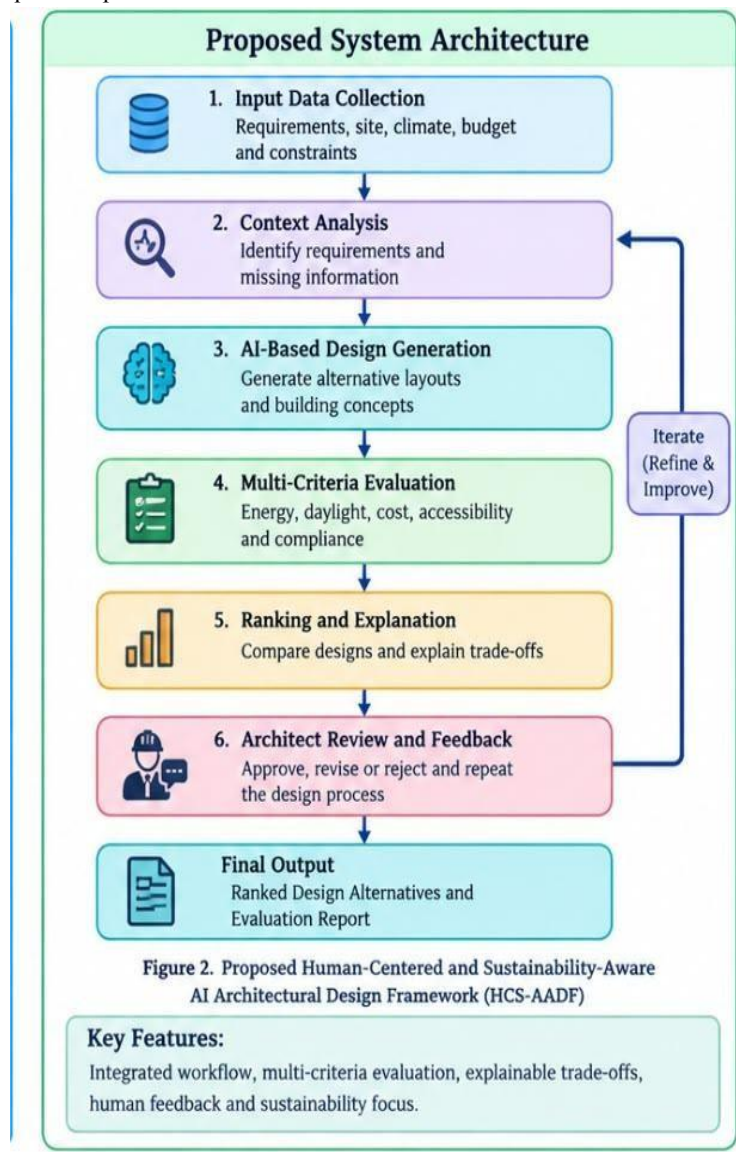
Stage 3 — Alternative generation: use a selected generative or parametric design method to create a set of candidate layouts or massing options. The generator may be a rule-based system, parametric model, optimization routine, or AI-enabled design tool. The output should retain the assumptions and parameters used to produce each candidate.



Stage 4 — Multi-criteria evaluation: assess each candidate using available performance tools and documented rules. Possible criteria include estimated energy demand, daylight availability, material or construction cost, circulation quality, accessibility, usable-area efficiency, and regulatory feasibility. Hard constraints should be checked separately from preferences: a candidate that violates a mandatory safety or code requirement should not be made acceptable merely by a high overall score.

Stage 5 — Ranking and explanation: normalize comparable metrics and compute a weighted score for candidates that pass mandatory checks. Present each score alongside its component values, uncertainty flags, and trade-offs. Weightings should be set with stakeholder input and tested for sensitivity.

Stage 6 — Human review and feedback: an architect reviews shortlisted alternatives, verifies assumptions, and records approve/revise/reject decisions. Feedback updates preferences or constraints and triggers another design iteration. Final approval remains with qualified professionals and relevant authorities



VII. MULTI-CRITERIA EVOLUTION MODEL

For candidate d , a conceptual weighted score can be defined as: $\text{Score}(d) = \sum_{i=1}^m w_i \times z_i(d)$ where w_i is the stakeholder-approved weight for criterion i , $z_i(d)$ is the normalized value for candidate d , and the weights satisfy $\sum w_i = 1$. For criteria where lower values are preferred, such as estimated energy use or cost, normalization must reverse the direction so that a higher normalized score always represents a more desirable outcome. A candidate is ranked only after mandatory constraints are checked. Illustrative criteria include: energy performance, daylight and thermal comfort, cost, spatial usability, accessibility, material/resource efficiency, and design preference. The actual set and weights should vary by project. A sensitivity analysis should test whether small changes in stakeholder weights cause large changes in rankings. Where performance values are unavailable, the system should mark them as unknown rather than invent estimates. Scores support comparison but cannot replace code review, structural engineering, or professional judgment.

VIII. RESEARCH METHODOLOGY AND VALIDATION PLAN

This paper uses a conceptual design-and-evaluation methodology based on synthesis of the three supplied research directions and relevant recent literature. It does not report a completed user study or building simulation. A future validation study can apply the framework to a small, documented set of building-design briefs, such as a compact residence, a classroom block, and a small community facility. For each brief, the study should record the requirements, site assumptions, candidate generation method, software versions, and evaluation criteria. Compare a baseline workflow (designer-led or tool-by-tool evaluation) with the proposed integrated workflow. Recruit qualified architecture reviewers where feasible and use the same briefs and constraints for both workflows. Reviewers should assess requirement coverage, feasibility, usability, transparency of trade-offs, and the usefulness of the shortlist. Energy and cost indicators should be calculated with suitable simulation or estimation tools rather than inferred from appearance. Data analysis can combine descriptive statistics with expert ratings.

IX. EVOLUTION METRICES

The proposed framework can be evaluated using the following measures:

- Requirement coverage: proportion of explicitly stated requirements addressed by a candidate.
- Constraint compliance: proportion of mandatory constraints verified as satisfied; violations must also be listed individually.
- Energy-performance estimate: simulated energy demand or another project-appropriate energy indicator, with assumptions recorded.
- Cost deviation: difference between estimated project cost and the target budget.
- Spatial usability: expert-rated suitability of room relationships, circulation, and usable area.
- Accessibility review: number and severity of accessibility issues identified against the applicable standard.
- Design diversity: degree of meaningful difference among generated alternatives, measured with a project-appropriate method.
- Explanation quality: expert rating of whether the system communicates why a candidate was ranked and what trade-offs remain.
- Iteration efficiency: time and number of revisions needed to reach a reviewable shortlist.
- Human acceptance: proportion of shortlisted options rated acceptable or suitable by reviewers. Metrics should be selected before testing, and all comparisons should use consistent project inputs. Visual appeal alone is not a sufficient indicator of architectural quality.

X. EXPECTED RESULTS AND DISCUSSION

The framework is expected to make design comparison more systematic by presenting alternatives with the same documented criteria and by distinguishing mandatory constraints from preferences. A traceable evaluation report could



help architects and clients understand why one alternative ranks above another and identify which trade-offs remain unresolved. The feedback loop is expected to support iterative refinement without treating the AI output as final authority. Earlier consideration of energy, daylight, cost, and accessibility may also help teams identify weak concepts before investing heavily in detailed development. These are expected outcomes, not observed findings. The magnitude of any improvement will depend on the quality of input data, the chosen generation tools, the reliability of simulations, and reviewer expertise. In some projects, a simpler manual workflow may be more appropriate, especially when data are sparse or the design is highly site-specific. The framework should therefore be evaluated for usefulness and transparency, not merely speed

XI. CETHICAL,PRACTICAL AND TECHNICAL LIMITATION

First, AI-generated concepts can contain geometric errors, implausible layouts, or unsupported assumptions. Second, training data may reproduce stylistic, cultural, or accessibility biases and may not represent local building traditions. Third, energy and cost estimates can be misleading if weather files, occupancy assumptions, material data, or construction prices are inaccurate. Fourth, regulations vary by jurisdiction and change over time; automated checks must not be treated as legal certification. Fifth, integrating multiple tools can create interoperability and data-governance challenges. Sixth, optimization weights may privilege measurable performance over cultural meaning, beauty, or community preferences. Finally, the proposed framework has not yet been empirically validated. Mitigation measures include recording provenance, marking uncertainty, applying hard safety and compliance gates, including diverse stakeholders, testing weight sensitivity, protecting confidential project data, and requiring professional review. The system should communicate when evs Sidence is insufficient and should not fabricate missing metrics.

XII. FUTURE WORK

The Future work should implement a working prototype connected to a parametric design environment and one or more building-performance tools. A reproducible benchmark of design briefs should be developed, with clear input data, evaluation scripts, and expert-rating criteria. Further studies could compare different weight-setting approaches, investigate how feedback changes candidate quality, and examine whether the framework transfers across climates and building types. Integration with BIM, digital twins, and immersive visualization may support later-stage coordination, provided that geometry, metadata, and model assumptions remain consistent. Research should also investigate how to document cultural and qualitative design values without reducing them to misleading numerical proxies

XIII. CONCLUSION

This paper has proposed HCS-AADE, a human-centered and sustainability-aware framework for AI-assisted architectural design. By connecting project-context analysis, alternative generation, multi-criteria evaluation, explainable ranking, and architect-led feedback, the framework addresses the practical need to assess AI-generated concepts beyond visual novelty. Its intended contribution is a transparent workflow that makes assumptions, trade-offs, and unresolved constraints visible to designers and stakeholders. The framework remains conceptual, and its effectiveness has not been established through experiments. Future implementation should evaluate it using real project briefs, reliable performance tools, and qualified reviewers. AI can broaden the design space and support analysis, but architectural responsibility, safety verification, cultural sensitivity, and final professional judgment must remain central

XIV. ACKNOWLEDGMENT

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