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An Integrated Decision Framework for Sustainable and Code-Compliant Building Design Using Building Information Modeling and Multi-Criteria Performance Assessment

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Research Article

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Abstract

The increasing demand for sustainable buildings has created a need for architectural design approaches that evaluate regulatory compliance, environmental performance, energy efficiency, occupant functionality, and construction feasibility within a single framework. Existing design methods often assess these aspects independently, which can lead to design conflicts and reduced project efficiency. This study proposes an integrated decision framework that combines Building Information Modeling (BIM), building performance assessment, and multi-criteria decision analysis to support building design decisions. The framework integrates architectural geometry, building envelope characteristics, daylight availability, energy performance, zoning regulations, construction costs, and lifecycle sustainability indicators into a unified evaluation model. An equal-weight MCDA model with constraint based evaluation is used to identify design alternatives that provide high overall performance while meeting applicable regulatory requirements. The framework is illustrated using publicly available BIM benchmark/reference resources, EnergyPlus reference-building documentation, ASHRAE standards, and open building-performance resources. No new EnergyPlus simulation is executed in this manuscript; the reported three-alternative numerical results are a controlled illustrative dataset used to demonstrate the calculation procedure. The proposed approach provides a general decision-

support framework for sustainable and code-compliant building design and supports consistent comparison of alternatives during the design stage.

Keywords

Building Information Modeling (BIM), Sustainable Building Design, Building Code Compliance, Multi-Criteria Decision Analysis (MCDA), Building Performance Assessment, Architectural Decision Support, Constrained Design Selection, Lifecycle Sustainability.

I. Introduction

The need for sustainable and code compliant building designs has grown stronger, prompting improvements in architectural workflows. Integrating multiple performance criteria into a cohesive decision making process remains a challenge in current practices.

A. Background and Motivation

Sustainable and code compliant building design has become a major objective in modern architecture due to increasing environmental concerns, stricter building regulations, and lifecycle performance requirements. Designers must evaluate energy efficiency, occupant comfort, environmental impact, construction cost, and regulatory compliance throughout the design process. Although Building Information Modeling (BIM) provides detailed digital building information, integrating multiple performance criteria into a single decision process remains a difficult task.

B. Problem Statement

Current methodologies tend to evaluate architectural performance, compliance, and sustainability separately. This separation results in conflicting goals, rework, and difficulties in identifying solutions that balance multiple objectives effectively. Additionally, existing frameworks lack the capability to incorporate geometric, environmental, regulatory, and lifecycle performance indicators into a unified model. The absence of standardized, scalable decision-support systems limits early-stage decision-making, reducing overall project efficiency and sustainability.

C. Proposed Solution

This study proposes an integrated BIM-based decision framework for sustainable and code-compliant building design. The framework combines BIM, building performance assessment, regulatory compliance verification, Multi-Criteria Decision Analysis (MCDA), and constrained design selection within a unified workflow. It evaluates building geometry, envelope characteristics, energy performance, daylight availability, thermal comfort, lifecycle cost,

embodied carbon, operational carbon, occupant comfort, and sustainability indicators using a common evaluation process. Regulatory requirements are assessed separately as mandatory feasibility conditions. Design alternatives that satisfy all required conditions are then evaluated using the MCDA model and ranked according to their overall performance. The framework is demonstrated using a controlled illustrative dataset informed by publicly available BIM benchmark/reference resources, EnergyPlus reference-building documentation, ASHRAE standards, and open building-performance resources.

D. Contributions

This research makes four contributions. First, it presents an integrated framework that combines BIM, performance assessment, regulatory compliance, and multi-criteria decision analysis within a unified decision process. Second, it develops a quantitative evaluation model for comparing alternative building designs using multiple performance indicators. Third, it defines a reproducible validation procedure based on calculation consistency, compliance classification, MCDA reproducibility, and final-selection consistency. Finally, it provides a generalized decision-support approach for sustainable, code compliant, and performance-oriented building design.

E. Paper Organization

The remainder of this paper is organized as follows. Section II reviews related work and identifies the research gap. Section III describes the proposed methodology, including data preparation, performance assessment, compliance verification, MCDA, constrained design selection, and validation. Section IV presents the demonstration results and discussion. Section V concludes the paper with the main findings, limitations, and future research directions.

II. Literature Review

Recent studies have examined Building Information Modeling (BIM), building performance assessment, sustainability evaluation, regulatory compliance, construction management, and multi criteria decision methods for sustainable building and infrastructure development [1]-[10]. Related studies have also addressed BIM coordination, sustainable project delivery, construction governance, structural assessment, digital technologies, risk management, and resilient infrastructure, providing additional perspectives for integrated building decision support [11]-[33].

A. Building Information Modeling for Sustainable Building Design

Building Information Modeling (BIM) supports architectural design, project coordination, lifecycle information management, and sustainability assessment. Research has extended BIM toward life cycle assessment, environmental evaluation, and performance-based design, supporting comparison of alternative building solutions [1]-[7]. BIM-based coordination has also been examined for reducing construction rework, while BIM-supported project delivery and digital construction governance have been discussed in relation to sustainable and resilient infrastructure development [11], [12], [14]. These studies indicate the value of integrated digital information for coordinating building and infrastructure decisions.

B. Building Performance Assessment and Multi-Criteria Decision Analysis

Building performance assessment considers indicators such as energy use, daylight availability, thermal comfort, lifecycle cost, carbon emissions, and occupant performance. Because these indicators involve different objectives and trade-offs, Multi-Criteria Decision Analysis (MCDA) can support the normalization, evaluation, and ranking of alternative design solutions [2], [3], [6], [8]. Related research on sustainable construction has examined performance-based evaluation, material selection, structural performance, and construction efficiency, demonstrating the broader use of quantitative indicators for comparing alternative solutions [15]-[20]. These studies provide supporting evidence for using multiple performance indicators within an integrated decision process.

C. Regulatory Compliance and Lifecycle Sustainability Assessment

Building regulations address requirements related to fire safety, accessibility, structural integrity, zoning, emergency evacuation, and energy performance. BIM-based compliance assessment can support rule-based verification, while BIM-based life cycle assessment can incorporate embodied carbon, operational impacts, lifecycle cost, and sustainability indicators into building design evaluation [1], [2], [5], [8], [10]. Related studies have examined structural safety, recycled construction materials, sustainable ground improvement, and infrastructure quality and compliance, highlighting the importance of combining performance assessment with engineering and regulatory considerations [16]–[18], [20], [22], [27], [28].

D. Digital Technologies for Intelligent and Resilient Building Design

Digital Twins and the Internet of Things (IoT) extend BIM toward continuous building monitoring, information integration, and operational analysis. Previous research has examined

BIM, IoT, and Digital Twin integration for smart construction and building applications [9], [10]. Digital Twin applications have also been explored for smart civil infrastructure and emergency preparedness, while AI-based risk prediction and data-driven infrastructure assessment provide additional directions for intelligent decision support [23], [26], [31]. Research on climate-resilient infrastructure, flood-resilient planning, and integrated infrastructure assessment further demonstrates the growing role of digital and analytical methods in resilient built-environment decision-making [21], [24], [25], [30], [32], [33].

E. Research Gaps and Future Directions

Previous research provides strong foundations for BIM-based sustainability assessment, lifecycle analysis, building performance evaluation, compliance assessment, digital construction, and infrastructure resilience [1]–[33]. However, these elements are still commonly treated as separate assessment activities. A unified decision-support framework that combines BIM, building performance assessment, regulatory compliance verification, MCDA, lifecycle sustainability indicators, and constrained design selection remains limited. This study addresses this gap through an integrated BIM-based decision framework for sustainable and code-compliant building design.

III. METHODOLOGY

This study develops an integrated BIM-based decision framework for sustainable and code-compliant building design. The workflow covers data preparation, building performance assessment, regulatory compliance checking, multi-criteria evaluation, and constrained design selection. The process is intended for comparison of alternative building designs at the design stage.

A. Overall Research Framework

Figure 1 presents the overall workflow of the proposed framework. BIM acts as the central source of geometric, material, environmental, and building-system information. The process begins with data preparation and integration, followed by building performance assessment and regulatory compliance verification. Performance indicators are normalized according to their evaluation objectives, while regulatory requirements are evaluated as mandatory feasibility conditions. Alternatives that satisfy all required conditions form the feasible design set. These alternatives are then ranked using MCDA, followed by constrained design selection. The main

outputs are performance results, compliance status, alternative rankings, and a final decision-support report.

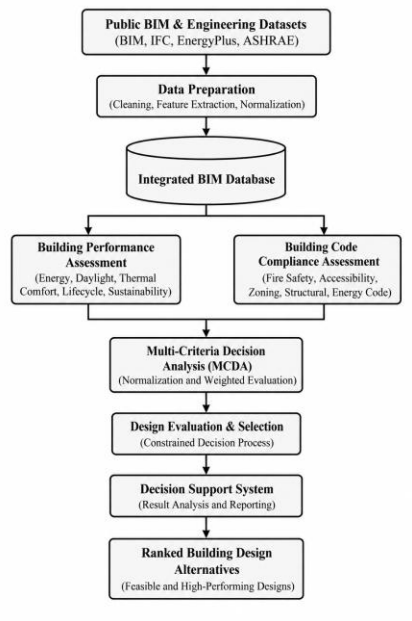


Fig. 1. Overall Framework of the Proposed Integrated Decision Framework.

Figure 1 illustrates the overall workflow from BIM and engineering data preparation through performance assessment, regulatory compliance verification, MCDA ranking, constrained design selection, and decision-support reporting.

B. Data Sources and Data Preparation

The framework is informed by publicly available BIM benchmark/reference resources, IFC model documentation, EnergyPlus reference-building documentation, ASHRAE standards, and open building-performance literature. These resources are used to define the methodological inputs and evaluation criteria; they are not used as the numerical source of the three-alternative results reported in this study. The available information covers building geometry, envelope characteristics, construction materials, HVAC systems, occupancy conditions, energy performance, thermal comfort, and sustainability-related measures. Data preparation includes cleaning, feature extraction, unit conversion, normalization, and database integration. Duplicate records, missing values, inconsistent attributes, and incompatible units are addressed before analysis. Building geometry, envelope properties, material information, HVAC specifications, occupancy schedules, and thermal characteristics are extracted from the available sources. For reproducibility, the manuscript distinguishes the source resources from the numerical demonstration data. No new EnergyPlus simulation was executed for the three-alternative results

reported in this study, and no completed-building measurement dataset was used. The numerical results therefore use a controlled illustrative dataset created to demonstrate the normalization, compliance filtering, and MCDA calculation procedure. These values are not presented as measured data or EnergyPlus simulation outputs. The three alternatives (A–C) are defined by the performance indicators and compliance conditions reported in the Results section. A future simulation based replication should report the exact BIM/IFC model identifier, EnergyPlus reference building, weather file, simulation period, occupancy schedules, HVAC assumptions, software version, and scenario-generation procedure. Since the performance measures have different units and directions, the normalization method depends on the objective of each criterion. For a criterion that is minimized, the normalized value is calculated as:

$$N_i = \frac{X_{max} - X_i}{X_{max} - X_{min}}$$

For a criterion that is maximized :

$$N_i = \frac{X_i - X_{min}}{X_{max} - X_{min}}$$

Where, (X_i) is the value of criterion i and (X_{min}) and (X_{max}) represent the minimum and maximum values of the corresponding dataset, respectively. Thermal comfort is treated as a target criterion because PMV values close to zero indicate better thermal conditions. Its normalized value is calculated as:

$$NPMV = \max\left(0{,}1 - \frac{|\,PMV\,|}{PMV_{\max}}\right)$$

Where, PMV_{max} the largest absolute PMV value within the evaluated alternatives. This normalization procedure converts the heterogeneous performance indicators into a common 0–1 scale before the weighted MCDA calculation.

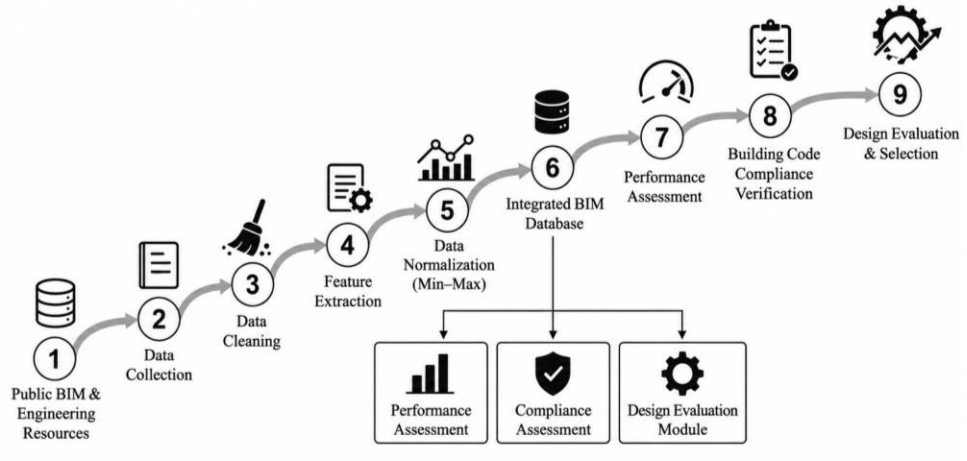


Fig. 2. Data Preparation and BIM Information Integration Workflow.

The centralized BIM database supplies standardized information for subsequent modules, supporting consistent evaluation of alternative building designs within the constrained decision-support process.

C. Building Performance Assessment

Building performance assessment evaluates each design alternative using eight indicators: Energy Use Intensity (EUI), Daylight Availability, Thermal Comfort (PMV/PPD), Lifecycle Cost (LCC), Embodied Carbon, Operational Carbon, Occupant Comfort Index, and Sustainability Index. The objective is to minimize EUI, lifecycle cost, embodied carbon, and operational carbon while maximizing daylight availability, occupant comfort, and the sustainability index. Thermal comfort is treated as a target criterion, with PMV values closer to zero receiving higher normalized scores. The assessment uses standardized information from the integrated BIM database and selected building-performance reference sources to define the evaluation criteria. The numerical values reported for Alternatives A-C are illustrative inputs used to demonstrate the proposed calculation and decision procedure. Each indicator is converted into a normalized score according to its evaluation objective before MCDA. The resulting performance vector is represented as:

$$P = \{N_1, N_2, \dots, N_8\}$$

Where, (N_i) represents the normalized value of one performance indicator i. This representation places the different measures on a common scale and permits comparison among the candidate designs.

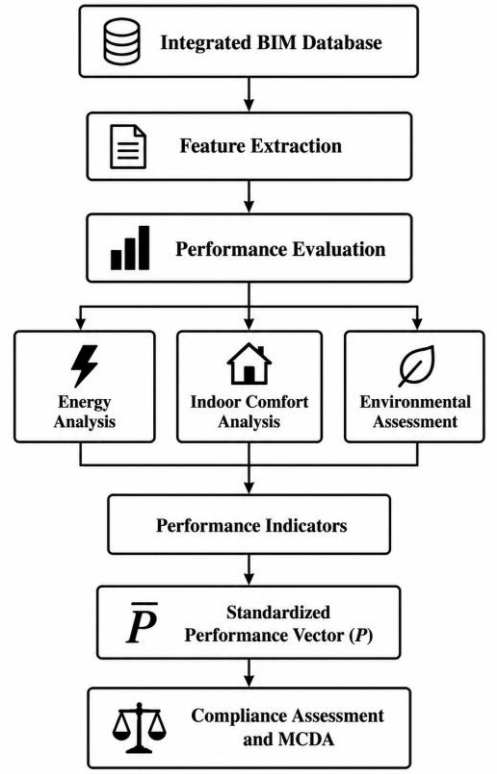


Fig. 3. Building Performance Assessment Workflow.

The normalized performance indicators provide a common basis for comparing building design alternatives before regulatory compliance assessment and MCDA.

D. Building Code Compliance Assessment

The compliance assessment evaluates each design alternative through rule-based verification of BIM information against mandatory engineering and regulatory requirements. Six compliance categories are considered, including fire safety, accessibility, structural integrity, zoning regulations, emergency evacuation, and energy-code compliance. These categories verify building safety, accessibility standards, structural adequacy, zoning restrictions, emergency egress, and energy efficiency before further evaluation.

$$R_j = \begin{cases} 1, & \text{if the } j^{th} \text{ requirement is satisfied} \\ 0, & \text{otherwise} \end{cases}$$

Where, (R_j) denotes the compliance status of the (j^{th}) regulatory requirement. The compliance rate is calculated as:

$$CS = \frac{1}{m}\sum_{j=1}^{m} R_j$$

Where, *CS* is the overall compliance score, *m* is the total number of regulatory requirements, and R_j is the compliance result for each requirement. A value of *CS=1* indicates full compliance. A design with *CS<1* is excluded from final selection. Thus, strong performance in energy, cost, carbon, or comfort cannot compensate for failure to satisfy a mandatory requirement.

TABLE I. *Building Code Compliance Categories*

Compliance Category	Evaluation Criteria	Objective
Fire Safety	Exit routes, travel distance, fire protection systems	Verify fire safety requirements
Accessibility	Building entrances, circulation paths, sanitary facilities	Verify accessibility standards
Structural Integrity	Structural dimensions and load capacity	Verify structural safety
Zoning Regulations	Building height, setbacks, floor area ratio	Verify zoning requirements
Emergency Evacuation	Exit capacity and evacuation routes	Verify emergency egress
Energy Code Compliance	Building envelope, HVAC systems, lighting efficiency	Verify energy-code requirements

Only alternatives with full compliance proceed to the MCDA ranking and constrained design selection stages.

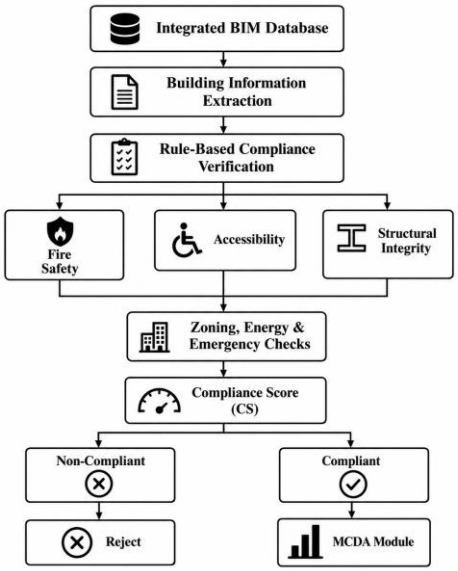


Fig. 4. Building Code Compliance Assessment Workflow.

The compliance assessment removes infeasible alternatives before performance-based ranking. A design that fails a mandatory regulatory requirement cannot compensate for that failure through superior energy, cost, carbon, or comfort performance.

E. Multi-Criteria Decision Analysis (MCDA)

After the compliance check, only feasible alternatives are considered for the final MCDA ranking. The evaluation uses the eight performance indicators described in Section III-C. Code compliance is not included as a weighted MCDA criterion because it is applied as a mandatory feasibility constraint before ranking. This separation prevents regulatory compliance from being counted twice. The MCDA score for alternative *k* is calculated as:

$$S_k = \sum_{i=1}^{n} w_i N_{ik}$$

Subject to,

$$\sum_{i=1}^{n} w_i = 1, \qquad w_i \geq 0$$

Where, S_k represents the score of alternative k, $w_i$is the weight assigned to criterion i, N_{ik} is the normalized value of criterion ii for alternative k, and nn is the total number of performance criteria. The MCDA model considers eight performance criteria: Energy Use Intensity (N1), Daylight Availability (N_2), Thermal Comfort (N3), Lifecycle Cost (N4), Embodied Carbon (N5), Operational Carbon (N6), Occupant Comfort Index (N7), and Sustainability Index (N8). Energy Use Intensity, Lifecycle Cost, Embodied Carbon, and Operational Carbon are treated as minimization criteria. Daylight Availability, Occupant Comfort Index, and Sustainability Index are treated as maximization criteria. Thermal Comfort is treated as a target criterion because PMV values closer to zero indicate better thermal conditions. The manuscript does not provide an original project-specific weighting scheme. Therefore, an equal-weight scheme is used for the reported demonstration:

$$w_i = 0.125, \qquad i = 1,\ldots\ldots,8$$

for each of the eight criteria, with:

$$\sum_{i=1}^{8} w_i = 1,$$

The normalized performance values are multiplied by their corresponding weights and summed to obtain the MCDA score. A higher score indicates better overall performance across the selected energy, environmental, economic, comfort, and sustainability criteria. Only alternatives that satisfy all mandatory regulatory requirements are included in the final ranking. Alternatives that fail any mandatory requirement are excluded before MCDA ranking. The resulting scores are used to rank the feasible alternatives for constrained design selection.

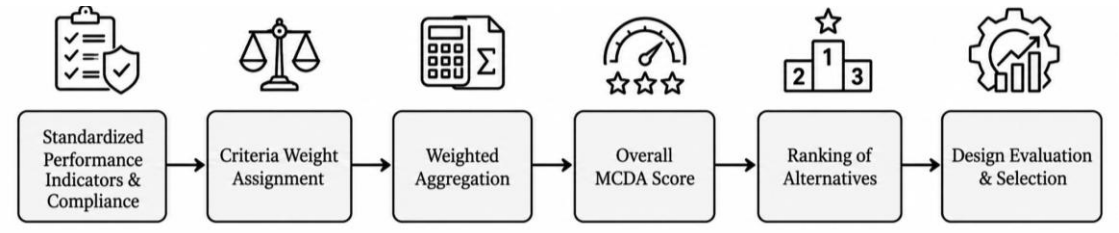


Fig. 5 . Multi-Criteria Decision Analysis Workflow.

The MCDA module combines the normalized performance indicators using the assigned criterion weights and produces a single score for each feasible design alternative. The resulting scores are used to rank the alternatives before constrained design selection.

F. Constrained Design Selection

The design variables considered in the framework are building orientation, window-to-wall ratio, insulation thickness, HVAC efficiency, glazing type, and roof reflectance. The design vector is expressed as:

$$x = [\theta, WWR, t, \eta, G, \rho]$$

where θ represents orientation, WWR represents window-to-wall ratio, t represents insulation thickness, η represents HVAC efficiency, G represents glazing type, and ρ represents roof reflectance. The design alternatives are subject to the following constraints:

Energy Performance,

$$E \leq E_{max}$$

Where, (E) is the predicted Energy Use Intensity (EUI) and (E_{max}) is the maximum allowable energy consumption.

Lifecycle Cost,

$$LCC \leq B$$

Where, (LCC) denotes the lifecycle cost and (B) represents the available project budget.

Embodied Carbon,

$$EC \leq EC_{max}$$

Where, (EC) is the embodied carbon emission and (EC_{max}) is the allowable environmental limit.

Thermal Comfort,

$$PMV_{min} \leq PMV \leq PMV_{max}$$

Where, (PMV) remains within the acceptable thermal comfort range.

Building Code Compliance,

$$CS = 1$$

Where, (CS) is the compliance score obtained from the regulatory assessment.The current study does not use a solver-based search procedure. Instead, the reported experiment is treated as a constrained design selection procedure in which feasible alternatives are compared using their MCDA scores, while mandatory engineering and regulatory requirements determine eligibility for final selection.

TABLE II. *Design Variables and Candidate Ranges*

Design Variable	Symbol	Typical Range	Design Objective
Building Orientation	θ	0°-360°	Improve solar exposure
Window-to-Wall Ratio	WWR	0.20-0.60	Balance daylight and energy performance
Insulation Thickness	t	50-200 mm	Reduce heat transfer
HVAC Efficiency	η	0.70-0.98	Reduce energy demand
Glazing Type	G	Single-Triple	Improve thermal performance
Roof Reflectance	ρ	0.30-0.90	Reduce cooling demand

These ranges represent illustrative candidate design bounds for the general framework and were not used as project specific search limits in the present numerical demonstration. Alternatives A-C are controlled illustrative cases defined by the performance and compliance values reported in Tables III and IV.

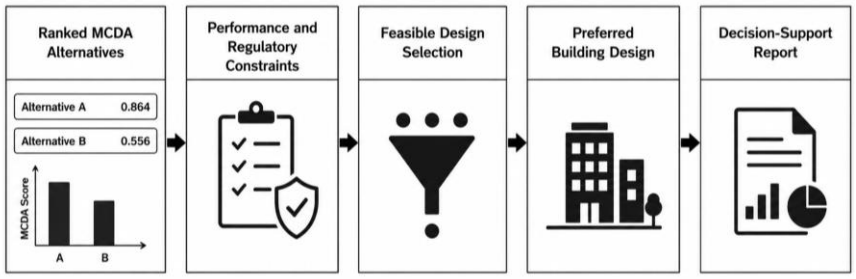


Fig. 6. Constrained Design Selection Workflow.

The constrained design selection procedure is applied to the feasible alternatives after MCDA ranking. Alternatives that satisfy the applicable constraints and mandatory regulatory requirements are retained for final selection. The alternative with the higher MCDA score among the feasible designs is identified as the preferred design alternative.

G. Framework Execution and Validation

Validation focuses on the consistency of the performance calculations, the classification of compliant and non compliant alternatives, the reproducibility of the MCDA ranking from the reported data and calculation procedure, and the consistency of the final design selection. For N alternatives and M evaluation criteria, the basic MCDA aggregation requires O(NM) computational operations. This complexity does not include the computational time required for external building-performance simulations. The current study does not report numerical sensitivity-analysis scenarios. Therefore, sensitivity analysis is identified as a future extension rather than a completed validation experiment. Future studies can examine changes in criterion weights and evaluate their effects on MCDA scores and alternative rankings.

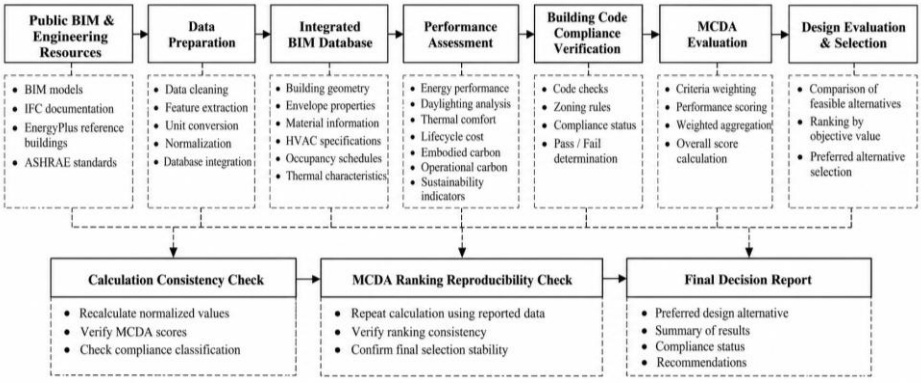


Fig. 7. Framework Execution and Validation Workflow.

The workflow integrates data preparation, performance assessment, compliance verification, MCDA, constrained design selection, and validation into a unified decision support process for evaluating sustainable building design alternatives.

IV. RESULTS AND DISCUSSION

The numerical demonstration identified Alternative A as the highest-scoring feasible design alternative. It achieved full regulatory compliance and obtained the highest MCDA score among the compliant alternatives.

A. Results

Three representative building design alternatives were evaluated as a controlled numerical demonstration using the performance indicators and compliance categories described in the methodology. These values are illustrative inputs for demonstrating the decision procedure and are not claimed as measurements or outputs from a new EnergyPlus simulation.

TABLE III. *Illustrative Building Performance Assessment Results*

Performance Indicator	Alternative A	Alternative B	Alternative C	Preferred Objective
Energy Use Intensity (kWh/m²/year)	96.4	108.7	121.9	Minimize
Daylight Availability (%)	82.6	78.4	74.1	Maximize
Thermal Comfort (PMV)	0.21	0.34	0.47	Near Zero
Lifecycle Cost (USD/m²)	1325	1287	1346	Minimize
Embodied Carbon ($kgCO_2e/m^2$)	248.6	261.9	279.8	Minimize
Operational Carbon ($kgCO_2e$/year)	17.5	20.3	23.8	Minimize
Occupant Comfort Index	91.8	87.5	83.4	Maximize
Sustainability Index	0.91	0.84	0.76	Maximize

Alternative A records the lowest EUI, embodied carbon, and operational carbon among the three designs. It also has the highest daylight availability, occupant comfort index, and sustainability index. Alternative B has the lowest lifecycle cost. Alternative C records less favorable values for most of the reported indicators.

TABLE IV. *Building Code Compliance Results*

Compliance Category	Alternative A	Alternative B	Alternative C
Fire Safety	✓	✓	✗
Accessibility	✓	✓	✓
Structural Requirements	✓	✓	✓
Zoning Regulations	✓	✓	✗

Emergency Exits	✓	✓	✓
Energy-Code Compliance	✓	✓	✗
Overall Compliance Rate	100%	100%	83.3%

Table IV shows that Alternatives A and B satisfy all six evaluated compliance categories. Alternative C fails the fire-safety, zoning, and energy-code checks and has an overall compliance rate of 83.3%. Because full compliance is required for final selection, Alternative C is excluded from the feasible design set. Using the transparent equal-weight calculation described above, the normalized scores from the Table III data give:

TABLE V. *MCDA Results for Feasible Alternatives in the Numerical Demonstration*

Design Alternative	**MCDA Score**	**Compliance Rate (%)**	**Final Rank**
Alternative A	0.864	100	1
Alternative B	0.556	100	2
Alternative C	—	83.3	Rejected

Using the unrounded normalized values from the illustrative Table III inputs, the equal-weight MCDA calculation places Alternative A first among the feasible alternatives, with a score of 0.864, while Alternative B ranks second with a score of 0.556. Alternative A performs better across most of the energy, environmental, comfort, and sustainability indicators, whereas Alternative B has the lowest lifecycle cost. Alternative C is excluded from the final ranking because its compliance rate is 83.3% and therefore does not satisfy the mandatory full-compliance condition. The resulting scores are used to rank the feasible alternatives for constrained design selection.

TABLE VI. *Normalized Performance Scores for the Illustrative Alternatives*

Indicator	**Alternative A**	**Alternative B**	**Alternative C**
EUI	1.000	0.518	0.000
Daylight Availability	1.000	0.506	0.000
Thermal Comfort	0.553	0.277	0.000
Lifecycle Cost	0.356	1.000	0.000

Embodied Carbon	1.000	0.574	0.000
Operational Carbon	1.000	0.556	0.000
Occupant Comfort Index	1.000	0.488	0.000
Sustainability Index	1.000	0.533	0.000

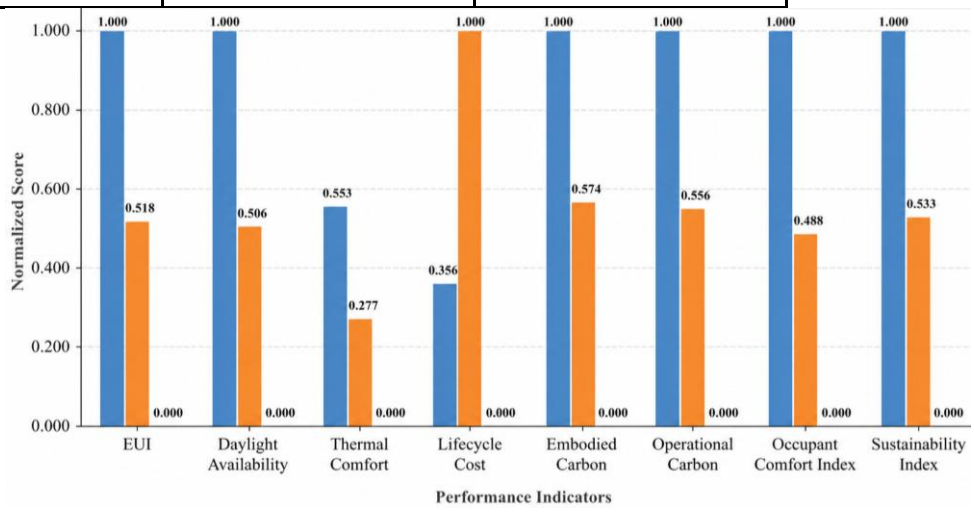


Fig. 8. Comparative Normalized Performance of Alternative Building Designs.

The constrained design selection procedure was applied to the compliant alternatives. Alternatives A and B satisfied the mandatory compliance requirements, while Alternative A achieved the higher MCDA score under the equal-weight calculation. Based on the reported performance indicators and compliance conditions, Alternative A was selected as the preferred design alternative.

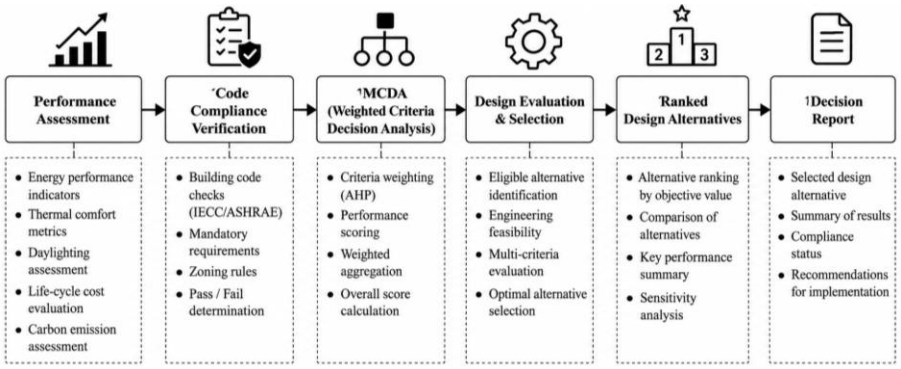


Fig. 9. Integrated Decision-Support Workflow.

The workflow summarizes the decision process from performance assessment and compliance verification through MCDA and constrained design selection. The final output provides performance results, compliance status, ranking of feasible alternatives, and the preferred design recommendation.

B. Discussion

This treatment separates mandatory regulatory requirements from the performance criteria used in MCDA. Alternative C records values for all eight performance indicators, but its failure in three mandatory compliance categories prevents it from entering the final feasible set. This treatment gives regulatory requirements a different role from the performance criteria used in MCDA. Alternative A performs well across most of the reported performance indicators. Its EUI is lower than those of Alternatives B and C, and its embodied and operational carbon values are also lower. It has the highest daylight availability, occupant comfort index, and sustainability index. Alternative B has a lower lifecycle cost, but this advantage does not compensate for its lower values on several other measures under the equal-weight calculation. The corrected normalization method is important because the performance indicators have different objectives. Lower EUI, cost, and carbon values should produce higher normalized scores, while higher daylight, comfort, and sustainability values should receive higher scores. PMV requires separate treatment because the preferred value is close to zero. The results also show the role of the compliance filter. A design with good performance values cannot become the final choice if it fails a mandatory requirement. This separates regulatory feasibility from the trade-offs among energy, cost, carbon, and comfort. The three-alternative experiment demonstrates the decision process described in the framework. It does not, however, provide enough evidence to claim that the same ranking would occur across different building types, climates, regulatory systems, or project priorities.

C. Limitations and Future Work

Several limitations should be considered when interpreting the results. First, the study uses publicly available benchmark/reference resources rather than measurements from completed buildings. Second, no new EnergyPlus simulation was executed for the three-alternative numerical demonstration, and no completed-building measurement dataset was used. Third, Tables III-VI contain a controlled illustrative dataset created to demonstrate the normalization, compliance filtering, and MCDA calculations; these values are not presented as measured or simulated building outputs. The exact source scope is therefore documented explicitly: BIM benchmark/IFC resources, EnergyPlus reference-building documentation, ASHRAE standards, and open building-performance resources are used as methodological sources, while Alternatives A-C are defined by the numerical values reported in Table III and the compliance states in Table

IV. The compliance assessment also depends on the regulatory requirements represented in the model. Building regulations differ across locations, so the compliance rules would need to be replaced or adapted for a specific jurisdiction. Future work should execute a reproducible EnergyPlus study using identified BIM/IFC model files, a named reference building, a specified weather file, simulation period, occupancy schedules, HVAC assumptions, software version, numerical constraint limits, and a documented scenario-generation procedure. Future studies can also examine stakeholder based weighting, uncertainty in cost and carbon estimates, automated rule checking, Digital Twin data, IoT measurements, and formal multi-objective decision analysis.

V. Conclusion

This study presented an integrated decision framework for sustainable and code-compliant building design. The framework brings together BIM information, building performance assessment, regulatory compliance checking, multi-criteria evaluation, and constrained design selection. The three evaluated alternatives show that different design choices produce different trade-offs. The current results are a controlled benchmark demonstration across the reported energy, environmental, comfort, and sustainability indicators rather than outputs from a new building energy simulation. Alternative B has the lowest lifecycle cost but lower values for several other measures. Alternative C is excluded from final selection because it does not satisfy all mandatory compliance requirements. The decision process separates regulatory feasibility from performance-based ranking. Mandatory requirements are checked first, followed by MCDA for the feasible alternatives. This structure prevents a favorable score in one area from offsetting a failed regulatory requirement. Additional testing with real projects, identified datasets, documented simulation settings, project-specific weights, and a specified computational method would provide stronger evidence for practical application.

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