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A DECISION-MAKING FRAMEWORK FOR PRIORITIZING GREEN RETROFIT STRATEGIES IN CLINIC BUILDINGS USING AHP

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ABSTRACT

Clinic buildings face challenges in improving environmental performance while maintaining operational efficiency and occupant comfort. This study aims to develop an Analytical Hierarchy Process (AHP)-based decision-making framework to prioritize green retrofit criteria for clinic buildings. The research was conducted by identifying relevant criteria and sub-criteria through a literature review and obtaining pairwise comparison judgments from 18 experts. The results indicate that the Economic criterion has the highest priority with a weight of 66.05%, followed by Health & User Comfort (18.96%), Technical (9.26%), and Environmental (5.74%) criteria. These findings suggest that financial feasibility is the primary consideration in green retrofit decision-making, although indoor environmental quality and occupant well-being remain important factors in healthcare facilities. The consistency test produced a Consistency Ratio (CR) of 0.0744, indicating acceptable judgment consistency. Furthermore, sensitivity analysis confirmed that the priority structure remained stable under various weight variation scenarios. Therefore, the proposed AHP framework can serve as a practical decision-support tool for prioritizing green retrofit initiatives in clinic buildings.

INTRODUCTION

Buildings contribute significantly to greenhouse gas emissions and environmental degradation (Röck et al., 2020). As concerns over climate change and sustainable development intensify, improving the environmental performance of existing buildings has become a priority (Ma et al., 2012). Among the current approaches, green retrofitting has emerged as a practical strategy to enhance building performance by minimizing environmental impacts, without compromising building functionality (Jagarajan et al., 2017).

Healthcare facilities present unique challenges and opportunities in this context. Unlike many other building types, clinic buildings must provide environments that support not only operational efficiency but also patient health, comfort, and well-being. Indoor environmental quality, including air quality, thermal comfort, and adequate lighting, creates a healing environment that supports healthcare delivery (Ackley et al., 2024). Consequently, the adoption of sustainable building practices in clinics extends beyond environmental concerns and directly contributes to improving healthcare outcomes.

Despite their importance, many clinic buildings in Indonesia continue to face challenges related to high energy consumption, inefficient resource utilization, and increasing operational costs (Igusti et al., 2025; Simarmata et al., 2023). Many healthcare facilities in Indonesia continue to rely on conventional building systems, including aging lighting installations, inefficient air-conditioning equipment, and limited passive ventilation strategies, resulting in relatively high energy consumption and operational expenditures (Annura et al., 2022; Hidayah & Husin, 2024; Salim Nur Rohman et al., 2023). Furthermore, maintaining adequate indoor environmental quality remains challenging, particularly in tropical climates where thermal comfort and ventilation directly influence patient satisfaction, staff productivity, and healthcare service quality. These challenges highlight the urgent need for systematic green retrofit planning that simultaneously improves energy efficiency, occupant comfort, and long-term operational sustainability in clinic buildings.

To address these issues, various green retrofit strategies have been proposed, including energy-efficient lighting systems, smart controls, natural ventilation, solar photovoltaic systems, rainwater harvesting, and the integration of green spaces (Hashempour et al., 2020; Juan et al., 2009; Timuçin, 2018). While these strategies offer potential environmental and operational benefits, they differ considerably in terms of investment requirements, technical feasibility, implementation complexity, and expected performance.

Selecting the most appropriate retrofit strategy is a complex decision-making process due to limited resources. Furthermore, decision-makers must balance a range of often competing considerations, including economic performance, environmental benefits, technical practicality, occupant health, and user comfort. In healthcare domains, these considerations are particularly important because building conditions can directly influence the quality of care and the overall patient experience.

Previous studies have investigated green retrofit strategies in educational, commercial, and office buildings (Hanif & Hadi, 2025; Messakh et al., 2025; Rahmatullah Masruchin et al., 2024). However, research focusing specifically on clinic buildings remains limited, particularly in relation to the prioritization of retrofit alternatives that simultaneously consider sustainability objectives and healthcare-related environmental quality. Moreover, studies that develop structured decision-support frameworks for prioritizing green retrofit initiatives in Indonesian clinic buildings remain scarce. Most existing studies primarily discuss retrofit concepts or individual technologies without providing a comprehensive prioritization approach that integrates economic, environmental, technical, and occupant-related considerations (Shi et al., 2023; Shi & Chen, 2024). This research gap underscores the necessity of developing a practical decision-making framework tailored to the operational characteristics of clinic buildings in Indonesia.

To address this challenge, this study aims to develop a decision-making framework for prioritizing green retrofit strategies in clinic buildings using the AHP approach (Saaty, 1982; Timuçin, 2018). The proposed framework is expected to assist healthcare facility managers in identifying the most appropriate retrofit actions, improving environmental performance, enhancing the quality of healthcare environments, and supporting the development of healthier, more efficient, and sustainable healthcare facilities.

METHODS

This study implements a positivist paradigm and a quantitative approach to develop a decision-making framework for prioritizing green retrofit strategies in clinic buildings. A case study strategy was employed, focusing on Syafana Medika Clinic, located in Demak Regency, Central Java, Indonesia. The clinic was selected as the study object because it operates daily as a healthcare facility and requires a building environment that is efficient, healthy, comfortable, and supportive of healthcare service delivery. In addition, the clinic presents considerable opportunities for implementing green retrofit strategies to improve energy efficiency, resource conservation, and indoor environmental quality.

As illustrated in Figure 1, the research began with field observations and a comprehensive literature review to identify the existing building conditions and potential green retrofit strategies applicable to clinic buildings. Based on the literature review, site observations, and expert consultations, eight retrofit alternatives were identified: energy-efficient LED lighting (A1), inverter air-conditioning systems (A2), natural ventilation (A3), smart lighting systems (A4), solar photovoltaic systems (A5), rainwater harvesting systems (A6), green roofs (A7), and vertical gardens (A8).

The evaluation criteria were established based on sustainable building principles, green retrofit concepts, and the operational requirements of healthcare facilities. These criteria were grouped into four major dimensions: economic, environmental, technical, and health and user comfort aspects. The economic dimension included the initial investment cost and the payback period. The environmental dimension consisted of energy-saving potential, carbon emission reduction potential, and water conservation potential. The technical dimension covered ease of implementation as well as operation and maintenance requirements. The health and user comfort dimensions included indoor air quality, thermal comfort, lighting quality, and support for a healing environment. Operational definitions for all criteria were developed from the literature and validated by the expert panel prior to the evaluation process.

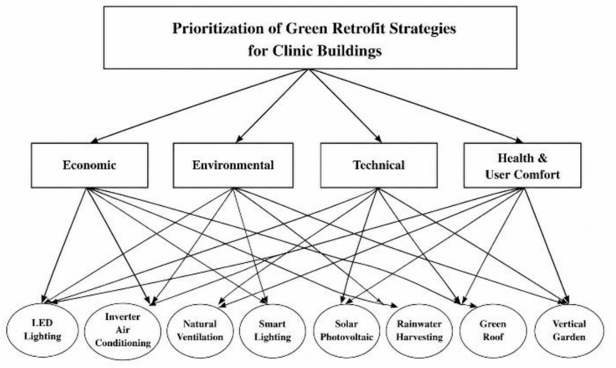

Figure 1. Hierarchical Structure of the Decision-Making Model (Source: Authors, 2026)

The study involved an expert panel comprising professionals and academics with expertise in green buildings, facility management, civil engineering, architecture, environmental health, and healthcare facility management. Participants were selected using purposive sampling based on the criterion of having at least five years of professional or academic experience in a relevant field. A total of 18 experts participated in the study by providing judgments on the evaluation criteria and retrofit alternatives through a pairwise comparison questionnaire.

Data analysis was conducted using Python within the Jupyter Notebook environment. Custom scripts were developed using NumPy, Pandas, and SciPy libraries to automate the AHP model. The use of Python enabled efficient data processing, minimized computational errors, and enhanced the transparency, reproducibility, and reliability of the analytical results.

To ensure the validity of the results, two validation procedures were performed. First, the consistency of expert judgments was evaluated using the Consistency Ratio (CR) derived from the pairwise comparison matrices. A CR value below 0.10 was considered acceptable and indicated a satisfactory level of consistency. Second, sensitivity analysis was conducted by modifying the weights of the main criteria under several scenarios to assess the stability of the resulting rankings. Consistent rankings across different scenarios indicate that the proposed decision-making framework is robust and reliable for prioritizing green retrofit strategies in clinic buildings. The whole process of the research framework is presented in Figure 2.

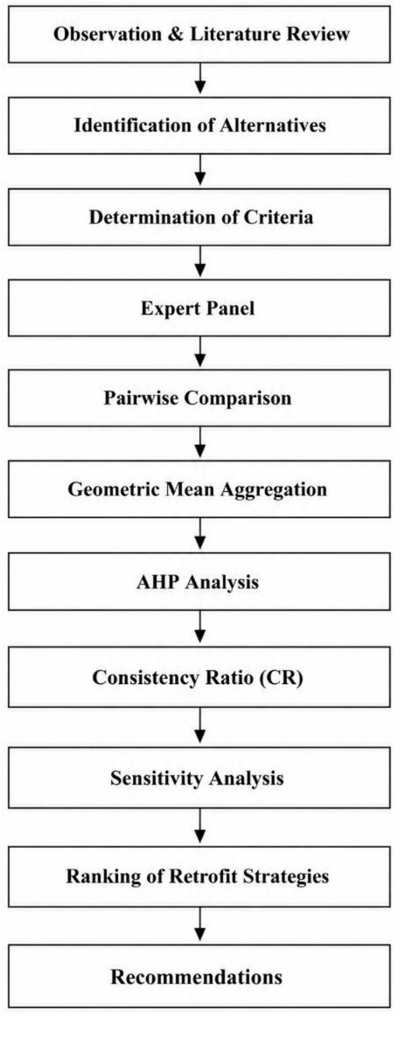

Figure 2. Research Framework of the Study (Source: Authors, 2026)

RESULT AND DISCUSSION

The collected pairwise comparison data from the expert panel were first aggregated using the geometric mean method to obtain a consensus judgment for each comparison. The resulting aggregated values served as the basis for constructing the aggregated AHP pairwise comparison matrix and determining the relative importance of the evaluation criteria. Furthermore, consistency analysis was performed to ensure the reliability of the aggregated expert judgments before proceeding to the weighting and ranking stages.

Geometric Mean Aggregation

The geometric mean was employed in this study, since it preserves the reciprocal properties of pairwise comparison data and reduces the influence of extreme judgments. The results of the geometric mean aggregation are presented in Table 1.

Table 1. Geometric Mean Aggregation of Expert Pairwise Comparison Judgments

Code	Comparison	Geometric Mean
A1	Economic vs Environmental	7.186
A2	Economic vs Technical	5.686
A3	Economic vs Health & Comfort	6.202
A4	Environmental vs Technical	0.573
A5	Environmental vs Health & Comfort	0.204
A6	Technical vs Health & Comfort	0.422
B1	Initial Investment Cost vs Payback Period	3.288
C1	Energy Saving vs Carbon Reduction	4.901
C2	Energy Saving vs Water Conservation	4.077
C3	Carbon Reduction vs Water Conservation	3.802
D1	Ease of Implementation vs Operation & Maintenance	6.691
E1	Indoor Air Quality vs Thermal Comfort	3.992
E2	Indoor Air Quality vs Lighting Quality	4.309
E3	Indoor Air Quality vs Healing Environment	4.678
E4	Thermal Comfort vs Lighting Quality	0.332
E5	Thermal Comfort vs Healing Environment	0.250
E6	Lighting Quality vs Healing Environment	0.204

Aggregated Main Criteria Matrix

The geometric mean values obtained from the expert panel were used to construct the aggregated main criteria matrix. This matrix represents the collective judgments of the experts regarding the relative importance of the four evaluation criteria: Economic, Environmental, Technical, and Health & User Comfort. The reciprocal structure of the matrix preserves the consistency requirements of the AHP methodology and serves as the basis for calculating the priority weights of the criteria. The aggregated main criteria matrix is presented in Table 2.

Table 2. Aggregated Main Criteria Matrix

Criteria	Economic	Environmental	Technical	Health & Comfort
Economic	1.000	7.186	5.686	6.202
Environmental	0.139	1.000	0.573	0.204
Technical	0.176	1.746	1.000	0.422
Health & Comfort	0.161	4.894	2.371	1.000

The matrix indicates that the Economic criterion was considered substantially more important than the Environmental and Technical criteria, as reflected by the relatively high comparison values. Similarly, the Economic criterion was also preferred over Health & User Comfort, suggesting that financial considerations play a dominant role in the prioritization of green retrofit strategies for clinic buildings. These aggregated judgments were subsequently used to derive the criteria weights and evaluate the consistency of the expert assessments.

Preliminary Criteria Weights

Table 3 indicates that the Economic criterion is the most influential factor in the decision-making process, receiving a normalized weight of 0.6605 (66.05%). This is followed by Health & Comfort with a weight of 0.1896 (18.96%) and Technical considerations with 0.0926 (9.26%). The Environmental criterion has the lowest priority, accounting for 0.0574 (5.74%) of the total importance. These results suggest that economic performance is the primary concern in the evaluation framework, while environmental aspects play a comparatively smaller role in influencing the final decision.

Table 3. Preliminary Criteria Weights

Rank	Criteria	Weight
1	Economic	0.6605
2	Health & Comfort	0.1896
3	Technical	0.0926
4	Environmental	0.0574
Total	—	1.0000

Consistency Check

The consistency of the aggregated expert judgments was evaluated using the Consistency Index (CI) and Consistency Ratio (CR). Table 4 shows that a maximum eigenvalue (λmax) of 4.201, resulting in a CI value of 0.067 and a CR value of 0.074. Since the obtained CR is below the recommended threshold of 0.10, the aggregated pairwise comparisons can be considered sufficiently consistent. Therefore, the expert judgments are reliable and suitable for subsequent weighting and ranking analyses.

Table 4. Consistency Analysis Results

Parameter	Value
λmax	4.2010
Consistency Index (CI)	0.0670
Consistency Ratio (CR)	0.0744
Decision	Consistent

Sensitivity Analysis

A sensitivity analysis was performed to evaluate the robustness of the obtained criteria weights by increasing the weight of each main criterion by 10% while keeping the remaining criteria unchanged. The results indicate that the ranking structure remained stable across all scenarios. Economic considerations consistently retained the highest priority, followed by Health & User Comfort, Technical, and Environmental criteria. Although minor changes in the weight distribution were observed, no substantial shifts occurred in the relative importance of the criteria. This finding suggests that the proposed AHP-based decision-making framework is robust and not overly sensitive to moderate variations in criterion weights.

Table 5. Sensitivity Analysis Results

Scenario	Economic	Environmental	Technical	Health & Comfort
Base	0.6605	0.0574	0.0926	0.1896
Economic +10%	0.6815	0.0538	0.0868	0.1778
Environmental +10%	0.6567	0.0628	0.0920	0.1885
Technical +10%	0.6544	0.0569	0.1009	0.1878
Health & Comfort +10%	0.6482	0.0563	0.0908	0.2046

Discussion

The results indicate that the Economic criterion is the most influential factor in prioritizing green retrofit strategies for clinic buildings, accounting for 66.05% of the total decision weight. This finding suggests that investment-related considerations, particularly initial investment cost and payback period, are the primary concerns in retrofit decision-making. Such a result is reasonable because healthcare facilities often operate under budget constraints and therefore prioritize measures that can generate tangible financial benefits within a relatively short period. This finding is consistent with Shi et al. (2023), who reported that economic feasibility plays a dominant role in prioritizing hospital retrofit strategies.

Health & User Comfort ranked second with a weight of 18.96%, highlighting the importance of indoor environmental quality in healthcare facilities. Factors such as indoor air quality, thermal comfort, lighting quality, and healing environment remain essential because they directly affect patient well-being and the quality of healthcare services. This result indicates that experts consider occupant health and comfort as an important complement to economic performance.

The Technical and Environmental criteria received weights of 9.26% and 5.74%, respectively. These findings suggest that ease of implementation, maintenance requirements, energy savings, carbon emission reduction, and water conservation are considered important but secondary to economic and healthcare-related considerations. This priority structure reflects the practical challenges faced by clinics in balancing sustainability objectives with financial and operational requirements.

The consistency analysis yielded a CR value of 0.0744, which is below the acceptable threshold of 0.10, indicating that the expert judgments are sufficiently consistent and reliable. Furthermore, the sensitivity analysis showed that variations of ±10%, ±20%, and ±30% in the criteria weights did not substantially alter the overall priority structure. This demonstrates the robustness of the proposed AHP framework and confirms the stability of the decision-making model.

Overall, the findings suggest that green retrofit planning in clinic buildings should prioritize strategies that provide economic benefits while simultaneously improving indoor environmental quality. The derived criteria weights can serve as a basis for the subsequent ranking of retrofit alternatives and the formulation of recommendations to support sustainable healthcare facility development.

CONCLUSIONS

This study developed an AHP-based decision-making framework to support the prioritization of green retrofit strategies for clinic buildings. The results indicate that the Economic criterion is the most influential factor, with a weight of 66.05%, followed by Health & User Comfort (18.96%), Technical (9.26%), and Environmental (5.74%) criteria. These findings suggest that financial feasibility remains the primary consideration in green retrofit decision-making, while indoor environmental quality and occupant wellbeing also play important roles in healthcare facilities. The consistency analysis yielded a CR value of 0.0744, indicating that the expert judgments were reliable and acceptable. In addition, the sensitivity analysis confirmed that the priority structure remained stable under various weight variation scenarios, demonstrating the robustness of the proposed framework. Therefore, the developed AHP model can serve as a practical decision-support tool for evaluating green retrofit priorities in clinic buildings.

Future research is recommended to incorporate the performance evaluation and ranking of specific retrofit alternatives, such as LED lighting, inverter air-conditioning systems, natural ventilation, solar photovoltaic systems, and rainwater harvesting systems. This will enable a more comprehensive prioritization process and provide more practical recommendations for green retrofit implementation in healthcare facilities.

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REFERENCES

Ackley, A., Olanrewaju, O. I., Oyefusi, O. N., Enegbuma, W. I., Olaoye, T. S., Ehimatie, A. E., Ukpong, E., & Akpan-Idiok, P. (2024). Indoor environmental quality (IEQ) in healthcare facilities: A systematic literature review and gap analysis. *Journal of Building Engineering*, *86*, 108787. https://doi.org/10.1016/j.jobe.2024.108787

Annura, S., Arabikum, J., Aminingrum, R., Ulu, Z., Saputra, P., Wahyudi, D., & Zuhriyah, L. (2022). EFFICIENT AND SUSTAINABLE ENERGY MANAGEMENT FOR HOSPITAL BUILDING. *Journal of Community Health and Preventive Medicine*, *2*.

Hanif, M. F., & Hadi, A. A. (2025). Pendekatan Eco-Design Dalam Desain Lanskap Hutan Kota Eduforest Bekasi. *Jurnal Ilmiah Arsitektur*, *15*(1), 40–50. https://doi.org/10.32699/jiars.v15i1.7560

Hashempour, N., Taherkhani, R., & Mahdikhani, M. (2020). Energy performance optimization of existing buildings: A literature review. *Sustainable Cities and Society*, *54*, 101967. https://doi.org/10.1016/j.scs.2019.101967

Hidayah, S., & Husin, A. E. (2024). Retrofitting healthcare facility based on regulation of green performance assessment in Indonesia. *AIP Conference Proceedings*, *2710*(1). https://doi.org/10.1063/5.0162033

Igusti, N., Amalia AP, A. R., & Arman, A. (2025). Optimizing Hospital Tariffs and Resource Allocation through Unit Cost Analysis: Lessons from a Major Indonesian Public Hospital. *Journal of Current Health Sciences*, *5*(3), 177–184. https://doi.org/10.47679/jchs.2025127

Jagarajan, R., Abdullah Mohd Asmoni, M. N., Mohammed, A. H., Jaafar, M. N., Lee Yim Mei, J., & Baba, M. (2017). Green retrofitting – A review of current status, implementations and challenges. *Renewable and Sustainable Energy Reviews*, *67*, 1360–1368. https://doi.org/10.1016/j.rser.2016.09.091

Juan, Y.-K., Perng, Y.-H., Castro-Lacouture, D., & Lu, K.-S. (2009). Housing refurbishment contractors selection based on a hybrid fuzzy-QFD approach. *Automation in Construction*, *18*(2), 139–144. https://doi.org/10.1016/j.autcon.2008.06.001

Ma, Z., Cooper, P., Daly, D., & Ledo, L. (2012). Existing building retrofits: Methodology and state-of-the-art. *Energy and Buildings*, *55*, 889–902. https://doi.org/10.1016/j.enbuild.2012.08.018

Messakh, J., Ndoen, R., & Riwu, D. D. (2025). Pemanfaatan Ruang Terbuka Publik dalam Kajian Pengembangan Potensi Daya Tarik Wisata Kota Kupang. *Jurnal Ilmiah Arsitektur*, *15*(1), 1–12. https://doi.org/10.32699/jiars.v15i1.8578

Rahmatullah Masruchin, F., Faisal, M., Yasin Alfa Dani, M., & Rizkyansyah Diyaul Haq, D.

(2024). Implementasi Arsitektur Hijau pada Perumahan Subsidi pada Studi Kasus Perumahan Kokoh City Bangkalan Madura. *Jurnal Ilmiah Arsitektur*, *14*(2), 99–107. https://ojs.unsiq.ac.id/index.php/jiars

Röck, M., Saade, M. R. M., Balouktsi, M., Rasmussen, F. N., Birgisdottir, H., Frischknecht, R., Habert, G., Lützkendorf, T., & Passer, A. (2020). Embodied GHG emissions of buildings – The hidden challenge for effective climate change mitigation. *Applied Energy*, *258*, 114107. https://doi.org/10.1016/j.apenergy.2019.114107

Saaty, T. L. (1982). The Analytic Hierarchy Process: A New Approach to Deal with Fuzziness in Architecture. *Architectural Science Review*, *25*(3), 64–69. https://doi.org/10.1080/00038628.1982.9696499

Salim Nur Rohman, R. H., Abidin, Z., & Arsyad, M. I. (2023). ENERGY AUDIT OF LIGHTING SYSTEM, AIR CONDITIONING SYSTEM AND MEDICAL EQUIPMENT IN YARSI PONTIANAK GENERAL HOSPITAL. *Telecommunications, Computers, and Electricals Engineering Journal*, *1*(2), 150. https://doi.org/10.26418/telectrical.v1i2.72005

Shi, Y., & Chen, P. (2024). Energy retrofitting of hospital buildings considering climate change: An approach integrating automated machine learning with NSGA-III for multi-objective optimization. *Energy and Buildings*, *319*, 114571. https://doi.org/10.1016/j.enbuild.2024.114571

Shi, Y., Wang, R., & Chen, P. (2023). Multi-criteria decision-making approach for energy-efficient renovation strategies in hospital wards: Balancing energy, economic, and thermal comfort. *Energy and Buildings*, *298*, 113575. https://doi.org/10.1016/j.enbuild.2023.113575

Simarmata, T., Maulana, G., & Fahlevi, O. (2023). Artikel Energy Performance Indicator for Health Care Building: A Case Study of a Small sized Hospital in Indonesia. *MigasZoom*. https://doi.org/10.37525/mz/2023

Timuçin. (2018). Analytic Hierarchy Process (AHP) as an Assessment Approach for Architectural Design: Case Study of Architectural Design Studio Timuçin Harputlugil * Timuçin Harputlugil. *ICONARP International Journal of Architecture & Planning Received*, *6*(2), 217–245. https://doi.org/10.15320/ICONARP.2018.53-E-ISSN