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ASEAN Journal of Science and Engineering Education

Journal homepage: http://ejournal.upi.edu/index.php/AJSEE/

AJSEE ASEAN Journal of Science and Engineering Education

Development of a Multi-Criteria Assessment Tool for Evaluating Thermal Building Performance with Educational Integration

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ABSTRACT

An increase in global temperature due to climate change and rapid urbanization presents significant risks to building performance, particularly in energy efficiency and thermal comfort. Residential and institutional buildings in Angeles City, the Philippines, face challenges such as thermal discomfort and excessive energy use during dry seasons. This study developed a Multi-Criteria Assessment Tool (MCAT) using an expanded STEEEP framework (i.e., Social, Technological, Environmental, Economic, Educational, and Political factors). The mixed-methods approach combined surveys, interviews, on-site inspections, and simulations using DesignBuilder. Educational factors considered occupants' training, awareness programs, and institutional integration of sustainable building knowledge. The tool, validated by experts and tested with 17 professionals, achieved a Cronbach's Alpha, indicating high reliability. Results revealed a moderate average performance score with strengths in political compliance and weaknesses in technological adoption. The MCAT demonstrates strong potential for assessing and improving thermal building performance while promoting educational awareness for sustainable construction practices.

ARTICLE INFO

Article History:
Submitted/Received 06 May 2025
First Revised 09 Jun 2025
Accepted 11 Aug 2025
First Available online 12 Aug 2025
Publication Date 01 Sep 2025

Keyword:
Building standards,
Designbuilder,
Multi-criteria assessment tool,
STEEP,
Thermal comfort,
Thermal building performance.

1. INTRODUCTION

Climate change and rapid urbanization have intensified global temperature rise, significantly affecting building performance, particularly in terms of thermal comfort and energy efficiency. Many reports regarding climate have been well-documented (Rahmat & Mutolib, 2016; Nurramadhani *et al*., 2024; Belhadi *et al*., 2025; Namoussa *et al*., 2025; Asif *et al*., 2021; Phylosophie *et al*., 2024; Olutola & Gift, 2025; Karmaker & Lemon, 2024; Reyes, 2024; Ibrahim *et al*., 2024; Manullang *et al*., 2021). In tropical urban areas such as Angeles City, Philippines, the urban heat island effect exacerbates heat stress, impacting human health, productivity, and infrastructure resilience (Georgescu *et al*., 2021). Residential and institutional buildings, which accommodate large populations and support critical social functions, are highly vulnerable during prolonged dry seasons, leading to increased cooling demands, higher energy costs, and reduced occupant comfort (Maller & Strengers, 2011).

Effective thermal building performance evaluation requires a holistic framework that integrates multiple dimensions influencing energy use and comfort. The expanded STEEEP framework (i.e., Social, Technological, Environmental, Economic, Educational, and Political factors) offers a comprehensive approach by incorporating human behavior, design features, environmental context, economic constraints, knowledge dissemination, and governance (Nwankwo *et al*., 2022). Education plays a critical role in fostering awareness, technical skills, and behavioral changes that promote sustainable building practices, ensuring that both professionals and occupants are equipped to implement adaptive strategies (Altassan, 2023; Koukpu *et al*., 2024; Mian *et al*., 2020; Malik, 2024; Osuji & Nwuke, 2024; Debrah *et al*., 2021).

This study aims to develop, validate, and apply a Multi-Criteria Assessment Tool (MCAT) based on the STEEEP framework to assess thermal building performance in Angeles City. By integrating quantitative and qualitative methods with simulation modeling, the MCAT seeks to identify strengths, reveal deficiencies, and propose targeted policy, engineering, and educational strategies to enhance energy efficiency and occupant well-being.

2. METHODS

A case study technique formed the basis of evaluating the thermal efficiency of selected buildings within Angeles City, the Philippines, subject to the real situation. It employed a mixed methods design that also combined both quantitative and qualitative information collection strategies to examine factors influencing thermal comfort. Based on the STEEP framework, quantitative data yielded measurable performance outcomes of the buildings, occupant experience, and perspectives, and the qualitative methods (structured interview and observation) were addressed. These are supplementary approaches that informed the development of a comprehensive multi-criteria evaluation tool that comprises technical accuracy and user-oriented programmable aspects of improving thermodynamic performance.

The methodological framework in **Figure 1** shows the succession of policy development and provides optimized versions based on the results of efficient thermal building performance. Before proceeding to the series of phases, a research design and validation of our multi-criteria approach should be accomplished. In this research, a comprehensive and complete understanding of thermal building performance has been thoroughly explained through related literature and studies, and a case study mixed-method approach was utilized throughout the study. In the first phase, data gathering was employed, as the second phase was the preliminary assessment of buildings that were divided into two categories: residential

DOI: https://doi.org/10.17509/ajsee.v5i2.89058
p- ISSN 2775-6793 e- ISSN 2775-6815

and institutional buildings, with the utilization of the validated multi-criteria assessment tool supported by the DesignBuilder. In the third phase, data analysis was accomplished to provide comprehensive data to be analyzed to establish a policy recommendation. As in the last phase, an optimized version based on the results was discussed.

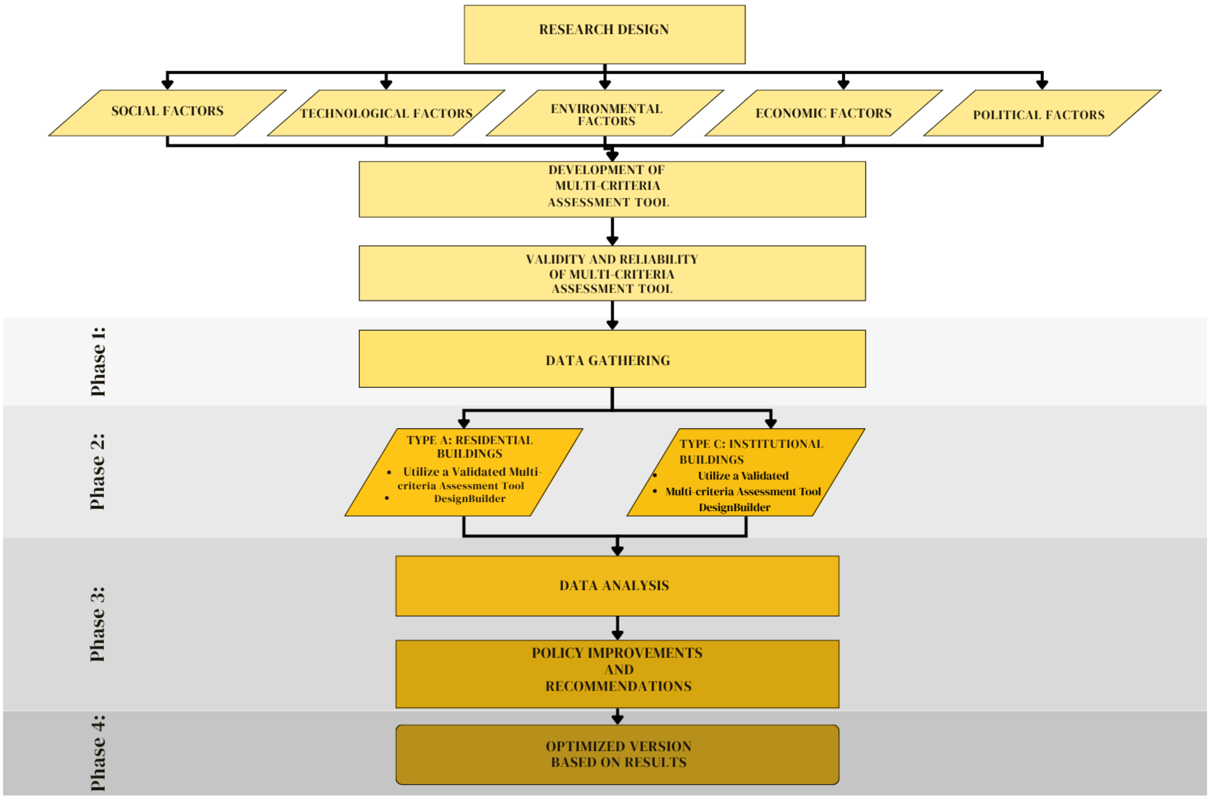

Figure 1. Methodological framework.

Highlighted the essence of making the right selection of sample size in research, which makes G*Power software advisable for proper estimation. In this research, the same approach was adopted, where G*Power was used to calculate the minimum sample size needed. Even the interface of the used software exemplified the use of ANOVA: fixed effects, one-way, which is an F-test aimed at revealing the significant differences and the minimization of the probability of type II error. The most important parameters were the effect size of 50, implying that the study may have survived with only a few participants, as in the case of residential and institutional buildings. The alpha level (95% level of confidence) and the power (80% probability level of determining a true non-negative effect) of 0.05 and 0.80, respectively, were used, with two groups mentioned, and the sample size was 34 respondents. (Kang, July 30, 2021).

A convenience sampling method was used to select participants, and the professionals were chosen, including engineers, architects, energy efficiency specialists, and safety officers. This strategy guaranteed the involvement of competent people with the ability to offer pertinent research data to the research study.

The methodological approach of the study considered both quantitative and qualitative data to solve extreme heat index problems. Surveys and structured interviews were used to collect primary data as they were based on the STEEP framework. Data were integrated using DesignBuilder software, and Likert-scale questionnaires were also used to determine the perceptions of thermal comfort (temperature, humidity, air movements).

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A proposed multi-criteria assessment tool was prepared and presented in appendices, where parameters and statements were captured with references to the review of related literature. Items contained in the tool were refined to suit clarity, reliability, and accuracy. Experts were used in carrying out validation, which included two civil engineers and one architect, through making use of the Instrument Validation Form. They played a part in determining the clarity, relevance, and completeness of the tool.

Reliability testing used Cronbach's Alpha (α) to evaluate internal consistency. The formula applied (see Equation 1).

$$\alpha = \frac{k}{k-1}\left(1 - \frac{\Sigma\sigma_{item}^2}{\sigma_{total}^2}\right) \quad (1)$$

where α is the Cronbach's Alpha coefficient (reliability index); k is the total number of items in the scale; σ_{item}^2 is the variance of individual items; and σ_{total}^2 is the variance of the total summed scores of all items.

The tool considered five main factors, namely: the social factor, which incorporated such aspects as the socio-economic status, the preferred temperature in the peak period of time, general awareness and the patterns of occupancy; the technological factor, which examined the factors like the presence of the insulation, shading systems, the level of efficiency of the air-conditioning, the parameters of the window size, and the use of the renewable energy sources; the environmental factor, which affected the accuracy of the degree of urbanization, the access to green spaces, the presence of water bodies, and the quality of air; the economic factor, which addressed the building's operational efficiency, productivity, the satisfaction of the occupants, the frequency of inspections and maintenance activities, the budget allocation, and the willingness to invest in improvements; and lastly, the political factor, which revolved around the integration of heat index risks and mitigation strategies, adherence to local ordinances and regulations, compliance with ceiling height standards, the implementation of government programs, and the formulation and enforcement of policies and strategies.

It consisted of 26 questions that were rated on a scale of 1 (non-compliant) to 5 (exceeds standards) using 17 respondents. This sample size relied on the central limit theorem and was confirmed through Microsoft Excel. Its 0.70 level of minimum acceptable alpha was calculated, and any category was revised or removed accordingly.

The study also referenced (MohaMad adaM Bujang1, 2018), who applied Bonett's formula to calculate sample size for Cronbach's Alpha, using Equations 2 and 3.

$$n = \left[\left\{\left(\frac{2k}{k-1}\right)\left(Z_{\alpha/2} + Z_B\right)^2\right\} / ln(\bar{\delta})^2\right] + 2 \quad (2)$$

$$\delta = \frac{1-CA_0}{1-CA_1} \quad (3)$$

where CA_0 is the value of Cronbach's alpha in the null hypothesis (most commonly assumed at 0); CA_1 is the expected value of Cronbach's alpha or the value of Cronbach's alpha in the alternative hypothesis; α is the probability of type 1 error (it was set at 0.05 at all times); k is the the number of items or raters; and β is the value (0.1).

Additional information covered two crucial aspects: environment and design specifications of the building. Environmental data were gathered through weather stations operated by PAGASA and nearby local stations in Angeles City, which captured climate variables such as temperature, humidity, wind speed, and solar radiation. Furthermore, advanced GIS tools were used to assist in the analysis, matching urban heat islands and green spaces, building orientation via the satellite images and aerial photographs.

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To verify the accuracy of GIS, field surveys, and ground truthing, measured canopy cover, tree density, and plant types using tools like drones and laser range finders. These data highlighted the cooling role of green areas in improving thermal comfort. Longitudinal monitoring observed seasonal changes in vegetation and environmental conditions, offering insights into how these factors affected local temperatures, airflow, building performance, and occupant comfort.

Simultaneously, reviewing existing building documents provided insights into architectural and engineering features. Access to floor plans, blueprints, and CAD files offered crucial information on orientation, materials, and layout, essential in evaluating ventilation, lighting, and insulation.

Adherence to building codes, especially the ASHRAE 55, proved that the building had energy-efficient and thermally responsive provisions such as reflective roofs, insulated walls, and thermally efficient windows, among others, but also indicated the areas that still require improvement. Other reports, feasibility studies, design brief, and post-construction evaluation gave a bigger picture of the proposed and actual performances of the building. The systems and materials, such as the use of HVAC, lighting, glazing, and insulation, were described in specification manuals about energy and thermal efficiency.

Finally, site visits were also used as a way of verifying the documents, where one can physically look at the systems and characteristics, such as the thickness of the walls, HVAC systems, and shading systems. Observations made were able to highlight the differences between the recorded designs and the real construction of the building.

DesignBuilder simulation software was utilized to evaluate the thermal performance of a residential and an institutional building located in Angeles City. Accurate modelling relied on the integration of localized weather data from Energy Weather Plus to reflect actual climate conditions. Architectural and engineering plans were analyzed to faithfully represent the buildings' spatial configurations, envelope systems, and mechanical infrastructure. Additional modelling considerations included the thermal properties of materials such as masonry, interior and exterior finishes, insulation systems, and air-tightness. Operational schedules for window and door openings were incorporated to simulate natural ventilation and user behaviour. Internal heat gains were computed based on occupant density and activity schedules, lighting usage, equipment loads, and solar exposure through glazed surfaces. These comprehensive inputs enabled the software to generate outputs such as indoor and outdoor temperature profiles, thermal comfort simulations aligned with ASHRAE standards, and heat gain analysis.

Thermal performance scores were derived through a systematic evaluation of simulation results. Each parameter was rated, and an average score was computed using the arithmetic mean formula (see Equation 4).

$$\bar{x} = \frac{\sum_{i=1}^{n} Xi}{n} \tag{4}$$

Where, $\bar{x}$ is average of score and Xi is value of score.

This approach ensured uniformity across assessment categories and facilitated objective comparison. Results were benchmarked against both local building codes and international standards, particularly those outlined by ASHRAE and ISO. Parameters were assessed according to technological, architectural, and operational compliance. Scoring variation reflected the degree of conformity to each criterion. The overall thermal rating of each building was computed using the same formula, yielding a reliable index of the building's effectiveness in managing internal thermal environments.

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Assessment findings informed the development of optimization strategies targeting specific inefficiencies. Measures addressed performance gaps such as inadequate insulation, excessive internal heat gains, and suboptimal ventilation practices. Each intervention was tailored to the building's functional typology, usage patterns, and architectural design. Feasibility, cost-effectiveness, and alignment with sustainability objectives were also considered to ensure the practical relevance of the recommendations. Once optimizations were applied, a second round of simulations using DesignBuilder was conducted to measure the impact of the improvements. Results confirmed enhancements in energy efficiency, thermal comfort, and overall sustainability, thereby validating the optimization process as effective and replicable.

3. RESULTS AND DISCUSSION

We explained the interpretation and analysis of the collected data. Additionally, the formulated assessment tool will be discussed, along with how each STEEP factor was determined according to its specific requirements and respective criteria.

3.1. Formulation of Assessment Tool

Tables 1 and 2 show the formulated multi-criteria assessment tool, intended to evaluate the thermal building performance of residential and institutional buildings in Angeles City, the Philippines. The table includes various parameters for each of the STEEP factors identified by the study as determining factors, along with corresponding criteria.

Table 1. Multi-criteria assessment tool.

Parameter	Determining factor		Data collection (evidence)	Site for data collection
SOCIAL	1.1	The socio-economic status in a selected building in Angeles City, Philippines.	1. Survey Questionnaire and interview	1. Barangay Balibago 2. Mariano Nepomuceno Elementary School, Barangay Cutcut
	1.2	Preferred temperature in their building/household based on their comfort level during peak temperature hours.	1. Ratio interval questionnaire and interview	1. Barangay Balibago 2. Mariano Nepomuceno Elementary School, Barangay Cutcut
	1.3	General awareness of the occupants about the heat index and its effects on daily lives.	1. Survey questionnaire and interview	1. Barangay Balibago 2. Mariano Nepomuceno Elementary School, Barangay Cutcut
	1.4	Frequency and spatial pattern of occupant-perceived thermal discomfort	1. Survey questionnaire and interview	1. Barangay Balibago 2. Mariano Nepomuceno Elementary School, Barangay Cutcut
	1.5	Thermal stability of the building based on occupant stay duration and room temperature consistency.	1. Survey questionnaire and interview 2. Site Inspection	1. Barangay Balibago 2. Mariano Nepomuceno Elementary School, Barangay Cutcut

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Table 1 (continue). Multi-criteria assessment tool.

Parameter		Determining factor	Data collection (evidence)	Site for data collection
TECHNOLOGICAL	2.1	The presence of insulation materials on masonry and plastered walls of the building, alongside the path of the sun.	1.Drawing plans and specifications 2.On-site inspection	1. Angeles City Hall 2. Barangay Balibago 3. Mariano Nepomuceno Elementary School, Barangay Cutcut
	2.2	Application of a shading system on the windows of the building.	1. Evidence from the elevation plan 2. On-site observation and measurement	1. Angeles City Hall 2. Barangay Balibago 3. Mariano Nepomuceno Elementary School, Barangay Cutcut
	2.3	Efficiency rating of air-conditioning units installed in a building.	1. HVAC plans 2. Inventory checking	1. Angeles City Hall 2. Barangay Balibago 3. Mariano Nepomuceno Elementary School, Barangay Cutcut
	2.4	Standard area of windows installed in a building.	1. Architectural plans 2. On-site inspection	1. Angeles City Hall 2. Barangay Balibago 3. Mariano Nepomuceno Elementary School, Barangay Cutcut
	2.5	Utilization of renewable energy sources as a means of reducing energy waste in the building.	1. Roofing and Solar rooftop installation specification 2. Site inspection 3. Comparison of renewable energy used vs used electric on the grid provider.	1. Angeles City Hall 2. Barangay Balibago 3. Mariano Nepomuceno Elementary School, Barangay Cutcut
	2.6	The color of the building envelope (roofing) in a building.	1. Perspective plans 2. Roofing specification 3. Site inspection	1. Angeles City Hall 2. Barangay Balibago 3. Mariano Nepomuceno Elementary School, Barangay Cutcut
	2.7	The existence of roof insulation on building envelopes	1. Roofing specification 2. Site inspection	1. Angeles City Hall 2. Barangay Balibago 3. Mariano Nepomuceno Elementary School, Barangay Cutcut
ENVIRONMENTAL	3.1	The degree of urbanization surrounding a building contributes to indoor temperature.	1. QGIS 2. Comprehensive Development Plan (Table 2-6, 2020)	1. QGIS Software 2. City Planning Development Office (CPDO), Angeles City Hall

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Table 1 (continue). Multi-criteria assessment tool.

Parameter		Determining factor	Data collection (evidence)	Site for data collection
ENVIRONMENTAL	3.2	Green space coverage around a building.	1. QGIS 2. Area Ecological Profile (FIGURE 5-7 Green/open spaces map of Angeles City)	1. QGIS Software 2. City Planning Development Office (CPDO), Angeles City Hall
	3.3	Presence of a water body in proximity to the building (e.g., rivers, creeks, lakes, etc.)	1. QGIS 2. Area Ecological Profile (FIGURE 5-6 Blue Spaces Map OF Angeles City)	1. QGIS Software 2. City Planning Development Office (CPDO), Angeles City Hall
	3.4	Impact of surrounding air quality on building thermal performance.	1. IQAIR reports on AQI levels, and Windy Software on PM2.5 pollutants	1. IQair website 2. Windy Software
ECONOMIC	4.1	The efficiency of building through energy consumption.	1. Available electricity bill and the floor area of the building	1. Residential building in Barangay Balibago 2. Mariano Nepomuceno Elementary School, Barangay Cutcut
	4.2	The ratio of heat index improvements on building performance, productivity, and occupant satisfaction.	1 January Electricity bill compared with the April Electricity bill	1. Residential building in Barangay Balibago 2. Mariano Nepomuceno Elementary School, Barangay Cutcut
	4.3	Frequency of inspections and maintenance in terms of thermal efficiency and overall comfort.	1. Checkbox answer from Demographic Information	1. Residential building in Barangay Balibago 2. Mariano Nepomuceno Elementary School, Barangay Cutcut
	4.4	The budget allocated for addressing thermal comfort in a building.	1. Interview questionnaires for the Officials of the Office of the City Building Official	1. Office of the City Building Official, Angeles City Hall.
	4.5.	Willingness of the occupants to invest in improving thermal comfort.	1. Question number 4 of the Semi-structured Interview for the occupants of residential and institutional settings.	1. Residential building in Barangay Balibago 2. Mariano Nepomuceno Elementary School, Barangay Cutcut

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Table 1 (continue). Multi-criteria assessment tool.

Parameter		Determining factor	Data collection (evidence)	Site for data collection
POLITICAL	5.1	Integration of heat index risks and mitigation strategies in local planning and investment documents.	1. Climate Disaster Risk Assessment 2. Local Development Investment Program 3. Area Ecological Profile	1. City Planning Development Office (CPDO) (Zoning Division), Angeles City Hall
	5.2	Compliance with the ceiling heights of the building according to the NBCP.	1. Floor Plans and Elevations Plans	1. Office of the City Building Official, Angeles City Hall
	5.3	Inclusion of heat-related design requirements in local building codes and ordinances.	1. Building Permit Checklists	1. Office of the City Building Official, Angeles City Hall
	5.4	Willingness of the local government to implement programs addressing heat index issues.	1. Interview and Official LGU Projects	1. City Environment and Natural Resources Office (CENRO), Angeles City Hall
	5.5	The level of independence the local government has in creating and implementing policies and strategies for heat index mitigation.	1. Interview with the government officials	1. City Environment and Natural Resources Office (CENRO), Angeles City Hall

Table 2. General criteria.

Rating	Interpretation	Description
5.00	Fully Compliant	The gathered data/documents provided all necessary information for the assigned item and exceeded the expected additional details useful to the overall understanding of the tool.
4.00 – 4.99	Strong Compliant	The gathered data/documents provided all necessary information for the assigned item and provided additional details useful to the overall understanding of the tool.
3.00 – 3.99	Compliant	The gathered data/documents provided the necessary information for the assigned item.
2,00 – 2.99	Partially Compliant	The gathered data/documents provided the necessary information for the assigned item.
1.00 – 1.99	Non-Compliant	The gathered data/documents provided the necessary information for the assigned item.

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3.2. Statistical Analysis

In terms of statistical measurement, all twenty-six items within the assessment tool will be evaluated to determine their internal consistency. To confirm the reliability of the items, the resulting Cronbach's Alpha (α) value must be greater than or equal to 0.70 to be considered acceptable. We presented the Alpha values for the twenty-six items included in the developed assessment tool: Cronbach's Alpha of 0.899 and a number of items of 26.

The results revealed that the assessment tool achieved a Cronbach's Alpha value of 0.899, indicating a high level of internal consistency among the 26 items. The value is higher than 0.70 suggests that the tool is statistically reliable. Therefore, the assessment tool can be confidently used to evaluate building performance factors as intended in the study.

3.3. Preliminary Assesment of Buildings

The preliminary assessment of buildings in Angeles City establishes a baseline understanding of how buildings in the area perform under the current problem of heat index. This phase of the assessment shows how the review of related literature and simulation using DesignBuilder software support each other in identifying key variables of a building that affect the thermal performance of a building.

The building materials and composition were considered in the modelling process (**Figure 2**). The DesignBuilder software interface displayed is a "Construction Template" that is employed to specify building construction characteristics for energy design and thermal simulation, specifically addressing features such as external walls, roofs, floors, and others, depending on what kind of finishes are applied to the building. Activity occupants were considered in the simulation process, which contributes more to the internal heat gain of the building.

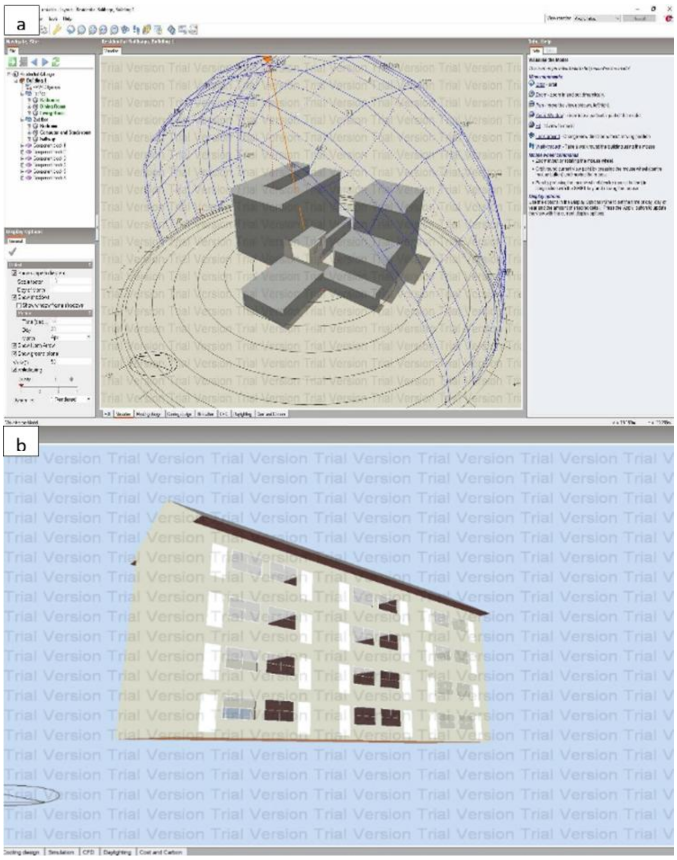

Figure 2. Results: (a) from far-sight, (b) from near-sight.

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The simulation provided insights into the building's internal heat gain, using data from the study area, to identify necessary improvements for reducing heat buildup and enhancing thermal performance (**Figure 3**). The EnergyPlus output for Mariano Nepomuceno Elementary School from March 1 to May 31 shows daily internal gains and solar gains. General lighting consistently uses 124.40 kWh daily, except for brief drops to 10.72 kWh and 3.57 kWh. Computer and equipment usage averages 71.63 kWh daily, with occasional dips to 5.93 kWh. Occupancy-related gains vary widely, peaking at 63.44 kWh and dropping to 0.00 kWh on some days. Solar gains through exterior windows fluctuate between 135.27 kWh and 181.67 kWh, showing the highest daily variation.

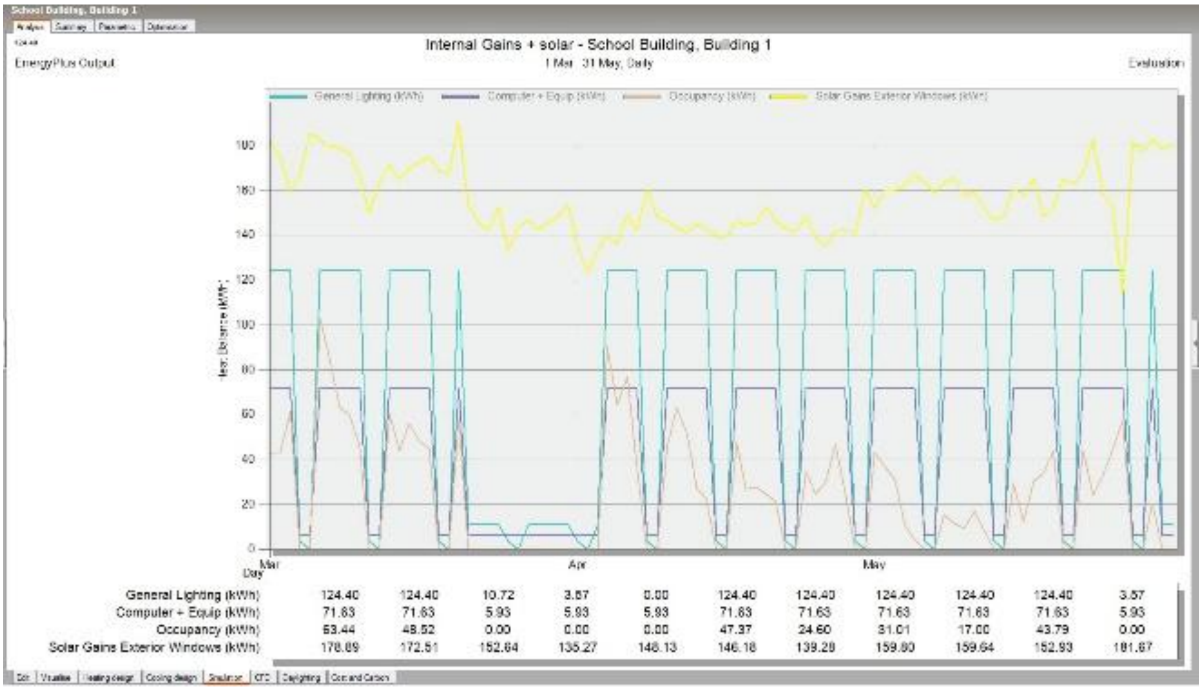

Figure 3. Results.

3.4. Results of the Assessment for both Residential and Institutional Buildings

The MCAT, based on the STEEP framework, assessed the thermal performance of residential and institutional buildings in Angeles City, Philippines, with a Cronbach's Alpha of 0.899, showing high internal consistency. Both building types achieved an average score of 3.65, which indicates moderate performance meeting minimum standards but with areas for improvement. Political factors scored highest (4.45 residential, 4.28 institutional), reflecting strong compliance with building standards and local government engagement. However, technological factors (2.66 residential, 3.51 institutional) and economic factors (3.79 residential, 3.05 institutional) revealed deficiencies in advanced technology adoption and budget allocation for thermal comfort, while environmental factors (3.72 residential, 3.61 institutional) showed potential for enhancement through better green space integration and air quality management.

3.5. Development of Policy Improvement and Engineering Strategies

To address identified gaps, the study proposes targeted policy and engineering strategies. For social parameters, community-led education and optimized occupancy schedules aim to enhance awareness and mitigate heat gain. Policies should promote energy-efficient HVAC

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systems, high R-value insulation, and passive cooling methods like shading and light-colored finishes for technological factors. For environmental factors, expanding green spaces, introducing vertical gardens, and real-time air quality monitoring are recommended. Economically, improving access to funding for thermal efficiency and promoting cost-saving measures are prioritized. For political parameters, strengthening local ordinances, enhancing government autonomy, and aligning planning documents with heat mitigation goals will support sustainable, thermally efficient buildings, aligning with local and global sustainability standards.

3.6. Final Assessment of Building

During the phase of the second-round simulation of the residential building, adjustments like scheduled patterns, adjusting the number of occupants in a room, applying insulation materials, particularly external walls, and proper roofing insulation were considered (**Figure 4**). Modifications of shading systems are also considered by putting appropriate overhangs and glazing properties on windows to minimize solar heat gain.

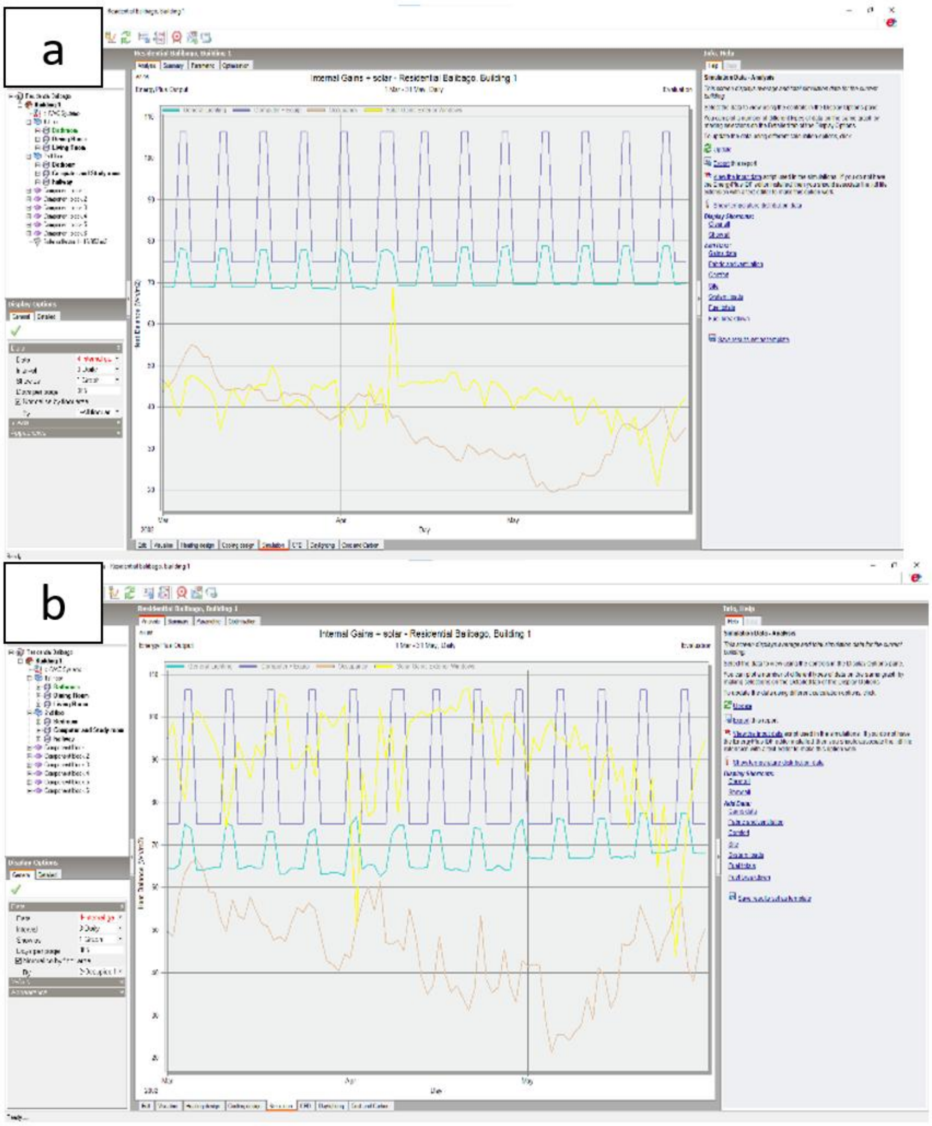

Figure 4. First-round simulation of residential building (a) and second-round simulation with improved materials (b).

DOI: https://doi.org/10.17509/ajsee.v5i2.89058
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According to the model of the original modelling, as seen in the graph, there are high and volatile solar gains because of inadequate shading and window orientation, alongside moderate lighting and equipment gains being used amidst unfavorable conditions. This leads to increased energy demand and thermal discomfort during the hot season from March to May. As for the improved version, there is a peak reduction in solar gains to 120 W, which could be a result of proper shading, cool roof and wall materials, or a shift in orientation. Moreover, lighting and equipment gains have lower bounds of 80-100 W and 60-80 W, respectively, implying that the building utilizes energy-efficient appliances and better scheduling. Slightly lower occupancy gains (20-30 W) indicate adjustments to workloads to avoid peak heat hours. Overall, the optimized design enhances thermal comfort by reducing internal gains and energy use with a continuously required responsive state, preferring to mitigate predisposed risks like heat exhaustion.

3.7. Education Factor

Educational factors emerged as a crucial yet often overlooked dimension in enhancing thermal building performance. While the study primarily measured social awareness and policy compliance, it also revealed that structured education and training programs for building occupants, facility managers, and local government personnel can significantly improve the adoption of energy-efficient practices. Educational interventions—such as workshops on passive cooling techniques, integration of thermal efficiency topics into school curricula, and capacity-building sessions for construction professionals—can bridge the gap between technical solutions and behavioral change. This aligns with global sustainability goals, particularly SDG 4 (Quality Education), by fostering informed decision-making and encouraging the use of innovative building technologies. Embedding education within thermal performance strategies ensures that improvements are not only technically feasible but also socially sustainable, creating a culture of continuous learning that supports long-term building efficiency.

4. CONCLUSION

This study developed and validated an MCAT grounded in the expanded STEEEP framework (i.e., Social, Technological, Environmental, Economic, Educational, and Political factors) to evaluate the thermal performance of residential and institutional buildings in Angeles City, Philippines. The tool demonstrated high reliability, with a Cronbach’s Alpha of 0.899, and effectively identified both strengths and deficiencies in current building performance. Findings indicated moderate overall compliance, with strong political engagement but notable gaps in technological adoption, economic resource allocation, and environmental optimization. The integration of the educational factor underscores the importance of sustained knowledge dissemination, capacity-building, and awareness programs in driving behavioral and operational change. By linking technical improvements with informed user practices, education catalyzes long-term energy efficiency and thermal comfort. The MCAT thus provides a comprehensive and adaptable approach for policymakers, engineers, educators, and community stakeholders to implement targeted strategies, aligning with national standards and global sustainability goals.

DOI: https://doi.org/10.17509/ajsee.v5i2.89058
p- ISSN 2775-6793 e- ISSN 2775-6815

5. ACKNOWLEDGMENT

This study would not have been possible without the guidance and help of several individuals who, in one way or another, contributed and extended their valuable assistance in the preparation and completion of this study. The researchers would like to extend their deepest gratitude and appreciation to the following individuals. To God, whose grace is always sufficient. To their research adviser, gratitude is extended for his consistent patience, mentorship, and critical insights during the study. To the professionals and experts in the field, whose valuable insights and generous sharing of knowledge greatly enriched the study. To the researchers' family and friends, for their understanding, encouragement, and emotional support that fuelled the researchers' determination during challenging times. Finally, to all individuals who were part of this team, this journey has been a rollercoaster of challenges, but ultimately a fulfilling adventure. The success of this endeavour was made possible through the collective motivation, dedication, and spirit of everyone involved.

6. AUTHORS' NOTE

The authors declare that there is no conflict of interest regarding the publication of this article. The authors confirmed that the paper was free of plagiarism.

7. REFERENCES

Altassan, A. (2023). Sustainable integration of solar energy, behavior change, and recycling practices in educational institutions: a holistic framework for environmental conservation and quality education. *Sustainability*, *15*(20), 15157.

Asif, M., Saleem, S., Tariq, A., Usman, M., and Haq, R.A.U. (2021). Pollutant emissions from brick kilns and their effects on climate change and agriculture. *ASEAN Journal of Science and Engineering*, *1*(2), 135-140.

Belhadi, M.A., Kadja, M., Mechighel, F., Khechekhouche, A., and Hamaiti, Y. (2025). Enhanced thermal performance of parabolic through collectors with TiO_2 nanofluids in an arid climate. *Indonesian Journal of Science and Technology, 10*(1), 93-112.

Debrah, J. K., Vidal, D. G., and Dinis, M. A. P. (2021). Raising awareness on solid waste management through formal education for sustainability: A developing countries evidence review. *Recycling*, *6*(1), 6.

Georgescu, M., Arabi, M., Chow, W. T., Mack, E., and Seto, K. C. (2021). Focus on sustainable cities: urban solutions toward desired outcomes. *Environmental Research. Letters*, *16*(12), 120201.

Ibrahim, I.M., Suryadi, K., Darmawan, C., and Nurbayani, S. (2024). Examining climate change issues for improving cross-generation awareness in 21st century agenda: A bibliometric approach. *ASEAN Journal for Science Education*, *3*(2), 173-182.

Karmaker, R., and Lemon, M.H.A. (2024). Is climate change a curse? Causing huge effect on various fields: An educational perspective. *Indonesian Journal of Teaching in Science*, *4*(1), 85-96

DOI: https://doi.org/10.17509/ajsee.v5i2.89058
p- ISSN 2775-6793 e- ISSN 2775-6815

Koukou, M. K., Lucas, S., Justino, J., Rafael, S., Livieratos, A. D., Carriço, N., and Aleksiejuk-Gawron, J. (2024). Training for sustainable and healthy building for 2050: New methodologies for an integrated and transnational education approach targeting skills development for the transition toward ZEB and PEB buildings. *Buildings*, *15*(1), 67.

Malik, F. (2024). The role of education in promoting environmental awareness and sustainable practices. *Frontiers in Environmental Science and Sustainability*, *1*(2), 242-254.

Maller, C. J., and Strengers, Y. (2011). Housing, heat stress and health in a changing climate: promoting the adaptive capacity of vulnerable households, a suggested way forward. *Health Promotion International*, *26*(4), 492-498.

Manullang, T.I.B., Nandiyanto, A.B.D., Suryadi, A., Rochyadi, E., Haerudin, D., Muspita, R.Sumiroh, E., Manullang, L.S. (2021). Improving students with intellectual disabilities science process skills through photosynthesis experiment in enhancing climate change awareness. *Journal of Engineering, Science and Technology*, 16(3), 2368-2377.

Mian, S. H., Salah, B., Ameen, W., Moiduddin, K., and Alkhalefah, H. (2020). Adapting universities for sustainability education in industry 4.0: Channel of challenges and opportunities. *Sustainability*, *12*(15), 6100.

Namoussa, T.Y., Boucerredj, L., Khechekhouche, A., Kemerchou, I., Zair, N., Jahangiri, M., Miloudi, A., and Siqueira, A. (2025). Innovative nanofluid encapsulation in solar stills: Boosting water yield and efficiency under extreme climate supporting sustainable development goals (SDGs). *Indonesian Journal of Science and Technology, 10*(3), 419-426.

Nurramadhani, A., Riandi, R., Permanasari, A., and Suwarma, I.R. (2024). Low-carbon food consumption for solving climate change mitigation: Literature review with bibliometric and simple calculation application for cultivating sustainability consciousness in facing sustainable development goals (SDGs). *Indonesian Journal of Science and Technology*, *9*(2), 261-286.

Nwankwo, N., Olaniyi, T. K., and Morgan, A. (2022). STEEP analysis of energy system transition to sustainability. *International Journal of Sustainable Energy Development*, *10*(1), 492-501.

Olutola, A.T., and Gift, I.D. (2025). Influence of school climate on senior secondary school students academic performance in the English language. *Indonesian Journal of Multidiciplinary Research*, *5*(1), 85-92.

Osuji, C. U., and Nwuke, T. J. (2024). Promoting environmental literacy and sustainable practices for effective administration in schools in rivers state: Implications for global transformation. *Rivers State University Journal of Education*, *27*(1), 189-199.

Phylosophie, B., Winarno, N., Ekawati, R., and Afrizon, R. (2024). Analyzing students' classroom emotional climate toward science learning in junior high school. *Indonesian Journal of Multidiciplinary Research*, *4*(2), 317-330.

DOI: https://doi.org/10.17509/ajsee.v5i2.89058
p- ISSN 2775-6793 e- ISSN 2775-6815

Rahmat, A., and Mutolib, A. (2016). Comparison air temperature under global climate change issue in Gifu city and Ogaki city, Japan. *Indonesian Journal of Science and Technology*, *1*(1), 37-46.

Reyes, J.G. (2024). Design and development of questionnaires for measuring school climate and achievement emotions in Philippine public elementary schools. *ASEAN Journal of Science and Engineering Education*, *4*(3), 249-260.

DOI: https://doi.org/10.17509/ajsee.v5i2.89058
p- ISSN 2775-6793 e- ISSN 2775-6815