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Evaluation of the Implementation of the Green Building Concept in Mid-Rise Buildings

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Abstract

This research looks into how Green Building principles are implemented to two medium-rise educational buildings placed in Yogyakarta: the Djarnawi Hadikusuma Building (E8) at Universitas Muhammadiyah Yogyakarta and the Integrated Forest Farming Learning Center (IFFLC) at Universitas Gadjah Mada. Referring to the Greenship Existing Building guidelines version 1.1, the data collection process is carried out by using on the spot surveys, measuring indoor air quality (IAQ), and reviewing allied project documents, then assessed with SPSS and Monte Carlo simulations. The results of the study illustrate that the cumulative performance of both buildings is in the very good category (Index Score 4.58; Risk Index 0.42). The Indoor Health and Comfort (IHC) quality is the strongest performing category, while Water Conservation (WAC) and Material Resources and Cycle (MRC) still need further improvement. The indoor air quality analysis also pointed out that the UGM building needs enhancements in its ventilation system and VOC control, while UMY needs to sustain the regularity of its already well-running operational management. The risk analysis corroborates the significance of cohesive management to decrease potential inadequacies while making sure the comfort for people. The findings also deliver particular guidance on steps to improve sustainability performance in mid-rise educational buildings.

INTRODUCTION

The construction industry in Indonesia has been growing significantly in an enterprise to address infrastructure needs and initiative national development. Nevertheless, this evolution rate often raises environmental issues, such as sinking natural resource availability, increased energy use, and increased greenhouse gas emissions. Globally, the construction sector is also known to contribute greatly to climate change by using its design, construction, operation, and even destruction stages (Monalisa, Putri, & Maharani, 2024). applying green building values is a critical stage in these situations to drop the environmental destruction and encouraging sustainable urban expansion.

The concept of green building is not simply a simple building trend, but rather a design approach that looks into energy efficiency, wise water management, waste decrease, and improving indoor air quality (Dinanti, Qonitan, & Ridhosari, 2023; Pribadi & Marfiana, 2022). The application of these ideologies has been recognized to deliver dual benefits; maintaining environmental sustainability and improving the health of its residents, while also lowering operational costs for long term (Timplalexis, Yap, Feriadi, & Hien, 2025; Yasinta, Pradana, & Dahlia, 2024). In Indonesia, the challenges to apply sustainable construction are supported by the Green Building Council Indonesia (GBCI) by using the development of guidelines and assessment tools such as the Greenship rating system. This background helps as a assessable average on behalf of calculating building performance, to make sure that progress bring into line with sustainability purposes (Cao, 2025).

Despite some attempts, the comprehension of the green building idea still faces a number of resistances. One of the main challenges reports to risk management at the planning, construction, and operational stages (Ansori &

Wahyudin, 2020). Incorrect risk identification and management can indicate to cost overflows, project delays, and even superiority decline, strongly in projects targeting green certification. Many reports also show that risk management in sustainable construction needs greater time and resources due to the complexity of adding environmental aspects into conventional construction performs (Zhu, Wang, & Hu, 2024).

Increasing eco-friendly pressures highlight the significance of fulfilling green buildings in Indonesia. Increasing More electricity use, less clean groundwater, dirty air, and too much trash show that the environment is getting worse (Li, Zhang, Wang, & Chen, 2024; Siadari, Chairin, & Erizal, 2023). In Yogyakarta itself, the weakening in groundwater levels and the disappearing quality of rivers direct the need for more environmental water management strategies (Sharma, Singh, & Gupta, 2024). This situation becomes a reminder to check if a building is doing well or not. Thus, we can consider whether the improvements made are truly in line with sustainability goals or not (Khoshdelnezamiha, Tookey, & Sahab, 2020).

Many studies have discussed green buildings and their benefits, but not many focus on mid-rise buildings in developing cities such as Yogyakarta. Most of the available training still focuses on large, profitable projects or high-rise buildings in major urban centers. Therefore, we do not get a complete picture of how the concept of green buildings actually works on a small scale that is developing rapidly.

Meanwhile, mid-rise buildings essentially form a significant part of urban growth and have a direct impact on resource use and how the environment is maintained. Therefore, this study seeks to take a deeper look at how the concept of green buildings can be practically applied to mid-rise buildings in Yogyakarta, especially in terms of risk management and sustainability performance. The goal is to gain a clearer understanding of the types of interventions that provide enjoyment and foster a desire to learn among users. The use of AI among students can have a significant impact in both cause and effect. The right approach can help reduce these problems. It is hoped that the results will influence future projects to be more resilient and environmentally friendly in the context of construction in Indonesia.

LITERATURE REVIEW

Green Building Concepts

Green buildings are an approach to designing and maintaining buildings that do not damage the environment while maintaining the comfort and health of occupants. This concept emphasizes saving electricity and water, reducing waste, and using environmentally friendly materials. In Indonesia, GBCI has developed a system called Greenship, which is used to evaluate the environmental friendliness of a building (Siadari et al., 2023). The application of the green building concept is very important in helping to combat climate change and encourage sustainable urban growth.

Risk Management in Green Building Projects

Risk management is very important in green building construction because there are various problems that may arise. These problems can stem from technical factors, limited funds, strict regulations, and the need for good cooperation between all parties involved. Recent studies have recognized that project success be contingent heavily on how well risks are recognized early, evaluated, and achieved using targeted mitigation strategies. For example, Afiq & Nurdiana (2024) exposed that technical risk is the most foremost factor in green building construction, whereas Monalisa et al. (2024) says that a danger identification and risk analysis approach can help minimize interruptions during the construction process. In other words, if risk management is not fully employed, projects can experience delays, cost overflows, and even a decline in targeted sustainability results.

Previous Studies on Green Building Implementation

A amount of earlier studies have talked about both the problems and the good sides of trying to put green building ideas into practice, not only in Indonesia but as well in other countries. Ansori & Wahyudin (2020) authorized the possible of green building in decreasing greenhouse gas emissions by up to 30% in 2030. Pribadi & Marfiana (2022) examined the role of green building in mitigating global warming and improving workplace environmental health, while Rosanti et al. (2021) pointed out that the implementation of green building in educational facilities is still hampered by inconsistent implementation and lack of contribution from the parties involved. More recent research, Linggo & Sutandi (2023) also shows that financial, technical, and regulatory barriers are the biggest factors hindering the success of green building projects in Jakarta. In addition, research Katiandagho et al (2025) in Batam City shows benefits for the surrounding community, even though the initial costs are quite high. But overall, green buildings in Batam bring many positive benefits in the long term, as well as their impact on urban areas towards a more advanced Batam City. And also research Putra Jaya et al. (2025) evaluating the impact of real-time environmental monitoring and adaptive energy management using an IoT-based smart HVAC system. The results of the experiment showed a significant decrease in energy consumption, averaging 27.3%, while maintaining optimal interior temperature and humidity stability. Although the research was useful, most of it focused only on large buildings in big cities. However, research that truly tests how green building concepts work in medium-sized buildings in small cities such as Yogyakarta is still limited. In fact, these types of buildings are important for urban growth and influence how much energy and water is used by residents and the surrounding environment. That is why understanding this gap is crucial so that green development can be implemented in various regions, not just in large cities.

METHODS

The research method used in this study was descriptive quantitative method to obtain a clearer picture of how green building ideas are actually implemented in mid-rise buildings around Yogyakarta. This research design was picked so that the results not only describe measurable sustainability indicators but as well as reveal the real conditions related to building implementation in the field. This study was conducted on two mid-rise green buildings in Yogyakarta: the Djarnawi Hadikusuma Building (E8) at Muhammadiyah University Yogyakarta and the Integrated Forestry Learning Center (IFFLC) at Gadjah Mada University. These two buildings were chosen as study subjects because they are measured to represent the most advanced application of green building concepts in educational facilities and associations in the region. Therefore, this case study can provide a relevant overview of the application of sustainability in the context of contemporary educational buildings.

Data collection in this study appeared from both primary and secondary sources. Primary data was collected by using surveys and structured questionnaires directed to parties straightforwardly involved in the management and deployment of the buildings being studied. Respondent criteria included building managers, technical staff, and occupants who understood and had used the building. The age range of respondents was centered on 18 to 27 years old, indicating intensive use of the building and sensitivity to comfort aspects such as lighting, ventilation, and air quality. In terms of education, most respondents were high school graduates or college students, who had a basic understanding of green building concepts but emphasized the user experience perspective rather than technical details. During the exploration phase, secondary data was collected through various project documents, such as design drawings and official reports on building certification and sustainability assessments. The main tool used in this study was a structured questionnaire based on the Greenship Existing Building Version 1.1 guidelines from the Green Building Council Indonesia (GBCI). The questionnaire covered six main assessment categories, namely: (1) site development, (2) energy efficiency and conservation, (3) water conservation, (4) material use and management, (5) indoor comfort and health, and (6) environmental management for buildings. Each item in the questionnaire was adjusted to match the performance indicators listed in the standard.

The collected data was assessed descriptively by likening the actual presentation of the building against the standards established in Greenship. The analysis process complex assigning scores and weights to regulate the extent to which the structure encountered green building standards. Moreover, some risk factors were documented and grouped into technical, financial, managerial, ecological, and regulatory categories. The evaluation results were used to assess the efficiency of the green building concept application and to classify aspects requiring improvement in risk management. In this study, two software packages were used to support the data analysis process. SPSS (Statistical Package for the Social Sciences) was used to perform descriptive statistical analysis of survey responses, Greenship questionnaire results, and indoor air quality (IAQ) measurements using a Lux meter air quality detector in the corridors and toilets of the E8 Dharmawangsa Hadikusuma UMY building. Additionally, measurements were also taken in the corridors and restrooms of the Integrated Forest Farming Learning Center (IFFLC) building, Faculty of Forestry, UGM, over a period of 7 days from July 6 to July 12.

The software helps in data tabulation and validation, while also producing imaginative statistics to assess the sustainability of the buildings studied. To be added, risk analysis is managed using Oracle Crystal Ball, which is used to run Monte Carlo simulations on the six Greenship variables. Using probabilistic modeling, this tool provides a more comprehensive visualization of risks, including supply output, overlay charts, tornado charts, and sensitivity charts. This allows for a better interpretation of the risks associated with the potential implementation of green buildings.

RESULTS AND DISCUSSION

Indoor Air Quality (IAQ) Measurements

Indoor air quality (IAQ) was tested over a full week in two main areas selected to represent the actual conditions of the building: the corridor is a semi-open circulation space, and the bathroom is a fully enclosed facility area. Measurements included several parameters, namely CO_2 concentration (ppm), formaldehyde/HCHO (mg/m^3), total volatile organic compounds (TVOC) (mg/m^3), temperature (°C), oxygen levels, and lighting intensity (cd). All of these parameters were described according to room type, then compared between the two buildings (UGM–IFFLC and UMY–E8). We also analyzed daily altitude patterns, while taking into account room usage schedules and cleaning habits in each area.

Table 1. IAQ Measurement Data in the Corridors of UGM and UMY Buildings

Building	*Day*	CO2 (PPM)	HCHO (mg/m^3)	TVOC (mg/m^3)	*Temperature*	Oxygen (%)	Lighting (cd)
UGM	*Day* 1	1146	0.121	0.336	28	72	195
UGM	*Day* 2	1141	0.111	0.322	25	66	189
UGM	*Day* 3	1140	0.131	0.385	27	65	180
UGM	*Day* 4	1139	0.165	0.387	25	66	190
UGM	*Day* 5	1140	0.121	0.358	24	67	176
UGM	*Day* 6	1125	0.132	0.367	26	68	190
UGM	*Day* 7	1132	0.155	0.335	28	63	189
UMY	*Day* 1	486	0,014	0,047	26	64	190
UMY	*Day* 2	734	0,044	0,128	24	60	194
UMY	*Day* 3	475	0,017	0,042	26	52	185
UMY	*Day* 4	459	0,016	0,047	28	41	189
UMY	*Day* 5	607	0.017	0,058	23	56	195
UMY	*Day* 6	596	0,023	0,075	24	54	180
UMY	*Day* 7	445	0,018	0,050	24	74	170

Indoor air quality (IAQ) was tested over a full week in two mAs shown in Table 1, a comparison of indoor air quality (IAQ) between the UGM (IFFLC) and UMY (E8) corridors reveals significant differences. The average CO_2 level at UGM is consistently above 1,000 mg/m^3 (~1,140 mg/m^3), indicating inadequate ventilation, while UMY has an average of ~543 mg/m^3 without exceeding the threshold. Formaldehyde (HCHO) concentrations at UGM (~0.134 mg/m^3) are about six times higher than at UMY (~0.021 mg/m^3) and exceed WHO recommendations, indicating continuous emissions from building materials or cleaning products. The TVOC level at UGM (~0.356 mg/m^3) was also 5–6 times higher than at UMY (~0.064 mg/m^3), although both were still below the WELL standard. The temperature (~26.1 °C vs. 25.0 °C) and lighting (~187 cd vs. 186 cd) of the two rooms were relatively similar, indicating that indoor air quality is more influenced by ventilation, building materials, and cleanliness than by thermal or lighting conditions. The daily pattern shows that UGM has a high and consistent pollutant load, while UMY shows lower but more fluctuating peaks, which may be related to busy days or cleaning activities.

Indoor air quality capacity shows that each building has different problems. In the Gadjah Mada University (UGM) building, high CO_2 levels mean that the supply of outside air is inadequate and ventilation performance still needs to be improved, including by adjusting AHU operations, increasing fresh air, or adjusting room usage to keep CO_2 concentrations below 1,000 ppm.ain areas selected to represent the actual conditions of the building: the corridor is a semi-open circulation space, and the bathroom is a fully enclosed facility area. Measurements included several parameters, namely CO_2 concentration (ppm), formaldehyde/HCHO (mg/m^3), total volatile organic compounds (TVOC) (mg/m^3), temperature (°C), oxygen levels, and lighting intensity (cd). All of these parameters were described according to room type, then compared between the two buildings (UGM–IFFLC and UMY–E8). We also analyzed daily altitude patterns, while taking into account room usage schedules and cleaning habits in each area. (WHO, 2021). At the same time, the UMY building looks to have performed better in terms of ventilation, but the steadiness is still needed, especially in HVAC scheduling and air cleaning processes when the area is busy. If people are repetitively exposed to high CO_2 levels, their thinking ability may drop and they may feel sleepy, tiredness, and even more serious health problems (World Health Organization, 2021).

For the formaldehyde (HCHO) parameter, UGM's circumstance indicates the need to calculate the cleaning materials or air fresheners used, switching to low-VOC products are recommended. In addition, airflow in service areas should be upgraded and sensors regularly adjusted to preserve accurate monitoring. UMY is still in comparatively good condition and only needs to maintain its regular ventilation management. Its impact cannot be underestimated, as formaldehyde is an importance pollutant that can start irritation and even cancer risk if exposed to it over the long term (L. Du, Batterman, & Godwin, 2020).

The findings suggest that improving ventilation, selecting eco-friendly materials and products, and maintaining consistent building operations are important to keep indoor conditions healthy. Both UGM and UMY still have opportunities to enhance their Indoor Environmental Quality (IEQ), supporting the goals of environmentally responsible green buildings (Wolkoff, 2018).

Since temperature plays an effect on how human beings feel in a space, it is also important to consider. When a number of users rises, it is suggested that you alter the AC settings or operation hours for UGM in order to prevent the room from being overheated. Considering the situation at UMY, creating a consistent and comfortable temperature in accordance with the principles of sustainable buildings requires regular filter cleaning, balancing the cooling system, and effective cooling load management (Frontczak & Wargocki, 2019).

Regarding lighting, UGM must ensure that main spaces receive adequate lighting. Energy-saving techniques that maintain a high level of visual comfort at UMY include the use of dimmers, lighting zones, presence sensors, and optimization of natural light (Park, Nagy, & Schlüter, 2021).

Essentially, what we see is that good ventilation, the use of environmentally friendly materials, and protecting the smooth operation of the building are key to maintaining healthy indoor air quality. Both UGM and UMY can make more efforts to improve their indoor air quality, which can help them become more environmentally friendly buildings (Wang, Abdul-Samad, & Salleh, 2024).

Table 2. IAQ Measurement Data in the Restroom of UGM and UMY Buildings

Building	***Day***	**CO2 (PPM)**	**HCHO (mg/m³)**	**TVOC (mg/m³)**	***Temperature***	**Oxygen (%)**	**Lighting (cd)**
UGM	*Day* 1	1129	0.028	0.086	28	73	56
UGM	*Day* 2	1663	0.033	0.053	25	67	50
UGM	*Day* 3	1178	0.031	0.086	27	65	55
UGM	*Day* 4	1218	0.152	0.046	25	63	45
UGM	*Day* 5	1178	0.016	0.042	24	67	49
UGM	*Day* 6	1099	0.054	0.057	27	61	45
UGM	*Day* 7	1167	0.098	0.087	27	65	40
UMY	*Day* 1	489	0.012	0.039	24	65	40
UMY	*Day* 2	580	0.017	0.047	24	70	35
UMY	*Day* 3	442	0.012	0.030	26	60	52
UMY	*Day* 4	446	0.016	0.044	27	48	30
UMY	*Day* 5	536	0.012	0.044	24	63	31
UMY	*Day* 6	552	0.012	0.033	24	60	33
UMY	*Day* 7	442	0.012	0.033	24	65	22

As shown in Table 2, indoor air quality (IAQ) in the UGM (IFFLC) toilet was consistently worse than that in the UMY (E8) toilet. The average CO_2 concentration at UGM is 1,233 mg/m³ compared to 498 mg/m³ at UMY, reflecting weaker ventilation and longer accumulation of pollutants. Formaldehyde levels at UGM (0.059 mg/m³) are higher and more variable, with episodic spikes associated with cleaning products, compared to stable low levels at UMY (0.013 mg/m³). TVOC at UGM (0.065 mg/m³) was also higher and more fluctuating than at UMY (0.039 mg/m³). The temperature at UGM was slightly warmer (26.1 °C compared to 24.7 °C), which could potentially accelerate VOC emissions, while the lighting was brighter but not chemically relevant. The daily peaks show that the toilets at UGM experience pollutant buildup in line with the schedule of use and cleaning, while the peaks at UMY are lower and more concentrated on certain days, which may foster their desire to study. The use of AI among students in toilets can have significant causes and effects between the two places.

At UGM, CO_2 levels are quite high, indicating that ventilation, whether through windows or fans, is not functioning properly. It seems that they need to increase the speed of the exhaust fans or perform regular air cleaning to remove stagnant air. This is a big problem because excessive CO_2 levels can make people feel tired, lose concentration, and if it lasts too long, it can even be harmful to their health (Du et al., 2020; Wu et al., 2022). In addition, UMY can consistently maintain low CO_2 levels, which means that its air circulation system is functioning properly and meets good indoor air quality standards (ASHRAE, 2023).

Judging from the formaldehyde (HCHO) results, the UGM readings were higher and no longer consistent. This often occurs when cleaning products, air fresheners, or some indoor furniture sporadically release this chemical. Formaldehyde has been declared a dangerous indoor pollutant, which can have adverse effects on human health and pose long-term health risks (Du et al., 2020). At UMY, there are lower and more stable figures, showing that their choice of materials and ventilation system supports the safety of occupants (Xiong, Zhang, & Weschler, 2021).

A similar situation occurs with TVOC. UGM has higher and more fluctuating TVOC levels, increasing the risk of discomfort or health problems, including coughing, headaches, and difficulty concentrating (Xiong et al., 2021). World Health Organization (2021) and ASHRAE Therefore, it is crucial to limit VOC exposure. UGM should review its use of better air filters and safer interior products. UMY is already doing better in this regard, but it still needs to monitor the situation to prevent sudden increases.

Another difference is the temperature. UMY can maintain a temperature close to the ideal comfort zone of 23–26°C for people who do not engage in strenuous physical activity, so it is likely to feel comfortable inside. Meanwhile, at UGM, the temperature is warmer and unpredictable, and as Timplalexis et al. (2025) mentioning this can make people feel uncomfortable and is consistent with findings that temperature really does affect how people feel.

When it comes to oxygen, UGM is better. At UMY, oxygen levels often drop, which can make people feel tired and less productive. Therefore, it is very important for them to ensure a consistent flow of fresh air. In terms of lighting, each building has its own problems (Ahvenniemi, Huovila, Pinto-Seppä, & Airaksinen, 2017).

When it comes to lighting, every building has its own problems. At UGM, the lighting is generally brighter, but it is unevenly distributed, making some areas feel uncomfortable (Veitch, 2018). In terms of lighting, UGM is generally brighter, but it is still uneven, resulting in some areas feeling uncomfortable. Lighting at UMY is more consistent, but sometimes falls below the recommended 100 lux for public toilets (Chartered Institution of Building Services Engineers (CIBSE), 2015). Therefore, UGM needs to fix the lighting layout, while UMY needs to increase brightness. These improvements support the principles of Green Buildings and Indoor Environmental Quality (IEQ), especially those related to visual comfort and the well-being of residents (Levin, 2017).

In short, the toilets at UGM require significant improvements to their ventilation systems, volatile organic compound (VOC) control, and temperature management. Meanwhile, UMY needs to ensure that oxygen levels remain stable and improve its lighting system. Both UGM and UMY will greatly benefit if indoor air quality (IAQ) management is more strongly linked to the concept of Green Buildings and the goal of improving indoor environmental quality (IEQ) to create healthy and sustainable indoor spaces.

Risk Level Analysis

This study uses Monte Carlo simulation as a technique to shorten the many possible input combinations and calculate the most likely results. This technique works by repeatedly sampling randomly, but not all values in the solution are re-sampled; only one value is randomly picked from each distribution at each iteration. By using this approach, several risk scenarios can be replicated and evaluated. In its execution, each risk variable was tested 100,000 times to produce a more descriptive probabilistic distribution. The highest value a parameter can achieve is designated as the maximum limit (Max), while the lowest value is designated as the minimum limit (Min). This carries a stronger and more assessable picture of possible performance deviations from standards. Using these parameters, risk levels were then assessed by comparing the mean index score of each variable (assumption data) against the overall mean forecast to identify relative risk intensity across variables.

Table 3. Recapitulation of Variable Data at UGM

No	Variables	Mean	StdDev	Min	Mode	Max	Index Score = Mean (Assumption)
1	Appropriate Site Development (ASD)	4.32	0.689	3	5	5	4.32
2	Energy Efficiency and Conservation (EEC)	4.10	0.543	3	4	5	4.10
3	Water Conservation (WAC)	3.98	0.628	3	4	5	3.98
4	Material Resource and Cycle (MRC)	3.96	0.693	3	4	5	3.96
5	Indoor Health and Comfort (IHC)	4.36	0.578	3	4	5	4.36
6	Building Environment Management (BEM)	4.20	0.567	3	4	5	4.20
					Index Average		4.15

In general, the implementation of Greenship in the object of study, namely the IFFLC Building (UGM), is in the good category (Index Score 4.15; Index Risk 0.85). Perception statistics (Likert 1–5) place IHC = 4.36 with the highest satisfaction score, followed by ASD = 4.32, BEM = 4.20, EEC = 4.10, WAC = 3.98, and MRC = 3.96.

In general, the implementation of Greenship in the object of study, namely the IFFLC Building (UGM), is in the good category (Index Score 3.98; Index Risk 1.02). Perception statistics (Likert 1–5) place IHC = 4.17 with the highest satisfaction score, followed by BEM = 4.07, ASD = 4.02, EEC = 3.90, WAC = 3.86, and MRC = 3.84.

Figure 1 presents the Forecast Index Score shows a bell-shaped distribution of simulation results (close to normal) with a peak around 4.14–4.17. The 95% confidence interval is 4.02–4.29, meaning that in 95% of scenarios, the combined index of the six variables will fall within that range. This indicates that the current performance of green building implementation with a very small chance of falling to a low value (< 4.02).

Figure 2 presents the Forecast Index Score shows a bell-shaped distribution of simulation results (close to normal) with a peak around 3.96-3.99. The 95% confidence interval is 3.85–4.11, meaning that in 95% of scenarios, the combined index of the six variables will fall within that range. This indicates that the current performance of green building implementation with a very small chance of falling to a low value (< 3.85).

Table 4. Recapitulation of Variable Data at UNY

No	Variables	Mean	StdDev	Min	Mode	Max	Index Score= Mean (Assumption)
1	Appropriate Site Development (ASD)	4.02	0.567	3	4	5	4.02
2	Energy Efficiency and Conservation (EEC)	3.90	0.744	3	4	5	3.90
3	Water Conservation (WAC)	3.86	0.732	3	4	5	3.86
4	Material Resource and Cycle (MRC)	3.84	0.749	3	4	5	3.84
5	Indoor Health and Comfort (IHC)	4.17	0.533	3	4	5	4.17
6	Building Environment Management (BEM)	4.07	0.774	3	4	5	4.07
					Index Average		4.15

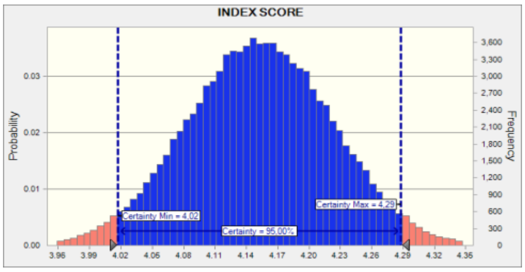

Fig. 1. Forecast Index Score Graph for UGM Building
Source: author

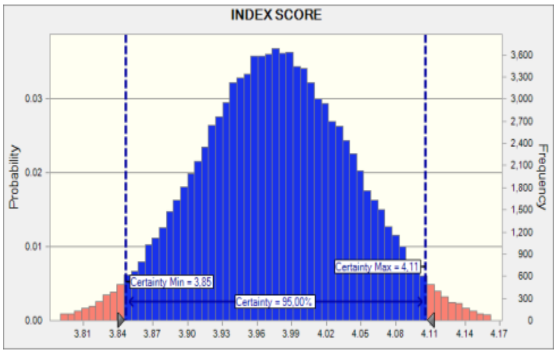

Fig. 2. Forecast Index Score Graph for UMY Building
Source: author

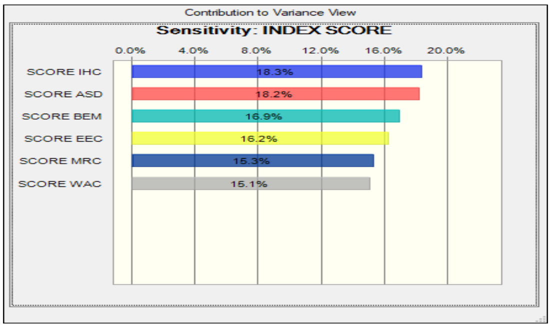

Fig. 3. Sensitivity-Overall Index Score of UGM Building
Source: author

Figure 3, the combined Sensitivity Score graph for the six variables used shows the variables that most influence the total score. The two biggest drivers are IHC (Indoor Health & Comfort) at 18.3% and ASD at 18.2%, meaning that small changes in these two aspects have the most significant impact on the rise and fall of the Index Score. Next are BEM at 16.9%, EEC at 16.2%, MRC at 15.3%, and WAC at 15.1%. Managerially, any shift in the IHC and ASD scores will affect the total result. The implication is that if you want to increase the overall score with the most efficient attempt, prioritize IHC (ventilation/purging, sensor calibration, toilet exhaust) and ASD (strengthening daily practices, drainage, access, green space). Then followed by BEM, EEC, MRC, and WAC, which remain important for operational quality, but their contribution to score variation is smaller, so they can be done in parallel.

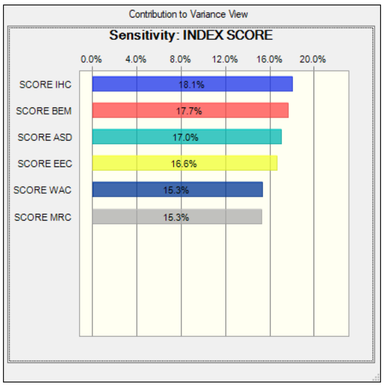

Fig. 4. Sensitivity-Overall Index Score of UMY Building
Source: author

Figure 4, The combined Sensitivity Score graph for the six variables used shows the variables that most influence the total score. The two biggest drivers are MRC (Material Resource & Cycle) at 25.4% and IHC (Indoor Health & Comfort) at 25.1%. This means that small changes in these two aspects have the greatest impact on the Index Score fluctuations. Next comes ASD at 19.3%, then BEM at 11.0%, EEC at 10.9%, and WAC at 8.3%. Managerially, any shift in the MRC and IHC scores will affect the total score. The implication: if you want to increase the overall score with the most efficient attempt, prioritize MRC (low VOC/eco-label policy, 3R, cleaning agent control) and IHC (ventilation/purging, sensor calibration, toilet exhaust), followed by ASD (strengthening daily site practices, drainage, access, green open space). EEC and WAC remain important for operational quality, but their contribution to score variation is smaller and can Thus be worked on in parallel.

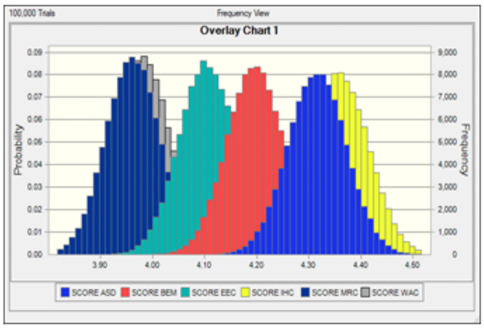

Fig. 5. Overlay Chart of UGM Building
Source: author

Figure 5, based on the Overlay Chart graph showing the frequency distribution of ASD, EEC, WAC, IHC, MRC, and BEM allows for analysis of the relationship between the two. Based on the Monte Carlo Overlay Chart, the center position (mean) and distribution of each variable are clear: IHC is on the far right (4.25–4.35), making it the component with the highest performance and low risk. ASD and BEM are grouped around 4.10–4.20, which is relatively good but still overlaps with EEC (3.95–4.05), which is slightly lower. The two lowest variables are WAC and MRC (3.80–3.90); both also show a wider distribution, indicating lower uncertainty/stability. This pattern confirms the priority for improvement, which is to encourage WAC (conservation & secondary water) and MRC (low-VOC/recycled materials) first, while maintaining high IHC and closing the energy control gap in EEC and strengthening BEM/ASD governance.

Figure 6, based on the Overlay Chart graph showing the frequency distribution of ASD, EEC, WAC, IHC, MRC, and BEM allows for analysis of the relationship between the two. Based on the Monte Carlo Overlay Chart, the center position (mean) and distribution of each variable are clear: IHC is on the far right (4.25–4.35), making it the component with the highest performance and low risk. ASD and BEM are grouped around 4.10–4.20, which is relatively good but still overlaps with EEC (3.95–4.05), which is slightly lower. The two lowest variables are WAC and MRC (3.80–3.90); both also show a wider distribution, indicating lower uncertainty/stability. This pattern confirms the priority for improvement, which is to encourage WAC (conservation & secondary water) and MRC (low-VOC/recycled materials) first, while maintaining high IHC and closing the energy control gap in EEC and strengthening BEM/ASD governance.

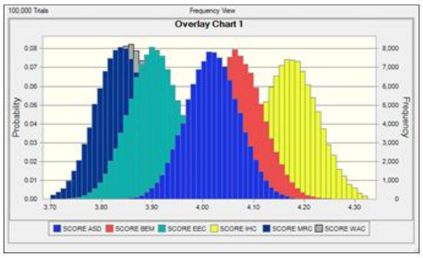

Fig. 6. Overlay Chart of UMY Building
Source: author

Table 5. Risks in IAQ Parameters

Parameter	Standard (Reference)	Risk if Exceeded/Below Standard
CO_2 (ppm)	≤ 1000 ppm (ASHRAE 55, 2023)	CO_2 above 1000 ppm may cause stuffiness, reduced concentration, headaches, and cognitive impairment.
Oxygen (%)	19.5–23.5% (ScanTech Technical Consulting, 2015)	Oxygen <19.5% may cause hypoxia and dizziness; oxygen >23.5% increases fire hazard risk.
Temperature (°C)	24–27 °C (Espandiari et al., 2021)	Increased heat causes thermal discomfort and reduced productivity; increased cold causes thermal stress.
Lighting (lux)	50–150 lux (corridors); ≥150 lux (restrooms) (BSN, 2000)	Too little light disrupts visual activities; increased light causes glare and energy waste.
TVOC (ppm)	<0.5 ppm (kaiterra.com, 2022)	TVOC >0.5 ppm may cause eye, nose, and throat irritation, as well as headaches.
HCHO (mg/m^3)	<0.05 mg/m^3 (WHO, 2010)	HCHO >0.05 mg/m^3 may cause eye irritation, respiratory problems, and long-term health risks.

This study did not use a particular dependent variable (Y) to explicitly measure risk, potential risks were identified as the likelihood of negative outcomes when the six Greenship variables (ASD, EEC, WAC, MRC, IHC, BEM) or indoor air quality (IAQ) parameters fall below the established standards. In this context, risk is defined as the degree of potential issues that may compromise the success of green building implementation and the comfort of building occupants. Risks appear when the results or user perceptions fall into the “moderate” or “poor” categories, or when IAQ results exceed the recommended thresholds.

Risks in Greenship Variables. In terms of Appropriate Site Development (ASD), inappropriate site selection and inappropriate land management can trigger a number of problems, such as erosion, environmental decline, and conflicts of interest regarding the use of space. Basically, it must be careful with how people use air conditioning and lights in a building, or it will run into problems. If a building does not comply with the regulations of organizations such as BSN, WHO, or ASHRAE, it can cause various problems. For example, when CO_2 levels exceed 1,000 ppm, people will feel sleepy, dizzy, and less focused. If oxygen levels are too low (less than 19.5%), it can cause a person to faint. However, if oxygen levels are too high (more than 23.5%), it can facilitate the spread of fire.

Another important factor is room temperature. If the temperature is not between 24–27°C, people will feel uncomfortable and have difficulty working. Light that is too dim or too bright can damage the eyes and waste energy. In addition, TVOCs exceeding 0.5 ppm can cause headaches and discomfort. Formaldehyde (HCHO) is also dangerous. If its concentration exceeds 0.05 mg/m^3, it can interfere with breathing and cause long-term health problems. To solve this problem, building managers must frequently check Greenship and indoor air quality (IAQ). If they find anything potentially dangerous, they can fix it quickly. For example, by improving airflow, replacing building materials, or teaching building users how to keep the air clean. All parties must work together, including management, cleaning staff, and building users.

Sometimes these issues are difficult to detect individually. However, you can determine if a building is in poor condition by reviewing its Greenship score and IAQ results. Therefore, ensuring all key points are followed is crucial to maintaining a safe, comfortable, and healthy environment for everyone inside the building.

CONCLUSION

This study aims to review the extent to which the Green Building concept is applied to medium-sized buildings around Yogyakarta. This study focuses on six main aspects applied by Greenship as indicators in the main checklist, namely Appropriate Site Development (ASD), Energy Efficiency and Conservation (EEC), Water Conservation (WAC), Material Resources and Cycles (MRC), Indoor Health and Comfort (IHC), and Building Environmental Management (BEM). These six features assist as a reference to determine the extent to which sustainability principles are truly applied in the operation and performance of the building. This study only uses the final stage of Greenship point assessment. The measurements were conducted solely to analyze the concept of green building in Indonesia, not to perform official certification by the Green Building Council Indonesia. The findings of this study settle that risk analysis shows a vital part in confirming the realization of green building projects. When risks are not properly done, several consequences, such as work delays, cost overflows, quality failure, and failure to achieve planned performance targets, can easily arise. In addition, successful implementation also changes on the collaboration of many parties, containing building owners and managers, design and engineering consultants, contractors, regulators, utility delivers, building users, and the surrounding community, all of whom are interconnected at every stage of the project. Risks were found to be present by using out all phases of development, from planning and design, procurement, construction, testing, and the operational point. Areas most vulnerable to potential disruptions include high-use spaces (such as corridors and restrooms), energy and automation techniques, water management and reuse, material use and housekeeping activities, and the transition phase to operation. Yogyakarta's humid and tropical environment further worsens the complexity of these operational risks. Hence, mitigation measures need to be pointed at accumulative energy automation and renewable energy integration, improving water gathering and recycling, using low-emission materials, improving indoor air quality, consolidation site availability and providing green open spaces, and developing ecological governance that aligns with ISO 14001/50001 standards and is applied sustainably. This strategy can improve building performance and ensure that the implementation of Green Buildings truly supports long-term sustainability, efficiency, and flexibility. For further research, enhancements are needed in water conservation and renewable energy systems, and the application of green building should not stop at the design and construction stages, but should also continue into the operational and maintenance stages in order to achieve real sustainability in the long term.

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