User Satisfaction and Correlation Analysis of Sustainable Features in Green Office Buildings

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Abstract
Buildings account for the majority of global energy consumption, and while traditional technical methods, such as design considerations, continue to be employed to reduce energy use, emerging research highlights the significant role of occupant behavior in achieving low or zero-net-energy goals. Several factors affect a building's energy use over its lifetime, including climate, equipment efficiency, human interaction, construction details, and thermal performance. Occupant satisfaction with sustainable features also directly influences productivity. This research investigates user satisfaction with sustainable elements in office buildings and examines correlations among different sustainability features. The study specifically evaluates green building features and occupants' thermal comfort. A survey was conducted among 80 participants during a training program on energy management in a green-certified building. Respondents assessed their satisfaction with nine sustainable building features. Results showed users were generally "satisfied" or "extremely satisfied" with all features. Notably, strong positive correlations were found between satisfaction with alternative energy use and both solar energy systems ($r = 0.786$, $p < 0.001$) and green rooftops ($r = 0.617$, $p < 0.001$). Moderate correlations were found among other sustainable features, indicating that users perceive these elements as interconnected and mutually reinforcing. The findings suggest that green office buildings are viewed as comprehensive environments where sustainability features collectively enhance comfort, environmental quality, and performance. Therefore, designers and developers should prioritize integrated sustainability strategies that simultaneously address multiple features, ultimately improving user satisfaction and promoting more sustainable and productive workspaces.

Keywords
Energy Efficiency; Post Occupant Evaluation; Sustainability; Thermal Comfort; Well-Being

1. Introduction

Building sustainability addresses ecological, technical, social, economic, and environmental factors (Hafez et al., 2023). The construction sector plays a major role in sustainability due to its high resource use and emissions (Olanrewaju & Chong, 2021). Rising CO_2 emissions from human activities have widened the gap between actual emissions and climate goals. Buildings are key contributors, using over 40% of global energy and 60% of electricity (Liu et al., 2022). The construction sector alone accounts for one-third of energy use and 15% of direct CO_2 emissions (Lakhiar et al., 2024). To reduce these impacts, buildings must be designed for efficiency, low emissions, and improved occupant well-being. Sustainable buildings should also be waste-free, energy-generating, and well-ventilated (Olanrewaju & Tan, 2019).
The modern green building movement emphasizes sustainable practices like energy and water conservation, waste reduction, and improved indoor air quality throughout a building's lifecycle, aiming to enhance both environmental performance and occupant well-being (Cole, 2019; Kim & Lim, 2019). Given the amount of time people spend indoors, maintaining healthy indoor environments is critical (Lakhiar et al., 2024). Occupant satisfaction has become

a key measure of green office performance, guiding design improvements (Ye et al., 2022). In Malaysia, while green initiatives receive government support, more user-centered research is needed. Globally, sustainability, location, and accessibility affect office demand (Adnan et al., 2022), yet energy-saving strategies can sometimes compromise air quality and lead to health issues such as Sick Building Syndrome (Ashmawy et al., 2024). To address this, green offices incorporate advanced insulation, smart lighting, and automation to balance energy efficiency with user comfort, supporting corporate responsibility and climate resilience goals (Ashmawy et al., 2024).

Sustainable building assessment tools often lack accuracy because they overlook user behavior and social factors like satisfaction and community impact (Olanrewaju & Idrus, 2020). Including these elements can help optimize energy use. Green buildings may still face issues such as Sick Building Syndrome, highlighting the need for Post-Occupancy Evaluation (POE) to guide improvements. User feedback is crucial for validating green building investments and improving future designs. Satisfaction depends on how well buildings meet user needs, making occupant interaction a key part of evaluation (Kim & Kim, 2020).

Despite occasional discomfort, occupants of green buildings generally report high satisfaction with their indoor environments (Laiche et al., 2023; Khoshbakht et al., 2022). Most POE studies concentrate on environmental aspects such as air quality, thermal conditions, lighting, noise levels, and acoustic privacy. Yet identifying the precise drivers of satisfaction or dissatisfaction remains challenging because of the complexity of building systems. Perception-based surveys used in POE can also introduce bias; therefore, incorporating variables such as building type, occupant demographics, and user background is recommended to improve reliability (Altomonte et al., 2019; Halicioglu et al., 2024). Seasonal changes and psychological factors further influence occupant satisfaction, and individuals with strong environmental values often report greater contentment with green buildings (Khalil et al., 2024; Sanmargaraja et al., 2023).

This study, therefore, emphasises the need to understand how occupants perceive comfort in green office buildings through a POE approach, to inform both design and operations. While thermal sensation reflects immediate physical responses to temperature, thermal experience encompasses deeper emotional and behavioural aspects such as satisfaction, adaptation, and preference. Examining these factors helps determine whether green buildings meet user expectations and contribute to overall well-being. By focusing on occupant perceptions of thermal comfort and the interrelationships among sustainable building features, this research contributes evidence from a tropical Malaysian context, supporting efforts to create healthier, energy-efficient workplaces that align user comfort with sustainable development goals.

2. Methodology

This study adopted a purposive convenience sampling strategy to distribute surveys, an approach appropriate for targeting participants with specific characteristics of interest when comprehensive population data are not available (Olanrewaju & Idrus, 2020). The survey was administered in a GBI-certified office building in Kuala Lumpur that exemplifies the energy-efficient and water-saving design features advocated by the Malaysian Green Building Index, making it a reasonable proxy for a typical certified green office in the country. The survey was administered on 25 June 2023 during a two-day building energy management training held in a certified green building. It focused on thermal comfort and satisfaction with green building components. One hundred participants, energy-management professionals from both conventional and green office buildings, completed questionnaires covering thermal experience, clothing, activities, control over the environment, and satisfaction with green features. Satisfaction was rated on a five-point Likert scale, subsequently converted to a 0–100 scale, with “Least satisfied” corresponding to 0–20 and “Extremely satisfied” to 80–100.

Data were analyzed using IBM SPSS Statistics. Because the Likert data are ordinal, relationships between variables were examined using Spearman’s rank-order correlation (ρ), which does not assume interval-level measurement. As the satisfaction variables were measured with single-item questions, internal-consistency statistics such as Cronbach’s alpha are not applicable and were therefore omitted.

3. Results

3. 1 Results of Questionnaires

Out of 100 distributed questionnaires, 79 valid responses were collected and analyzed. Reliability and validity tests confirmed that the data were both strong and dependable. The gender distribution was nearly equal, with 51% male and 49% female respondents. Around 68% of participants were over the age of 30. Professionally, over 34% were from property developer organizations, and 30% were construction consultants, namely individuals involved in design, cost estimation, and advisory services, indicating the respondents had adequate expertise in green buildings. Additionally, Tables 1 and 2 provide insights into the participants' clothing types and activity levels during the survey.

Table 1. Clothing worn by participants during data collection

Clothing type	Percentage (%)
Traditional	8.86
English	60.76
Others	30.38

Table 2. Activities engaged in during the 30 minutes before the survey

Activity	Frequency
Reading/writing (seated)	48
Typing	16
Filing (seated)	12
Walking about (outside)	3

Table 3 contains the descriptive and explanatory statistics of the features. About 3% of the attendees affirmed that they were least satisfied with the components, and some 15% were less satisfied with the features. While 37% of the attendees were satisfied with the features, approximately 45% were very satisfied or extremely satisfied with the components. On average, most of the attendees are satisfied or extremely satisfied with the contribution of the components to the greenness or sustainability of the office building.

Table 3. Satisfaction with sustainable building features

Feature/component	Std. Deviation
Usage of solar energy systems	1.11
Usage of alternative energy	1.09
Thermal insulation	0.95
Energy-efficient equipment	0.93
Installation of a skylight for illumination	1.12

There are strong and moderate correlations between the satisfaction levels (Table 4). The results of the correlations were significant and suggest that the users were satisfied with the components. From Table 4, it is also obvious that there are positive correlations between satisfaction with all the green features in the buildings.

Table 4. Correlation between the green components

Component and statistics		Are you satisfied with the energy-efficient equipment?	Are you satisfied with the thermal insulation?	Are you satisfied with the installation of a skylight for illumination?	Are you satisfied with the usage of alternative energy?	Are you satisfied with the usage of solar energy systems?	Are you satisfied with the design for reducing energy use and embodied energy?	Are you satisfied with the current building orientation?	Are you satisfied with green rooftop features?
Are you satisfied with the energy-efficient equipment?	Pearson Correlation	1							
	Sig. (2-tailed)								
Are you satisfied with the thermal insulation?	Pearson Correlation	0.667**	1						
	Sig. (2-tailed)	0.000							
Are you satisfied with the installation of a skylight for illumination?	Pearson Correlation	0.517**	0.530**	1					
	Sig. (2-tailed)	0.000	0.000						
Are you satisfied with the usage of alternative energy?	Pearson Correlation	0.417**	0.501**	0.642**	1				
	Sig. (2-tailed)	0.000	0.000	0.000					
Are you satisfied with the usage of solar energy systems?	Pearson Correlation	0.477**	0.578**	0.660**	0.748**	1			
	Sig. (2-tailed)	0.000	0.000	0.000	0.000				
Are you satisfied with the design for reducing energy use and embodied energy?	Pearson Correlation	0.517**	0.620**	0.627**	0.553**	0.638**	1		
	Sig. (2-tailed)	0.000	0.000	0.000	0.000	0.000			
Are you satisfied with the current building orientation?	Pearson Correlation	0.385**	0.454**	0.693**	0.582**	0.591**	0.588**	1	
	Sig. (2-tailed)	0.000	0.000	0.000	0.000	0.000	0.000		
Are you satisfied with green rooftop features?	Pearson Correlation	0.348**	0.502**	0.545**	0.617**	0.571**	0.507**	0.497**	1
	Sig. (2-tailed)	0.002	0.000	0.000	0.000	0.000	0.000	0.000	

Table 5 shows that most respondents experienced a slightly cold to moderate thermal environment, with 25% feeling very cold or cold, and only 8% reporting slightly warm or warm conditions. Overall, occupants tended to perceive the indoor environment as neutral or slightly cold, suggesting that while green buildings are effective in maintaining cooler temperatures, they may require improvements in thermal regulation to better meet comfort expectations. The study also found a significant correlation between green building features and occupant satisfaction, highlighting the importance of integrating sustainable design and operational practices to enhance user comfort and well-being.

Table 5. How do you actually feel right now in your office (Thermal experience)?

Scale	Percentage
-3: Very cold	11.39
-2: Cold	15.19
-1: Slightly cold	34.18
0: Moderately warm; Room temperature; Balanced (neither cold nor hot)	31.65
+1: Slightly warm	2.53
+2: Warm	5.06

The occupants' thermal sensations were assessed, revealing that approximately 66% of respondents felt comfortable with the thermal conditions in the building. However, around 34% expressed discomfort with the thermal environment. Additionally, over 90% of the occupants perceived the office temperature as acceptable, while a small portion indicated it was only slightly acceptable or not acceptable.

3.2 Discussion

There will be two sections under discussion namely the discussion of the taxanomy of the satisfaction and discussion on the correlation results.

3.2.1 Discussion of the taxonomy of satisfaction

This study found that while the majority of green office building users were generally satisfied or very satisfied, the overall performance did not fully meet expectations, as only 20% reported extreme satisfaction. Although green buildings are designed to enhance sustainability and user experience, their effectiveness varies due to several influencing factors. A key determinant is Indoor Environmental Quality (IEQ), particularly thermal comfort, lighting, and acoustic conditions. Discomfort from poor ventilation, temperature control, insufficient daylight, or excessive noise can significantly lower satisfaction. Additionally, mismatched expectations and difficulty adapting to advanced technologies or sustainable features may lead to user frustration. Users may struggle to interact with complex systems designed for sustainability, such as innovative HVAC or energy management tools.

Cultural values, personal preferences, and lifestyle choices also play a role in shaping perceptions and satisfaction with green buildings. When a building's design does not align with occupant norms or behaviors, it can create a disconnect that reduces overall satisfaction. The study revealed that 3% were least satisfied, 15% less satisfied, 37% satisfied, and about 45% were very or extremely satisfied. Despite some dissatisfaction, most users acknowledged the positive contribution of building components to sustainability. The study focused primarily on thermal comfort, recognizing that satisfaction varies depending on the time of evaluation and different energy uses (e.g., heating, lighting, or cooling). These findings underscore the importance of aligning green building design with user expectations, comfort needs, and cultural context to improve satisfaction and overall performance.

3.2.2 Discussion on the correlation results

The strong positive correlations identified among multiple green office components and occupant satisfaction underscore the interdependent nature of sustainability features and their influence on occupant well-being. In particular, the substantial association between satisfaction with energy-efficient equipment and thermal insulation suggests that occupants perceive these features as complementary in delivering thermal comfort and energy efficiency within the building envelope. These findings reinforce the premise that well-insulated buildings equipped with efficient HVAC systems can sustain acceptable indoor temperatures while reducing energy consumption, thereby supporting overall occupant satisfaction.

Similarly, the favourable relationships between satisfaction with alternative energy use, solar energy systems, and other sustainable features indicate that users value holistic sustainability strategies that incorporate renewable energy sources. This aligns with the increasing emphasis on renewable energy integration in green building design and reflects occupants' appreciation of environmental stewardship and energy resilience. The positive association between satisfaction with energy-reduction design and other green characteristics further highlights the importance of integrated design approaches that prioritise energy efficiency, daylighting, and passive design principles. Coherent design solutions that optimise building performance while minimising environmental impacts are likely to enhance occupant satisfaction.

Moreover, the observed relationships between satisfaction with building orientation, green rooftops, and other sustainability measures emphasise the contribution of biophilic design and accessible outdoor amenities to occupant well-being. Buildings that maximise natural light exposure and provide visual or physical access to greenery foster a healthier indoor environment and strengthen occupants' connection with nature, both of which are known to improve satisfaction and productivity.

Although most respondents reported being satisfied or very satisfied with thermal conditions, the relatively low proportion of extreme satisfaction (20%) merits closer examination. Post-occupancy evaluation (POE) studies in temperate climates often report higher comfort ratings when HVAC systems are carefully calibrated (Altomonte et al., 2019). The more moderate satisfaction observed here may reflect the persistent challenge of achieving consistent thermal comfort in Malaysia's hot-humid climate, where high outdoor temperatures and humidity prevail year-round. In addition, occupant expectations—shaped by the widespread reliance on air-conditioning in Malaysian offices—may narrow the perceived comfort range compared with regions that experience greater seasonal variability. These findings suggest that mere compliance with Green Building Index (GBI) criteria does not automatically ensure high thermal comfort, and that building operators must actively monitor and fine-tune indoor environments to meet occupant expectations.

5. Conclusions

In conclusion, this research has explored and investigated the satisfaction of occupants in a certified green office building. While a substantial body of literature examines green buildings in general, there is comparatively limited research on the post-occupancy performance of green office buildings. This study contributes to that gap by applying a Post-Occupancy Evaluation (POE) approach to capture user experiences and identify performance strengths and weaknesses from the occupants' perspective.

The data revealed that while the majority of participants were satisfied or very satisfied with the green building, the overall performance was not as optimal as anticipated. Only 20 % of users reported extreme satisfaction (≥ 80), a finding that aligns with broader POE studies showing that high expectations and complex building systems can lead to mixed perceptions of comfort. Specifically, 3 % of attendees were least satisfied, 15 % were less satisfied, 37 % were satisfied, and approximately 45 % were very satisfied or extremely satisfied with the building components. Several factors may contribute to lower ratings, such as Indoor Environmental Quality (IEQ) concerns including poor ventilation, inadequate temperature control, insufficient natural light, or excessive noise, as well as mismatched expectations, difficulties with advanced technologies, and cultural or lifestyle differences.

The positive correlations found between various components of the green office and occupant satisfaction underscore the interconnected nature of sustainability features and their collective impact on well-being. Well-insulated envelopes and efficient HVAC systems, for instance, support thermal comfort while reducing energy consumption, a result consistent with POE findings in other contexts. Likewise, favourable relationships between satisfaction with alternative energy usage, solar systems, and other sustainable features indicate that occupants value comprehensive strategies that incorporate renewable energy and strengthen energy resilience. These results highlight the importance of integrated design approaches that combine energy-reduction strategies, daylighting, and passive design principles.

Overall, the correlation findings indicate that occupants perceive green office buildings as holistic workplaces in which diverse sustainability aspects work together to improve comfort, performance, and environmental quality. POE proved to be a useful mechanism for revealing these perceptions and for providing evidence-based feedback to designers, facility managers, and policymakers. By documenting both strengths and areas needing improvement, this study supports the continuous refinement of Malaysia's green office design standards and informs future projects aiming for climate-resilient, user-centred outcomes.

Two key limitations should be noted. First, because participation in the survey was voluntary, respondents with a stronger interest in sustainability may have been more likely to participate, introducing potential self-selection bias. Second, as the data were drawn from a single site, the findings cannot be assumed to represent all Malaysian green offices; the results should therefore be viewed as indicative rather than fully generalisable. Future POE studies that include multiple buildings and diverse user groups would enhance representativeness and strengthen conclusions.

Finally, the government continues to play a pivotal role, through its various ministries, agencies, and departments, in shaping housing and building policies and providing an enabling environment for private developers. While the housing and green building markets are evolving, policy support remains essential to ensure that private initiatives are complemented by robust standards and incentives, allowing POE feedback to translate into tangible improvements in building performance and occupant well-being.

As Malaysia's green-building market matures, government ministries and agencies continue to play a critical role in shaping policy and creating an enabling environment for private developers. For practitioners, adopting adaptive comfort strategies, such as operable windows, zoned HVAC systems, and dynamic shading, can better accommodate diverse thermal preferences while reducing reliance on mechanical cooling. Facility managers can further enhance comfort by integrating real-time monitoring and occupancy-feedback platforms to enable proactive system adjustments. Policymakers, in turn, should consider updating the Green Building Index (GBI) to incorporate occupant-driven performance metrics gathered through regular POE and to incentivize transparent reporting of satisfaction data. Such measures would reinforce market confidence in green-building performance and drive continuous improvements in indoor environmental quality and occupant well-being.

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