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A Post-occupancy Evaluation of Occupant Satisfaction in Green and Conventional Higher Educational Buildings

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Abstract. Post-occupancy evaluation (POE) is a method for measuring building performance in terms of meeting design intent, and identifying any gaps between actual and modelled performances in the of aspects indoor environmental quality (IEQ), occupant satisfaction, energy consumption, etc. In this paper, a structured POE assessment was conducted using the Building Use Survey (BUS) methodology in two higher educational buildings in the United Kingdom. This study aims to help close the building performance gap, optimize building operation systems, and improve occupants' satisfaction levels. In this research, the questionnaire survey investigated the influences of environmental factors on user satisfaction from the main aspects of building overall design, thermal comfort, perceived control, indoor environment quality for noise, lighting, ventilation, and other non-environmental factors, such as the background information about age, gender, time in buildings, workgroup size, and so on. The results indicate that the occupant satisfaction with the main aspects of building overall design, indoor environment quality, and thermal comfort in summer and winter in both buildings is lower than the benchmark data. The feedback of this POE assessment has been reported to the building management team to allow managers to develop high-performance building operation guidelines to narrow down the performance gap and improve user satisfaction, comfort, and productivity.

1.Introduction

Facing the growing severity of environmental issues and energy crises, the development of green buildings has become a global trend with the growing awareness of sustainable development. Cater to the development needs, some green building rating tools (GBRTs) have been developed to evaluate building's performance achievement levels, such as the BREEAM (Building Research Establishment Environmental Assessment Method) in the United Kingdom, the U.S. LEED (Leadership in Energy and Environment Design), etc. Compared with the researches on green buildings in the aspects of energy-saving and resource efficiency, however, the occupant satisfaction aspect researches have not received the same emphasis. Since people spend more than 90% of their time indoors, so the built environment of buildings has a significant impact on occupants' satisfaction in the aspects of health and productivity[1]. The objective of developing sustainable buildings is to provide a user-centric, environment-friendly, and energy-efficient building to reduce the overall impact of the built environment on the natural environment and human health, compared with conventional buildings,



green buildings are expected to provide higher building performance achievements in indoor environmental quality(IEQ), occupant satisfaction, and occupants productivity [2].

As the built environment such as IEQ (e.g. thermal comfort, air quality, lighting, ventilation), building overall design, thermal comfort, perceived control, and so on, has a significant impact on occupant's satisfaction in the aspects of health and productivity, hence, by adopting the Building Use Studies (BUS) methodology, this paper conducted a post-occupancy evaluation in a green and a conventional higher educational office building separately. The results indicated that, compared with the similar buildings, the building's users were less satisfied with the main aspects of building overall design, indoor environment quality, and thermal comfort in summer and winter in both two buildings, and there is not much difference in satisfaction levels between the green building and non-green office building.

Post-occupancy evaluation (POE) is a systematic method to evaluate buildings' performance after buildings have been occupied for some time, it originated in the United States and has been widely used worldwide since the 1960s. The POE activities promote the participation of building occupants, the end-users, focus on their requirements of buildings in the aspects of health, safety, convenience, amenity, psychological comfort, living quality, and satisfaction [3]. Despite the rapid green building technologies development, the actual building performance is not performed as expected in some aspects. The outcomes of comparative studies of green and non-green buildings occupant satisfaction in terms of different built environment factors are varying from research to research.

In 1995, a U.K. government-led Post-occupancy Review of Buildings and their Engineering (PROBE) project started the first systematic performance assessment among green and conventional office buildings in the U.K., the project result found that, as a group, the green buildings performed better than conventional buildings, however, the occupants had different satisfactions attitudes on their building. Compared with non-green buildings, some occupants were more satisfied and comfortable with green buildings, however, some occupants might show more discomfort or dissatisfaction with green buildings[2]. In 2016, another U.K. government-funded project conducted a POE survey of 56 buildings, results showed that even the BREEAM certificated office buildings were not performing as they should do, the buildings consumed up to 3 to 10 times the energy they should, and some occupants had lower satisfaction compared with the non-certificated buildings[4].

Khoshbakht, Gou, Lu, et al. [2] researched occupants satisfaction between green and conventional office buildings in different counties, the research found out that, in occident countries such as U.S. and U.K., there were no significant differences in occupants' satisfaction in almost all IEQ aspects between these two types buildings. However, in the orient countries, like China and South Korea, occupants in green buildings had significantly higher satisfaction than those in non-green buildings. Lee et al. [5] emphasized in their research on office buildings in Singapore that, compared with the non-green buildings, green buildings were expected to provide enhanced IEQ, higher satisfaction, and a healthier indoor environment. Also, this study results showed the occupants in green buildings were more satisfied with the indoor environment and had a lower risk of health problems than those in conventional buildings. Another research produced by S. Altomonte and S. Schiavon between LEED and non-LEED certified buildings concluded that there was not a significant impact of LEED certification on occupant satisfaction in IEQ performance, but the LEED buildings users are slightly more satisfied with air quality, and slightly more dissatisfied with the amount of natural light [6].

Based on the current studies, it is hard to explicitly define the relationships between green buildings and occupant satisfaction, and there is not enough evidence to assert that green buildings always have higher occupant satisfaction than conventional buildings. In this research, a Building Use Studies (BUS) methodology was applied in a BREEAM-certificated green and a conventional higher educational building to investigate the impacts of built environment factors on occupant satisfaction from the main aspects of building overall design, thermal comfort, perceived control, IEQ, and so on. And this study also investigated if there are significant differences in occupant satisfaction with green and non-green buildings.

2. Methodology

The Building Use Studies (BUS) methodology has been adopted to conduct post-occupant satisfaction surveys in a BREEAM certificated green building and a conventional building separately in a university in the United Kingdom. The BUS methodology is a paper-based and web-based questionnaire that covers various quantitative and qualitative questions in the aspects of background information (e.g. gender, room layout, and time stay in buildings), thermal comfort, ventilation, indoor air quality, lighting, noise, personal control, perceived productivity and health, etc. Building users rate different performance-related building parameters based on a 7-point scale (e.g. '1=too cold and 7= too hot') [7], it is an efficient tool widely used in POE researches. The collected survey data is analyzed by comparison with similar buildings' benchmark values from the database. When compared with the benchmark values, the survey data can compare with the single benchmark mean value, or also can compare with the lower/ upper critical value zone. The lower critical limit is the lower value of the scale midpoint lower and the benchmark lower, the upper critical limit is the higher value of the scale midpoint upper and the benchmark upper [8].

The survey of higher educational buildings, Eastern Gateway (ESGW) and Michael Sterling (MCST), were selected from a university in the United Kingdom. Both buildings were built with some smart technologies, the Eastern Gateway building achieved a BREEAM "Excellent" rating with heating provided by a wood pelleting boiler and much of the building using natural ventilation [9].

In this research, to increase the response rate, 150 paper-based questionnaires were handed out in each building, a total of 78 and 88 valid questionnaires were collected respectively from these two buildings, and the response rate was higher than 50%. The collected qualitative and quantitative data were analyzed against similar buildings in the established dataset. The survey results are shown in the next section.

3. Results analysis

By analyzing the collected non-benchmarked and benchmarked survey responses, this section illustrates the analysis results of this study.

3.1. Analysis of non-benchmarked survey responses

Table 1 presents non-benchmarked survey results in the aspects of age, gender, window seat, work duration in the building each day and every week, number of occupants in the shared office or work area, etc. These two buildings are both office buildings and have similar functions. Most of the assessment parameters have slight differences in results. However, there is a significant difference in the factor of the space shared with the people in the office, this factor is related to the noise factor and might be related to air quality in the room, etc. In building ESGW, there are 9% of people shared with 5-8 others, and up to 51% of occupants shared office with more than 8 people; however, in building MCST, these two proportions are 45% and 27% separately. The work duration in buildings each day and every week might be related to health, productivity, and so on. There are significant differences in these two buildings, more than 60% of occupants work spent more than 8 hours in MCST, that number in ECST is only 46%, the seating to the window might be related to occupants lighting satisfaction. Surveying the sample buildings' background information would help to understand the correlations between these sample parameters with benchmarked survey results and minimize potential errors.

Table 1. Analysis of non-benchmarked survey response

Sample characteristics		Eastern Gateway	Michael Sterling
30 years of age or older		74%	75%
Gender	Female	65%	51%
	Male	35%	49%
Occupied building for a year or more		74%	77%
Number of occupants in office or work area	occupied by you alone	11%	2%
	Shared with 1 other	11%	5%
	Shared with 2-4 others	14%	19%

	Shared with 5-8 others	9%	45%
	Shared with more than 8 others	51%	27%
Hours spent in the building each day	6 or less than 6 hours	12%	15%
	7 hours	39%	22%
	8 hours	39%	46%
	9 or more than 9 hours	7%	14%
Days spent in the building each week	2	--	1%
	3	6%	10%
	4	16%	16%
	5	77%	66%
	6	--	5%
Next to window		34%	35%

3.2. Analysis of benchmarked survey responses

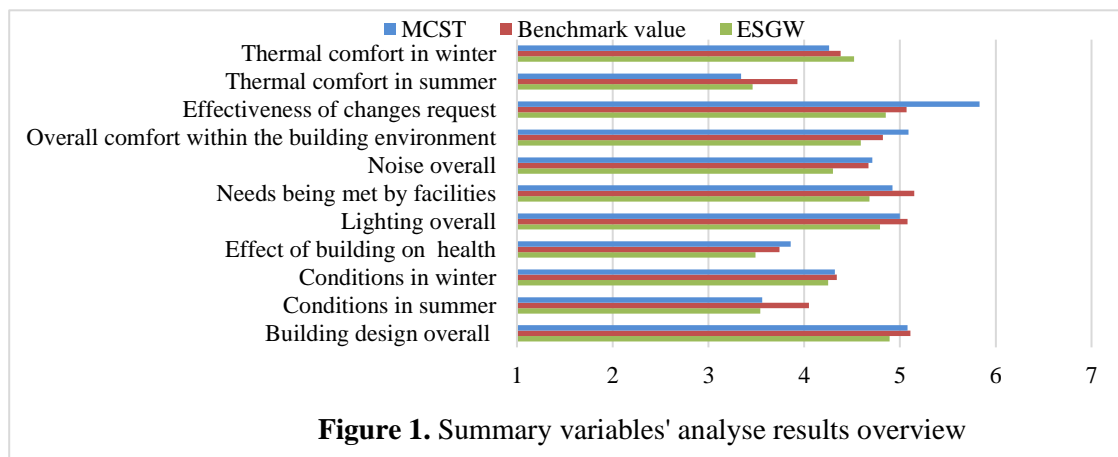


Figure 1. Summary variables' analyse results overview

As shown in figure 1, the summary analysis gives an overview of the benchmarked questions results in comparison with the benchmark mean value dataset. In building MCST, the survey values of thermal comfort in winter and summer are slightly lower than building ESGW; the rest summary variables' results have a higher value than building ESGW, which means building MCST provides occupants more satisfaction in these aspects. However, in the aspects of the thermal comfort in summer, needs to be met by facilities, lighting overall, conditions in winter and summer, building design overall, both two buildings have lower satisfaction value compared with the benchmark dataset. Building MCST provides higher values than the benchmark dataset values in the aspects of the effectiveness of changes request, overall comfort within the building environment, noise overall, and effect of building on health. In building ESGW, only the thermal comfort in winter value is higher than the benchmark value.

As shown in figure 2 (a) and (b), instead of comparing with the single benchmark mean value, this paper here analyzed the survey data by comparing it with the lower/ upper critical value. For the temperature in summer/ winter, humidity in summer/winter, air movement in summer/winter parameters, if the survey value between the lower critical value and upper critical value, that means occupants are satisfied with the assessment parameters; if the survey value is lower than the lower critical value, that means the temperature is too cold, the air is too still, or it is too dry; if the survey value is higher than the upper critical, that means the temperature is too hot, the air is too draughty, or it is too humid.

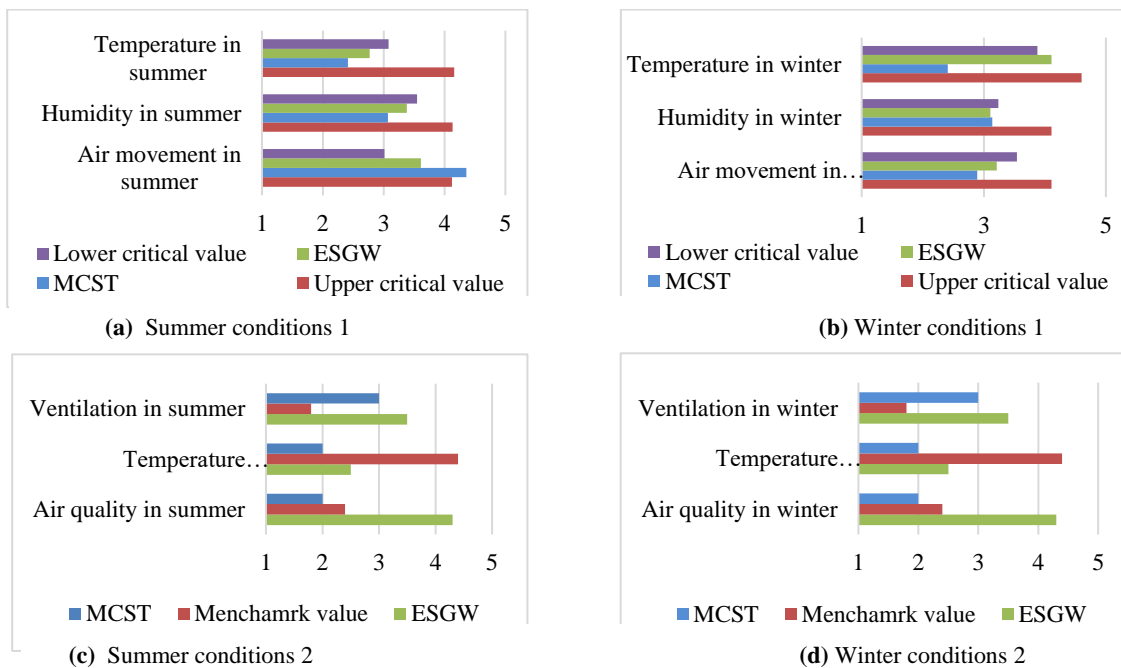


Figure 2. The satisfaction in summer and winter overall conditions

The outcomes of this survey show that the BREEAM-certificated ESGW building and the conventional MCST building have similar results on the aspects of overall building conditions and thermal comfort in summer and winter. Overall, occupants in these two buildings were both not satisfied with the overall conditions and the thermal comfort in summer, but both were satisfied with these two aspects in winter. In summer, the two survey buildings have some common problems in their building environment, like poor air quality (too smelly), low humidity (too dry), high temperature (too hot), poor ventilation (too stuffy). In winter, these two buildings have some common problems in air movement (too still), humidity too dry, but both show a good result on air quality. In building ESGW, the temperature in winter is satisfactory, but ventilation in winter is stuffy; in Building MCST, the temperature in winter is too cold, ventilation in winter is satisfactory.

Table 2. The survey results in lighting and noise

Building environment parameters		MCST	Lower critical value	Benchmark Mean	Upper critical value	ESGW
Lighting	Amount of artificial light	4.25	3.93	4.41	4.48	4.44
	Amount of natural light	3.99	3.66	3.77	4.11	3.65
	Glare from lights	3.00	3.49	3.60	4.10	3.27
	Glare from sun and sky	3.70	3.48	3.63	4.15	3.69
Noise	Frequency of unwanted interruptions	3.14	3.63	3.77	4.14	3.75
	Noise from colleagues	3.21	3.91	4.24	4.33	3.85
	Noise from outside	4.18	3.79	3.90	4.11	3.27
	Other noise from inside	2.91	3.92	4.09	4.17	3.72

Table 2 represents the survey results in lighting and noise assessment factors. The occupants from these two buildings are both satisfied with the light overall condition, especially highly satisfied with the glare from the aspect of the light, but people from building ESGW complained the amount of natural light in the room is not enough. And they are both happy with the personal control over light.

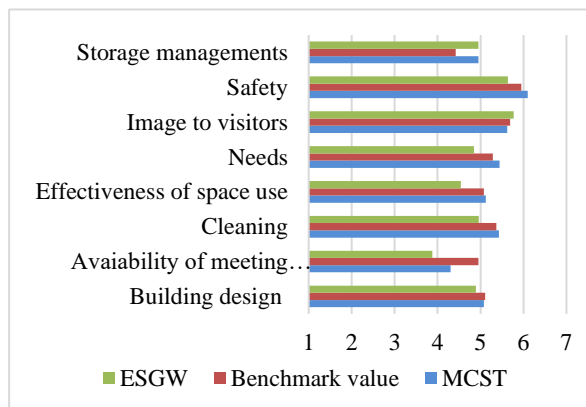


Figure 3. Building overall parameters

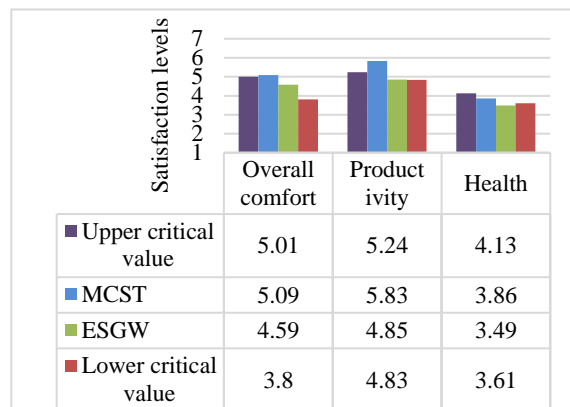


Figure 4. Overall occupant satisfaction

The survey from the noise overall condition shows a positive result in both buildings, but building MCST’s survey value (4.71) is slightly higher than the building ESGW value (4.30). Even people in MCST are satisfied with the noise overall, however, the survey result of noise from the outside in MCST shows too much, as this building is next to the main road of the campus, there is too much noise when it is busy in the campus.

As shown in figure 3, the assessed building overall parameters include the adequacy of space at work-area, availability of meeting rooms, cleaning, the effectiveness of space use, how well facilities meet needs, image to visitors, personal safety, storage arrangements, the usability of furniture. The building ESGW is at a satisfactory level with all factors; except the adequacy of space at work-area factor, building MCST at a satisfactory level with all the other factors. Building ESGW provides higher satisfaction in the factor of the image to visitors, but building ESGW provides higher satisfaction in the rest of the parameters. All things considered, the results of how occupants rate the overall comfort of the building environment, the decreased or increased productivity at work, feel less or more health are shown in figure 4. Based on the lower/ upper critical value zone analyses method, apart from the ESGW building failing to meet the health satisfactory result, both buildings' survey results are in a satisfactory zone in all the other assessment parameters of these three aspects.

The people give the MCST building a high rating in the aspects of productivity and overall comfort, both these two parameters values are higher than the benchmark upper critical value. Overall, it is clear to know that building MCST provides a better overall building environment than building ESGW.

This paper does not provide full detailed analyzed survey results, but only presents the results in the main building environmental parameters. This research also covers some other survey aspects, such as the speed and effectiveness of responses, journey time to work, effect on behaviour, space at the desk, etc. Occupants in these two buildings gave similar feedback that excepts for lighting and ventilation, they did not have enough personal control over the lighting, heating, noise in their work environment.

4. Conclusion

This research produced a POE research on occupant satisfaction in a green building and a conventional building. Overall, the results indicate that occupants in both buildings were not satisfied with the thermal comfort in summer, needs, lighting overall, conditions in winter and summer, building design overall.

In this research, the survey results show that the BREAM-certified green building could not provide a higher satisfaction level than the non-green building in the aspects of the overall comfort of the building environment, productivity, health. Limited by the sample size, there is not enough evidence to explicitly define the relationships between green buildings and occupants' satisfaction and comfort, and not enough to prove that green buildings have higher occupant satisfaction than conventional buildings for sure, and this is consistent with previous literature review outcomes.

The outcome of this research provides guidelines to facility managers to adjust the building operation plans to narrow down the performance gap and allows the building users to change their behaviour or use habits, to improve the occupants' experience satisfaction, comfort, and productivity.

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