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POE of Bioclimatic Design Building towards Promoting Sustainable Living

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Abstract

Post Occupancy Evaluation (POE) by using a set of questionnaire was conducted to assess the perception and comfort level required by residents in a college building with the best practice of bioclimatic design strategies, particularly natural ventilation and daylighting. The questionnaire was based on a five-point Likert scale, covering various performance criteria of building, specifically on the architectural elements, thermal comfort, indoor air quality, visual comfort, acoustic comfort and landscape elements. The initial outcomes showed a positive relationship between perceptions and building performance criteria.

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Keywords: Bioclimatic design; Likert scale; Post Occupancy Evaluation (POE); residential college building

1. Introduction

Dayasari Residential College (DRC), located at the University of Malaya (UM) in Kuala Lumpur, is acknowledged as a natural ventilated building with the most considerate implementation of bioclimatic design strategies that minimise the electricity consumption for lighting and cooling (Jamaludin et al., 2014). Thus, it showed amongst the lowest Energy Efficiency Index (34.52 kWh/m2/year) compared to other residential colleges in UM; which are in the range of 40 to 125 kWh/m2/year (Jamaludin et al.,

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2013). Unfortunately, the lowest consumption of electricity is not the ultimate criteria of a successful implementation of bioclimatic design strategies, especially if residents are to bare with unconducive environments. With regards to these conditions, POE is recognised as one of the ways to validate the successfulness of implementation of bioclimatic design strategies in providing conducive indoor environment for the residents (Preiser, 1995). This study aims to promote sustainable living through the efficiency of natural ventilated residential college buildings in UM. The objective is to evaluate on performance criteria of building: the architectural elements, thermal comfort, indoor air quality, visual comfort, acoustic comfort and landscape elements, with the purpose of justifying the residents' perception and satisfaction with the implemented bioclimatic design strategies.

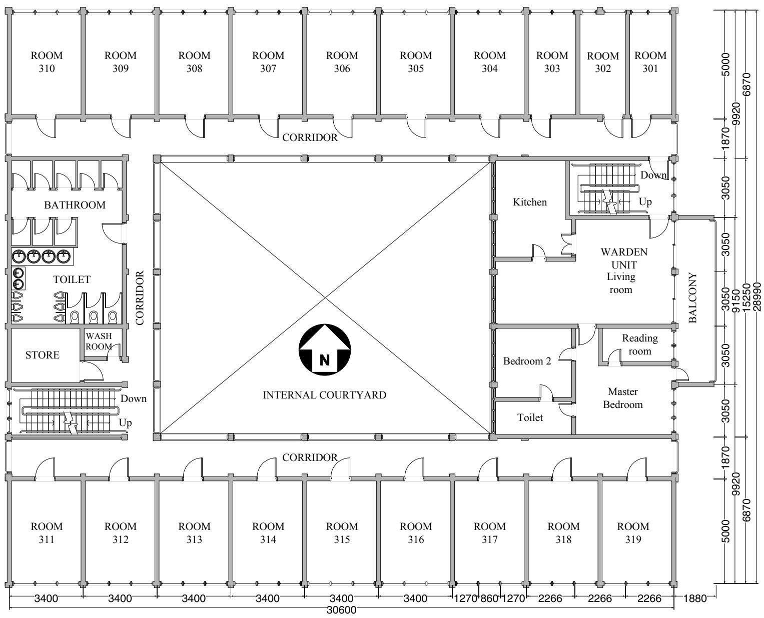
2. Literature review

Bioclimatic concept and design strategies in buildings involve many disciplines, including human physiology, climatology and building physics (Olgyay, 1963). The principle behind bioclimatic design is the understanding of the climatic factors of a site by analysing the influence of microclimate; including solar radiation, sunshine, temperature, humidity, rainfall, wind velocity and direction (Hyde, 2000). It is followed by a comparative analysis in assessing the climate data in relation to thermal comfort and ends with the selection of climate responsive modification concept. This concept adopts a passive mode that includes built-form configuration and orientation, enclosure and facade design, daylight, natural ventilation, landscaping, etc., in order to optimise internal comfort conditions while reducing energy demands for electricity (Yeang, 2008; Zr & Mochtar, 2013). POE is defined as a process of evaluating buildings in a systematic and rigorous manner to indicate the satisfaction and comfort level needed by occupants as lessons learned to identify problems in indoor environments (Khalil and Husin, 2009). Among plausible benefits of conducting the POE include applying design skills more effectively, improving commissioning process, user requirements and management procedures, providing knowledge of design guides and regulatory processes, and targeting of refurbishment (Whyte and Gann, 2001). POE begins with planning, conducting and applying phase, can be done in three levels: indicative, investigative and diagnostic levels (Preiser, 1995). Each level has different techniques that can be assessed and utilized with respect to the time frame, budget, manpower, aim and objectives that are to be achieved (Bordass and Leaman, 2005). There is audit (using quantitative technical assessments), discussions (use discursive techniques such as workshops and interviews), questionnaires (techniques that are used to adapt the procurement process to incorporate feedback in an organized manner) and packages (using probes). A critical evaluation using questionnaire system can be achieved when only most relevant issues are highlighted, rather than attempting to analyse everything and risk an overload of data (Niroumand et al., 2013). There are four major barriers to POE implementation: ownership, liability, lack of knowledge and progress (Hadjri and Crozier, 2009). Additionally, Riley et al. (2010) also highlighted culture as a barrier to POE process where the occupants may feel that moving into a new working environment is disruptive. Without any constructive database, the comparison cannot be carried out to identify the level of achievement (Mier et al., 2009). Therefore, with the findings from this evaluation works contribute to the establishment of constructive database and systematic data collection system, particularly for residential college building in the tropics. It is inevitable that by providing opportunities for the improvement of building performance and the relationships of users' behaviour, able to provide a significant role in Malaysia's construction industry (Khalil et al., 2012).

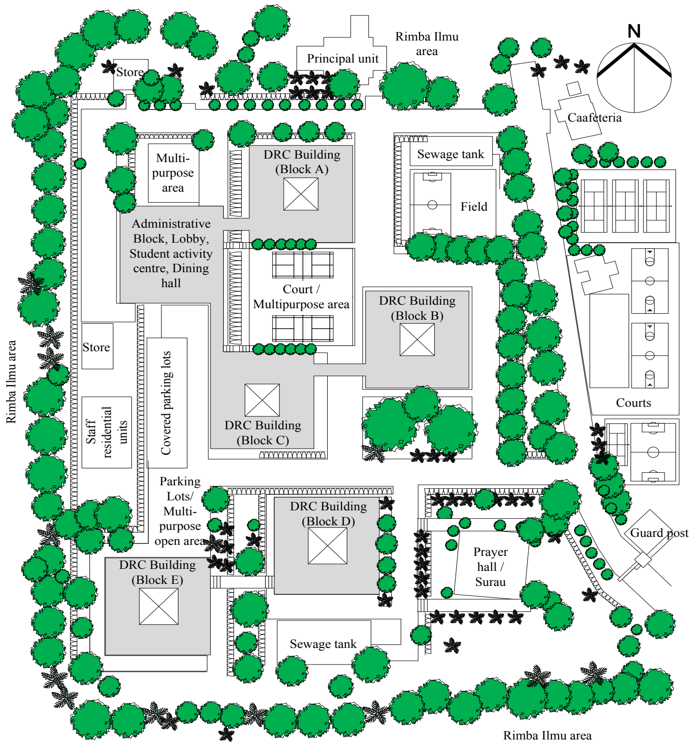
3. Methodology

3.1. Building description

DRC is a low rise multi-residential building in UM campus, equipped with leisure areas, lounges, meeting rooms and laundry facilities, which can accommodate up to 847 residents at one time. This naturally ventilated building was built in 1966 with 18,212.51m^2 of total floor area and 16.35m^2 of a typical room's floor area (Fig. 1a). As the residential college was established more than five decades ago, most of the trees are matured with the huge canopies that are capable of covering large grounds and provide shading effects to the building (Fig. 1b). The figure ground study obtained the 61:39 ratio of soft and hard landscape area with 0.607 of Biotope Area Factor. The building's north-south orientation and surrounded by a square internal courtyard reduces glare and thermal gain while providing natural daylight and ventilation at the corridor and staircase areas (Fig. 2a). This encourages air circulation and daylight distribution inside the rooms through the fixed transom on top of the entrance door and the internal walls facing the courtyard (Fig. 2b). Only service areas, such as toilets, bathrooms, stores, staircases and balconies are located at the west-east orientation. There are two types of windows: centre pivot and awning window, with standard float and tinted glasses were installed in each room that able to channel outside wind inside (Fig. 2c). Correspondingly play a role as adjustable low inlets and high exhaust opening. The combination of windows and fixed transom encourages cross ventilation while the presence of wall opening in the room theoretically helps create wind pressure inside the room (Fig. 2d). In order to defuse the undesirable amount of solar radiation, there are large horizontal overhangs along the windows in each room, which projects significant shadow effects to the external walls (Fig. 2e). These design strategies, however, are not implemented at rooms on the ground floor.



(a)



(b)

Fig. 1. (a) Typical floor plan of DRC building; (b) Site plan of DRC building

Fig.. 2. (a) Square internal courtyard; (b) Fixed transom on top of the entrance door and internal walls; (c) Types of windows – centre pivot and awning; (d) Wall opening in the room; (e) Large horizontal overhangs along the windows

3.2. Perception and satisfaction survey

Questionnaire used in this study was adapted from Khalil and Husin (2009) work on POE of the indoor environment improvement in Malaysia. Five performance criteria (architectural element, visual comfort, acoustic comfort, landscape elements and combination of thermal comfort and indoor air quality) with thirteen questions were enquired. In order to acquire for the residents' perception, the questionnaire was constructed on a five-point Likert scale, where each number responds to a specific scale:

- -2: very poor/very uncomfortable/much decreased/very hot/still air/too dark/very dissatisfied/very noisy
- -1: poor/uncomfortable/decreased/hot/inconspicuous still air/dark/dissatisfied/noisy
- 0: fair/neither/neutral/no changes,
- +1: good/comfortable/increased/cool/breezy/bright/satisfied/quiet
- +2: very good/very comfortable/much increased/very cool/very breezy/too bright/very satisfied/very quiet

The questionnaires were distributed to all occupants with the minimum number of feedbacks relying on 95% confidence level and ±5% margin of error from the overall population. All the collected questionnaires were analysed by using a statistical software package to find out the frequency of responses and the inter-correlation between each performance criteria. There is only one research limitation regarding on the landscape setting in the internal courtyard. Each block has a different landscape setting, which mostly dominated by shrubs and small plants. Thus, feedbacks by the respondents with regards to the landscape setting in the internal courtyard were in the general manner, not indicated to specific landscape setting and block of buildings.

4. Findings

A total of 266 out of 847 questionnaires were retrieved fully filled by the respondents. Findings of perception and satisfaction survey at multi-residential building with the best practice of bioclimatic design strategies are presented in Table 1.

Table 1. Findings of perception and satisfaction survey at DRC building

Performance criteria	Likert scale / *Residents' perceptions (%)*				
	-2	-1	0	+1	+2
Architectural elements					
1. Residential building layout (internal courtyard with open corridor)	*0.4*	*8.7*	*28.7*	Good *50.2*	*12.1*
2. Overall quality of the residential building	*1.1*	*6.0*	*28.7*	Good *52.1*	*12.1*
3. Overall comfort level of the room	*0.8*	*4.5*	*29.1*	Comfortable *53.6*	*12.1*
4. Influence of room conditions on the degree of work productivity	*0.8*	*4.5*	*26.8*	Increased *49.4*	*18.5*
Thermal comfort and indoor air quality					
5. Thermal comfort/indoor air temperature in the room	*3.4*	*11.7*	*29.7*	Cool *43.6*	*11.7*
6. Ventilation and air quality of the room	*1.9*	*13.4*	*29.8*	Good *46.2*	*8.8*
7. Air movement in the room (without the aid of mechanical fan)	*13.7*	*22.1*	*26.7*	Breezy *30.9*	*6.5*

<u>Visual comfort</u>					
8. Adequacy of natural daylight in the room	*4.2*	*12.0*	*34.4*	Bright *40.9*	*8.5*
9. Adequacy of artificial light in the room	*1.1*	*8.8*	*35.1*	Bright *46.2*	*8.8*
10. Quality of the lights in the room	*1.5*	*7.7*	*28.8*	Satisfied *48.5*	*13.5*
<u>Acoustic comfort</u>					
11. Noise/vibration level in the room	*2.7*	*15.6*	Neither *41.6*	*33.6*	*6.5*
<u>Landscape elements</u>					
12. Landscape quality at the surrounding residential building	*1.5*	*8.0*	*33.7*	Good *48.7*	*8.0*
13. Landscape setting quality in the internal courtyard	*1.5*	*6.1*	*35.9*	Good *48.9*	*7.6*

Majority of the residents is in comfort level in all aspects, where more than 40% of them are 'satisfied' with the condition of the room and building. About 50.2% and 52.1% of the residents claimed that the residential building layout which is the internal courtyard, and overall quality of the residential building is 'good', respectively. 53.6% of the residents were 'comfortable' with the condition of the room while 49.4% claimed that the degree of work productivity has 'increased' considerably. In terms of thermal comfort and indoor air quality, 43.6% of the residents felt 'cool' with indoor air temperature. About 46.2% claimed that the ventilation and air quality of the room are 'good' and 30.9% of them felt 'breezy' air movement in the room though without the aid of mechanical fan. In terms of the visual comfort, majority of the residents (48.5%) are 'satisfied' with the quality of light in the room. They claimed that the adequacy of both natural daylight (40.9%) and artificial light (46.2%) in the room are 'bright'. The acoustic comfort was the only performance criteria where majority of the residents felt no difference. About 41.6% voted for 'neither' on the noise/vibration level in the room. Finally, majority of the residents claimed that the landscape quality in both surrounding residential building (48.7%) and in the internal courtyard (48.9%) is 'good'.

Further statistical analysis to correlate each performance criteria with the overall comfort and the degree of work productivity with regard to the residents' perception and satisfaction by using Pearson correlation is presented in Table 2.

Table 2. Correlation between the performance criteria with the overall comfort and work productivity at DRC building

		Building layout	Overall quality of building	Thermal comfort	Ventilation & air quality	Air movement	Natural daylight	Artificial light	Light quality	Noise/ vibration level	Landscape quality	Internal courtyard quality
Overall comfort	Pearson correlation	.284**	.354**	.409**	.432**	.250**	.328**	.242**	.308**	.276**	.337**	.288**
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
Work productivity	Pearson correlation	.192**	.246**	.336**	311**	.239**	.135*	.268**	.268**	.230**	.236**	.125
	Sig. (2-tailed)	.003	.000	.003	.000	.000	.039	.000	.000	.003	.000	.052

**. Correlation is significant at the 0.01 level (2-tailed), *. Correlation is significant at the 0.05 level (2-tailed).

Relevant finding highlighted significant positive relationship of perception and satisfaction levels with the overall comfort and degree of work productivity in relation to the performance criteria. There is ‘moderate’ or ‘weak/fair’ relationship showed by all performance criteria in both relationships; overall comfort level and degree of work productivity, when the r values were in the range of 0.5 to 0.3 (moderate) and 0.3 to 0.1 (weak/fair).

5. Analysis and discussion

Majority of the residents at DRC is ‘satisfied’ and feel comfortable with the room and building condition. This is due to the building’s orientation with a square internal courtyard offer a substantial potential for indoor thermal comfort as the ability of a courtyard to cool the surrounding built spaces by creating different pressure fields along the wind-flow axis (Rajapaksha et al., 2003). In addition, the combination of two types of windows and fixed transom on top of the entrance door promotes cross ventilation. According to Haase and Amato (2006), the installation of a wall-mounted centre-pivoting window in a bedroom significantly improves the indoor air quality by increasing the efficiency of natural ventilation. Moreover, a shallow building with optimal orientation and a maximum of five floors is more applicable for exploiting wind for natural ventilation, which well demonstrated in the studied building. Majority of the residents is ‘satisfied’ with the quality of light in the room. The application of daylighting in buildings improving human performance and well-being through daylights impact on aesthetics and vision (Leslie, 2003) while gives a significant saving on energy (Jamaludin et al., 2013). Lechner (2009) pointed out that large window area than walls, high ceilings with high windows, and O-shaped floor plans (fully enclosed) are the basic design in providing daylighting in the building (Almhafdy et al., 2013). Additionally, the type of glazing and window gives major significance on the performance of natural light and thermal performance of adjacent space (Husin and Harith, 2012). The acoustic comfort was the only performance criteria where majority of the residents felt no difference. This finding concurred with a study conducted by Lee (2010) where the respondents of LEED-certified buildings showed significantly lower satisfaction with noise level.

The presents of ‘good’ landscape quality in both surrounding residential building and internal courtyard influence the microclimate atmosphere and improve thermal comfort especially in a warm and humid climate (Thani et al., 2012; 2013). Tree canopies reducing air temperature by evapotranspiration while provide insulation effects to reduce the conductive heat gains and preventing unpleasant solar to access into the building especially during the mid-afternoon (Yeang, 2008; Misni, 2013). Additionally, the green infrastructure is a crucial part of the urban fabric that is highly perceived by residents contributing to their physical, cognitive and social well-being (Mansor et al., 2010). Majority of the residents claimed that the degree of work productivity has ‘increased’ considerably and it indicates acceptance of occupants towards existing implementation of bioclimatic design strategies, as the building performance highly correlated with the occupant’s satisfaction (Hashim et al., 2012). The occupants expectations and needs in existing buildings is needed to achieve sustainability objectives in buildings (Shika et al., 2012). However, further improvements need to be done in all criteria due to the ‘moderate’ or ‘weak/fair’ relationship by all performance criteria in both relationships; overall comfort level and degree of work productivity as a result of statistical analysis by using Pearson correlation.

6. Conclusions and recommendations

The practice of bioclimatic design strategies particularly, daylighting and natural ventilation approaches at a residential college building has a significant impact on the perception and satisfaction level of the residents in a positive manner. Majority of the residents perceived that comfortable levels were achieved according to the performance criteria: architectural elements, thermal comfort and indoor air quality, visual comfort, acoustic comfort and landscape elements. Therefore, the north-south building orientation and internal courtyard, the fixed transom on top of the entrance door and internal walls, centre pivot and awning windows, the wall opening in the room, large horizontal overhangs along the windows and good landscape setting should be highly considered in building design especially for residential college building towards promoting sustainable living. As recommendations, POE should integrate, firstly, more than one of the data collection methods. The combination of several methods (questionnaire survey, focus group, documentary analysis and monitored data), which form a methodological triangulation, will be able to enhance the credibility and persuasiveness of a study. This is by giving a more detailed picture of the situation that facilitates the validation of data through cross verification from more than two sources in the study. Secondly, POE should integrate the number of respondents that must exceed the minimum number of feedbacks which relying on 95% of confident level and ±5% margin of error from the overall population. Therefore, the number and scope of questions must be properly designed with regards to the research objectives. Thirdly, POE should use language and phrases that are easily to be understood in getting a positive number of feedbacks. For comparison, other residential colleges should be included especially with the different application of bioclimatic design strategies.

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