



# POE: Bioclimatic design for sustainability

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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. The survey was based on a five-point Likert scale, covering various performance criteria of the building (architectural elements, thermal comfort, indoor air quality, visual comfort, acoustic comfort and landscape features). The positions of the rooms should be highly considered in implementing the improvement measures for increasing the comfort level of the room when this aspect considerably influences the satisfaction and perception levels of respondents.

Keywords: bioclimatic design, Likert scale, post- occupancy evaluation (POE), residential college building.

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DOI: <http://dx.doi.org/10.21834/ajbes.v3i10.85>

## 1.0 Introduction

Dayasari Residential College (DRC), located at the University of Malaya (UM) in Kuala Lumpur, is acknowledged as a naturally ventilated building with the most considerate implementation of bioclimatic design strategies that minimise the electricity consumption for lighting and cooling (Jamaludin et al., 2014). It showed amongst the lowest Energy Efficiency Index (34.52 kWh/m<sup>2</sup>/year) compared to other residential colleges in UM; which are in the range of 40 to 125 kWh/m<sup>2</sup>/year (Jamaludin et al., 2013). Unfortunately, the lowest consumption of electricity is not the ultimate criteria for a successful implementation of bioclimatic design, 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 a 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.

## 2.0 Literature Review

Bioclimatic concept and design strategies in buildings involve many disciplines, including human physiology, climatology and building physics (Olgay, 1963). The principle behind the bioclimatic design is the understanding of the climatic factors of a site by analysing the influence of microclimate (solar radiation, sunshine, temperature, humidity, rainfall, wind velocity and direction) (Hyde, 2000). It is followed by a comparative analysis in assessing the climate data concerning 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., 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 & 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 & Gann, 2001). POE begins with planning, conducting and applying phase, can be done on three levels: indicative, investigative and diagnostic levels (Preiser, 1995). Each level has different techniques that can be assessed and utilized to the time frame, budget, manpower, aim and objectives that are to be achieved (Bordass & Leaman, 2005). There is audit (using quantitative technical assessments), discussions (use discursive techniques such as workshops and interviews), questionnaires (methods 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 significant barriers to POE implementation: ownership, liability, lack of knowledge and progress (Hadjri & Crozier, 2009). 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, the findings contribute to the establishment of a valuable 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).

### **3.0 Methodology**

#### **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. This naturally ventilated building was built in 1966 with 18,212.51m<sup>2</sup> of total floor area and 16.35m<sup>2</sup> of a typical room's floor area (Figure 1). 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. 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. Only service areas (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. Correspondingly play a role as adjustable low inlets and high exhaust opening. The combination of windows and fixed transom encourages cross ventilation. 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. These design strategies, however, are not implemented at rooms on the ground floor. 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 (Figure 2). The figure ground study obtained the 61:39 ratio of soft and hard landscape area with 0.607 of Biotope Area Factor.

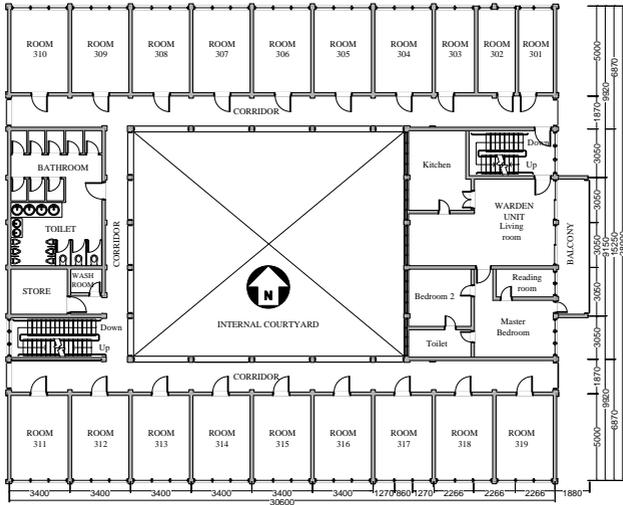


Figure 1: Typical floor plan of DRC building  
(Source: Author)

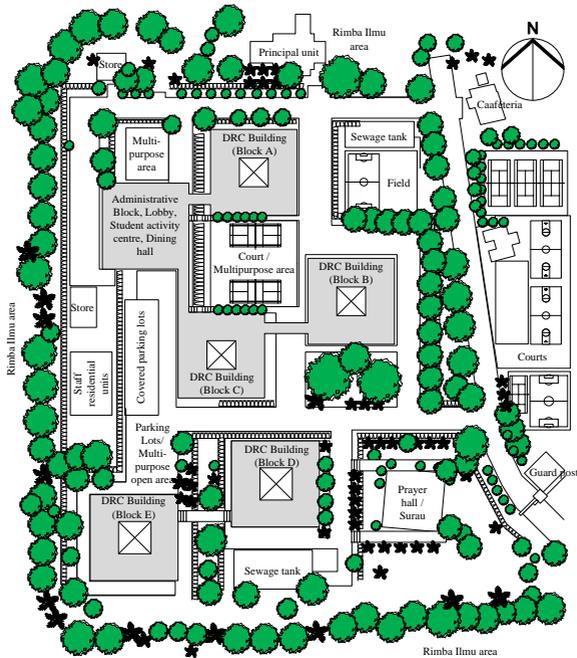


Figure 2: Site plan of DRC building  
(Source: Author)

### **Perception and satisfaction survey**

The 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 a combination of thermal comfort and indoor air quality) with thirteen questions were enquired. 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  $\pm 5\%$  margin of error from the overall population. All the collected questionnaires were analysed by using a statistical software package, and the analysis was extended by way of comparing the percentage of respondents concerning the location of the room according to the floor levels.

## **4.0 Results and Discussions**

A total of 266 out of 847 questionnaires were retrieved entirely filled by the respondents. Findings of perception and satisfaction survey are presented in Table 1.

The 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. About 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.

Regarding 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 a mechanical fan. The building's orientation with a square internal courtyard offers 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). Also, 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 the wind for natural ventilation, which well demonstrated in the studied building.

On 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 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 core 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 & Harith, 2012).

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Table 1: Findings of perception and satisfaction survey at DRC

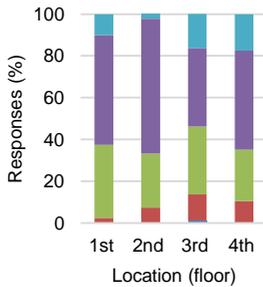
Performance criteria	Likert scale / Residents' perceptions (%)				
	-2	-1	0	+1	+2
<u>Architectural elements</u>					
1. Building layout (internal courtyard with open corridor)	0.4	8.7	28.7	Good 50.2	12.1
2. Overall quality of the residential building	1.1	6.0	28.7	Good 52.1	12.1
3. Overall comfort level 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
<u>Thermal comfort and indoor air quality</u>					
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 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>Landscape elements</u>					
11. Landscape quality at residential building	1.5	8.0	33.7	Good 48.7	8.0
12. Landscape setting quality in the internal courtyard	1.5	6.1	35.9	Good 48.9	7.6

Finally, majority of the residents claimed that the landscape quality in both surrounding residential building (48.7%) and the internal courtyard (48.9%) are 'good'. The presence of 'good' landscape quality influence the microclimate atmosphere and improve thermal comfort especially in a warm and humid climate (Thani et al., 2012; 2013). Tree canopies reduce air temperature while providing insulation effects for reducing 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., 2012).

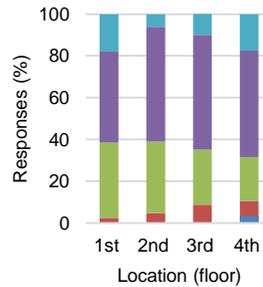
Numerous different responses were discovered by comparing the results according to the positioning of the rooms (Figure 3). Dissatisfactions were mainly expressed by those who live on the ground floors, especially regarding their visual comfort, thermal comfort and indoor air quality elements. They rated one rate lower than the overall rate, as compared to those who live on the other floors. These could be due to various barriers either natural or man-made structures including the covered parking areas for motorcycle and trees with big crowns

that prevent them from getting exposure to good daylighting and also from obtaining natural ventilation. Most of the respondents who live on the ground floor rated 'fair' for the ventilation and indoor air quality and all performance indicators of visual comfort. This differs from those who live at higher levels when the majority of them rated 'good' for all performance indicators of both visual comfort elements and thermal comfort and indoor air quality. Perhaps this is why higher-level rooms' occupants were reported to have their degree of work productivity 'increased' in comparison with 'no changes' noted for those occupying the ground floor.

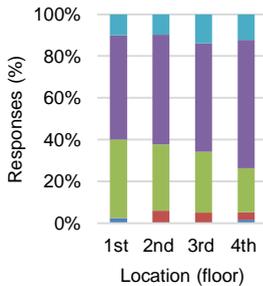
1. Residential building layout



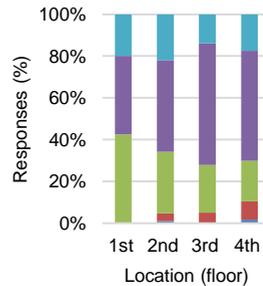
2. Overall quality of the residential building



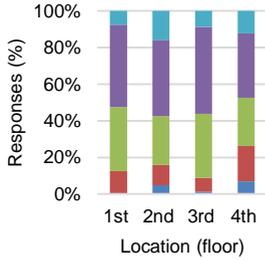
3. Overall comfort level of the room



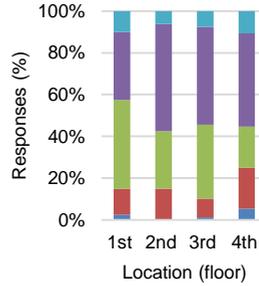
4. Influence on work productivity



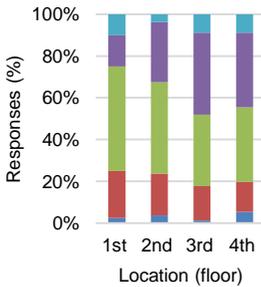
5. Thermal comfort/  
indoor air temperature in  
the room



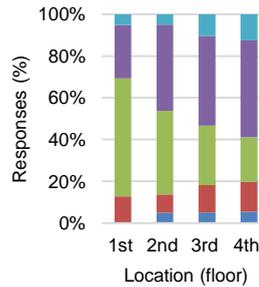
6. Ventilation and air  
quality of the room



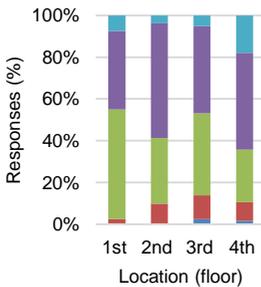
7. Air movement in the  
room



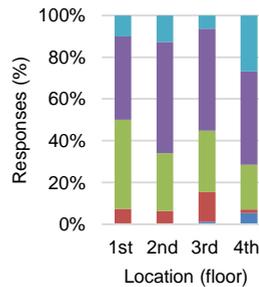
8. Adequacy of natural  
daylight in the room



9. Adequacy of artificial  
light in the room



10. Quality of the lights  
in the room



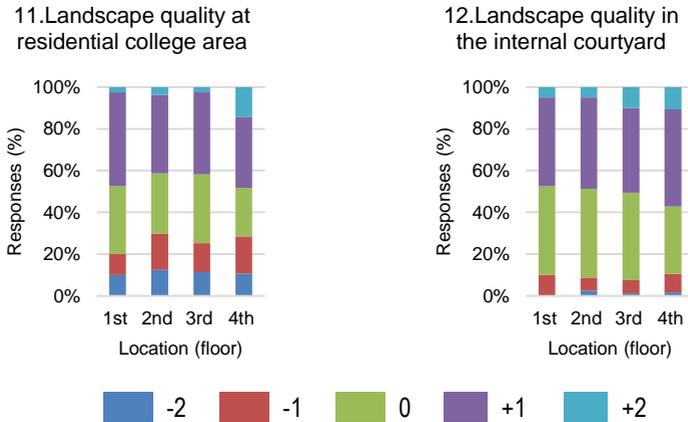


Figure 3: The result of satisfaction and perception survey according to the location of the rooms

Thus, it is necessary to determine the relationships between trees and buildings to optimise tree designs to gain access to good daylight and ventilation requirements (Hong et al., 2011). With regards to landscape, the majority of respondents on the second floor claimed that the landscape quality at both residential college areas and internal courtyards were 'good'.

## 5.0 Conclusion

The practice of bioclimatic design strategies at a residential college building has a positive impact on the perception and satisfaction level of the residents. Majority of the residents perceived that comfortable levels were achieved according to the architectural elements, thermal comfort and indoor air quality, visual comfort, acoustic comfort and landscape features. 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.

The location of the room, rather than the gender aspect considerably influences the satisfaction and the perception level of respondents. Different responses gave by the residents according to the floor levels. These aspects should be highly considered in implementing the improvement measures to ensure the comfort standards of the room towards sustainable transformation, especially in urban area. The internal courtyard should be fully optimised while trees in the landscape; either in the internal courtyard or surrounding residential buildings, must appropriately be designed to meet sufficient daylight and

ventilation requirements.

As recommendations, POE should integrate, firstly, more than one of the data collection methods. The combination of 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 the confident level and  $\pm 5\%$  margin of error from the overall population. Therefore, the number and scope of questions must be adequately designed with regards to the research objectives. Thirdly, POE should use language and phrases that are easy 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.

## Acknowledgement

Thank you to Dayasari RC for their permission to carry out POE. This analysis was financially supported by the Institut Pengurusan dan Pemantauan Penyelidikan, under BKP Grant (BK010-2015).

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