POST OCCUPANCY EVALUATION (POE) AND INDOOR ENVIRONMENTAL QUALITY (IEQ) ASSESSMENT: A CASE STUDY OF UNIVERSITI TEKNOLOGI PETRONAS NEW ACADEMIC COMPLEX

Mohd Faris Khamidi, Suriani Ngah Abdul Wahab Mohd Rodzi Ismail, Norhidayah Mohd Zahari
Civil Engineering Department,
Universiti Teknologi PETRONAS,

ABSTRAK

Post Occupancy Evaluation (POE) and Indoor Environmental Quality Assessment (IEQ): a Case Study of Universiti Teknologi PETRONAS New Academic Complex is an initiative taken for development of UTP. Universiti Teknologi Petronas are currently looking forward to be certified as green building university. Thus to achieved the mission of the university to meet the benchmarks of GBI standard, this study investigates and determine the level of building performance based on occupants' satisfaction and indoor environmental quality analysis according to Green Building Index (GBI) and Malaysian Standard MS1525. This project also provides recommendation for corrective plan and way forward should be taken to improve the elements that have not compliance to the standard. The sampling taken from the populations of UTP which are include lecturer, staff and students. Due to the restricted availability of the data; three buildings which is Block 13, 14 and Pocket C were chosen to represent the whole UTP new academic complex. The two methods involved covers qualitative and quantitative aspects which are Post Occupancy Evaluation (POE) and analysis field measurement of Indoor Environment Quality (IEQ). POE indicates the satisfaction level of occupants where the parameters need to pass the severity index boundary. IEQ verified the result of POE where six parameters; temperature, relative air humidity, noise level, illumination level, CO2 level and air velocity are measured. At the end of this project, correlation of POE and IEQ reports that noise and illumination level are not meet the standard. Recommendations are provided as corrective plan and way forward to be certified as green building according to GBI rating system.

Keywords: *Building Energy Index, Post occupancy evaluation, indoor environmental quality assessment*

INTRODUCTION

Background

Realizing the global issues regarding the climate change and global warming happen nowadays, most of the development of the building currently moves towards the sustainability development and green design in order to achieve significant reductions in climate change emissions. Effort to enhance the natural environment, promoting green design, construction, reconstruction and operation of buildings has never been more critical than now as the increasing of greenhouse gas emissions that are fuelling climate change more quickly.

A growing public concern over the harmful consequences of our industrialized societies on our planet and its natural resources is urging communities to reexamine their building practices. Same goes to the management of Universiti Teknologi PETRONAS. Due to the awareness to move forward to be certified as green building university, this project carry out the study to covers both qualitative and quantitative aspects. Post Occupancy Evaluation (POE) and Indoor Environment Quality Assessment (IEQ) will be the main keyword and

method used for this study in determining the level of building satisfaction according to MS1525 and GBI standard.

Literature Review

In developed country such as EU and USA buildings the total of energy used up to 20-40% more than industry and transport.Perez-Lombard et. Al (2008). Existing studies of occupant satisfaction and comfort in LEED buildings by the Center for the Built Environment at the University of California, Berkeley, shows high variability, with some buildings rated very positively and others having modest comfort and satisfaction levels. Fowler, K. & Rauch, E. (2008), Heerwagen, J. & Zagreus, L. (2005) Self ratings of performance showed that more than 60% of the occupants believed that lighting conditions (including daylight) and air quality had a positive impact on their ability to get their work done. In contrast, less than 40% said thermal and acoustical conditions were conducive to their work effectiveness. These findings suggest that the impact of interior environmental quality on work performance may depend on the particular interior conditions Rebecca R. et. al (2009)

Study conducted by Watson (2003) indicates that, Post Occupancy Evaluation (POE) is a systematic evaluation of opinion about buildings in use, from the perspective of the people who use them. POE are generally aimed at conveying the parameters of buildings that work well and also at focusing on the ones that should not be repeated in future building designs. Studies on indoor environment quality have mainly focused on and examined composition factors of ambient environment. Hikmat H. Ali et al.(2009) carried out technical evaluation on thermal and ventilation conditions PAM (2009), Yoo Bok-heui et al.(2010) analyzed residents perception on indoor air quality Hikmat H. Ali et.al (2009), Kim Young-kyung et al.(1996) carried out technical evaluation on facility noise conditions in apartments Kim, Yong-Kyoung et. at (2010) , and Jang Hana et al.(2007) examined residents' subjective evaluation on indoor air conditions of Officetels. Some researchers have combined several factors to conduct assessments Jang et.al (2007). Niklas Fransson et al.(2007) assessed perceived comfort of temperature, relative humidity, and noise level. Niklas Fransson et.al (2007), L.T.Wong(2008) examined the office's indoor environmental quality in four aspects which are thermal comfort, indoor air quality, noise level and illumination level L.T.Wong et.al (2008)

Driven by environmental needs and due to some modification, Green Building Index (GBI) was founded to drive initiative to lead the property industry towards becoming more environment-friendly. The Green Building Index is an environmental rating system for buildings developed in 2009 by Pertubuhan Arkitek Malaysia / Malaysian Institute of Architects (PAM) and the Association of Consulting Engineers Malaysia (ACEM) PAM (2009). For indoor environmental quality item, there are 16 area of assessment that each of the area contributes the points for total score for whole item. Carbon dioxide monitoring, thermal comfort controllability system, air change effectiveness, daylight glare control, internal noise level, and post occupancy comfort survey will carry 1 point. According to GBI, EQ16 outlines the requirement that need to be achieved for POE. Occupants‟ satisfaction must meet at least 80% and if the level of satisfaction does not meet the requirement, corrective action plan need to be developed. In correlation to verified the results of POE, IEQ also be assessed according to MS 1525. It is Malaysian Standard was developed by the Technical Committee on Energy Efficiency in Buildings under the authority of the Building and Civil Engineering Industry Standards Committee. This Malaysian Standard is the first revision of MS 1525:2001, *Code of Practice on Energy Efficiency and use of Renewable Energy for Non-residential Buildings, Malaysia, D.O.S MALAYSIAN STANDARD (2007)*

Problem Statement

Increasing of global concern towards preservation of environment caused an urge towards energy conservation end efficiency. Thus, Universiti Teknologi PETRONAS make initiative to move forward in order to improve the quality of the building and aiming to be GBI certified building.

Objectives

The main objectives of this project are:

- To study the level of occupants‟ satisfaction on UTP building.
- To identify building‟s performance according to GBI and MS1525 parameters.
- Proposed the way forward to UTP management in order to meet the benchmarks of GBI rating classification.

RESEARCH METHODOLOGHY

Questionnaire Survey : Post Occupancy Evaluation

The frame work is illustrated in Figure 1. It is consists of a systematic sequence of six steps: identify information of building parameters, evaluation of objectives, selection of planning approach, conduction of POE inspection, application of findings and actions in response to feedback. The steps fall within three phases, namely the initial phase, the process phase and the recommendation phase.

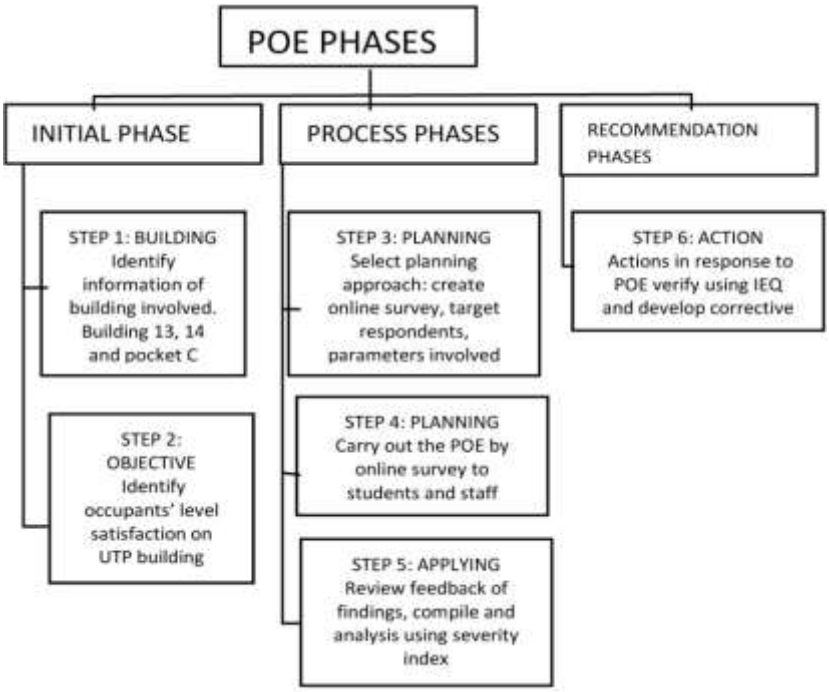

Figure 1 Modified Framework of POE from AUDE [13]

The building‟s impact on occupant satisfaction obtained through an occupant survey (POE). The occupant survey was addressed indoor environmental quality aspects and administered to the students and staff of Universiti Teknologi PETRONAS. The survey

covers three sections of questions which are on demographics, assessment on indoor environment quality and rating and recommendations. The occupant survey investigates the significance of building satisfaction to meet the standard Green Building Index (GBI) requirement. In order to assess the Universiti Teknologi PETRONAS building‟s functional comfort and occupant satisfaction; an online survey was carried out on 8th August 2011 for students and 18th December 2011 for staff. The surveys open for one week for responses. Below is the links for online survey:

Students:
https://spreadsheets1.google.com/spreadsheet/viewform?formkey=dHg5REtuSUFPd0YweHdJaDgwZUNUZWc6MQ
Staff:
https://spreadsheets.google.com/spreadsheet/viewform?formkey=dHluR2JzQjc0Q2kwdEkxTXkxYy0tWHc6MQ

Field measurement: IEQ

The measurements conducted within 10.30a.m to 3.30pm, and readings taken every 30 minutes interval. Readings obtained were compared to GBI Assessment Criteria and MS 1525:2007 to check on the compliance of UTP system to the standard. Below are the few locations involved in assessment.

Figure 2 Location of assessment

Parameter involved in this project:

Table 1 Standard Parameter Values [10.11]

No.	Area of Assessment	GBI standards	MS1525
1.	Indoor air temperature,		23 °C -26 °C
2.	Relative air humidity,		≤ 70% (55%-70%)
3.	Internal noise level	40dBAeq	
4.	Lighting (for working interiors)		300-500 Lux
5.	CO_2 level	≤ 1000ppm	
6.	Air movement		≤ 0.7 m/s (0.15m/s - 0.5m/s)

Tools/ Equipments

In this study, the equipment for the field measurement is AMI 300 Multifunction, Hygro-thermometer, sound level meter and solarimeter. AMI 300 Multifunction is used with the specific probes such as air quality probes for measuring CO2 level, temperature and hygrometry. Vane probes measure air velocity and has an accuracy of ± 0.5ºC and ± 0.6% for temperature and relative humidity readings, respectively. The Hygro- thermometer is also used for measuring the relative humidity and temperature. Noise level meter is to measure internal noise level while solarimeter to determine illumination intensity for lighting. All these equipments are calibrated before used to ensure reliability and accuracy in the readings taken during the field studies. The environmental parameter data are collected at the measuring points specified at each location. The measuring instruments are read at about 1 meter above the floor level.

RESULT AND DISCUSSIONS

Post Occupancy Evaluation- Online Survey (Student)

Post Occupancy Evaluation carried out to students and staff. A total of 80 respondents completed the online survey which is 63 respondents are students and 17 are UTP staff. The data for each questionnaires are automatically collected and been analyzed by using online Google document. There are three part included in the questionnaire which are Section A, B and C. The results of the analysis are tabulated in this section.

Section A: Demographics (Question 1-4)

Question 1: Gender

Table 2 Tabulation of Respondents

Respondent	Staff	Students	Total	Percentage (%)
Male	10	25	35	43.75
Female	7	38	45	56.25

Section A discussed on demographics items which are gender, occupations, age and time spent in building. Out of 80 respondents, 56.25% of the respondents are female and 43.75%

are male. If referring only for students out of 63 of students who are response, 60% of the students are female. This is indicates that female students are more concern in answering the survey form compare to male because reality in UTP, ratio between male and female students is 3:1. All of the respondents from students are in range 18-24 years old. For staff, the age is diverging into several stages and most of the staff that is responses is between 25-40 years old which contribute 47%. 59% of staff respondent are PhD holder.

Question 4: Time spend in building

Table 3 Allocation of time spend in academic building

Respondent	Staff	Students	Total	Percentage (%)
less than 1 hour	0	1	1	1.25
1-2 hours	0	8	8	10
3-4 hours	0	34	34	42.5
5-6 hour	0	12	12	15
7-8 hour	6	3	9	11.25
more than 8 hours	11	5	16	20

From the combination analysis, 42.5% of respondent spent 3-4hours in building. For students most students spend time in building between 3-4 hours a day which contribute to 54%, followed by 19% for 5- 6 hours, 13% for 1-2hours, more than 8hours is 8%, 5% for 7-8 hours and less than 1hour is only 2%. However, if focusing only for staff respondent, highest percentage which is 65% shows the staff spent more than 8 hours in building. It can be conclude that most of students not spending much time in academic building. Thus, the performance of the building might not give big impact to student but big matters for staff. Hence the contribution of staff survey is more important and relevant as based line for field measurement later.

Section B: Indoor Environmental Quality Assessment

Comfort and Satisfaction

Questions on interior environmental quality used a 7-point scale with variable end anchors. In the discussion of survey results below, the end anchors indicating problems or discomforts are termed “negative feedback” and the responses toward the positive end are termed “positive feedback". For example, in the temperature question regarding controllability over cooling, “no control” is classified as “negative feedback” and “full control” is classified as “positive feedback". For air quality questions, the air quality give negative

effects on work performance, “not significant” is classified as “positive feedback” and “very significant” is classified as “negative feedback”. A copy of the survey appears in the Appendix.

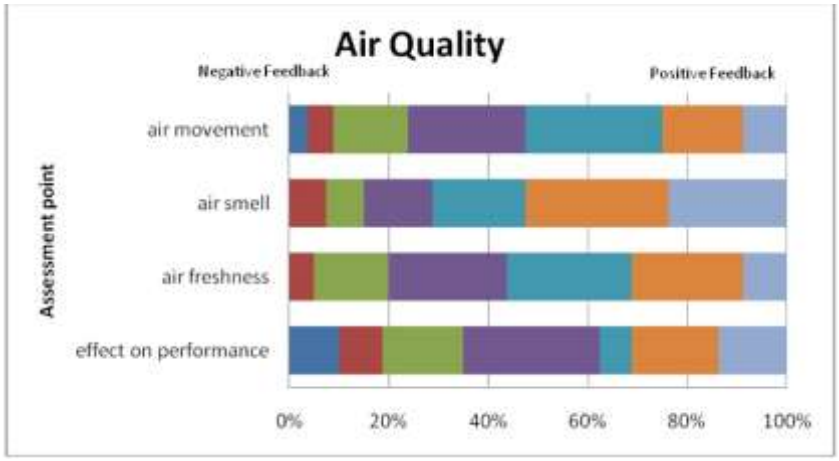

Figure 2 Summary of Air Quality Performance

The responses regarding air quality were largely positive, with the close of 65% responding positively regarding the effect of air quality to the work performance and overall items in air quality. Less than 35% reporting negative feedback.

Temperature

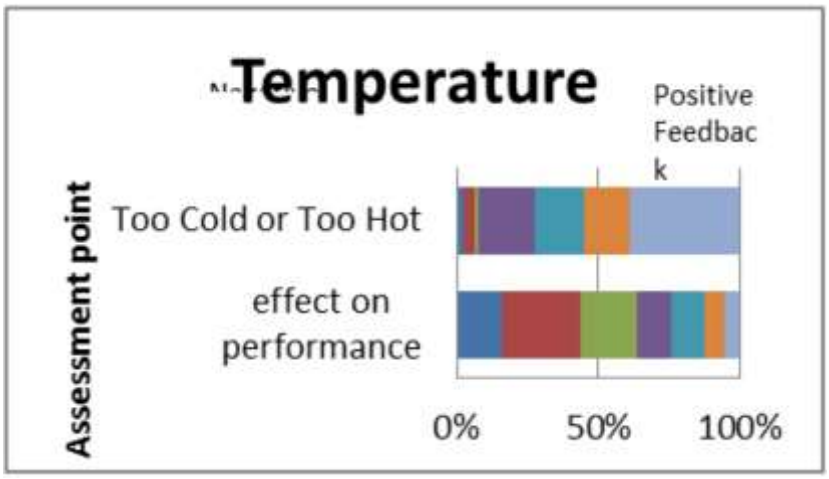

Figure 3 Summary of Themal Comfort

Overall regarding temperature, 38 % of the respondents gave positive feedback, on the questions on effect of temperature to work performance and another 23% reported indifference. Based on the chart, approximately 40% respondent are fully satisfied with the temperature level. Less than 10% reported of negative on thermal comfort.

Noise

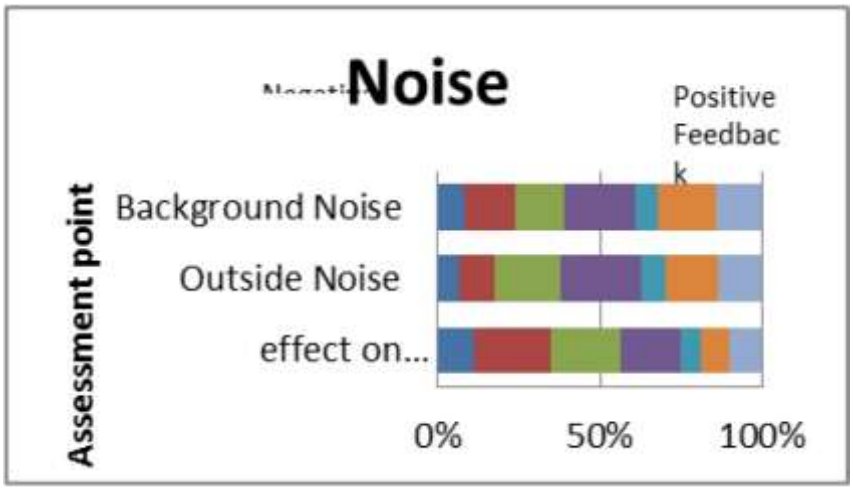

Figure 4 Summary of Noise Level

In contrast, approximately 55 – 60% of respondents gave positive feedback when rating the distraction noise from outside the building and background noise, except for effect of noise in work performance, in which case close to 60% of the feedback was mainly negative, respectively.

Lighting

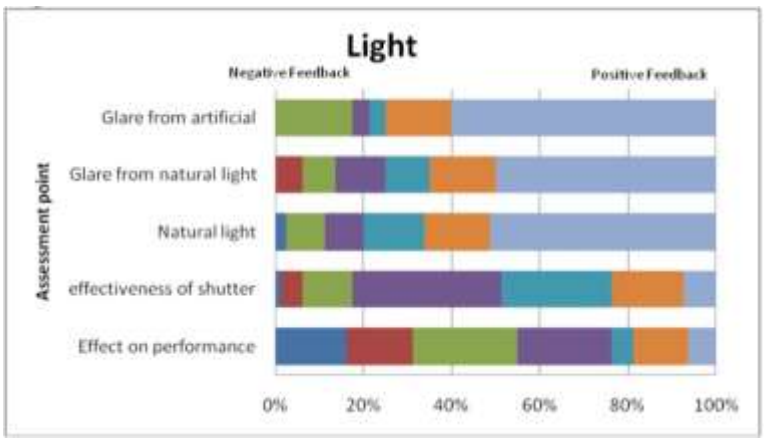

Figure 5 Summary of Light Performance

For the items in lighting, the chart shows almost 80%- 90% of respondent gave positive feedback. Most of the respondents satisfied with the light conditions. However, only 40% agree that quality of light have big impact on the work performance.

Personal Control

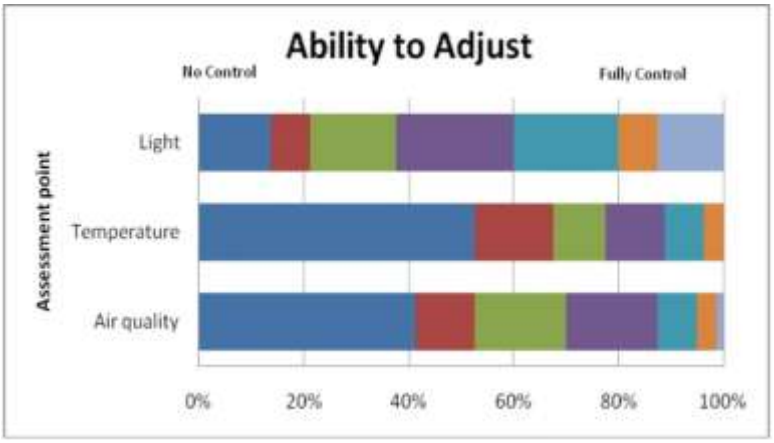

Figure 6 Summary of Light Performance

The ability to adjust electric light level, room temperature, and room ventilation were also assessed. Over half the respondents, 50% - 71%, reported “Poor or no control” regarding the ability to adjust lighting, temperature, and ventilation (see Figure 5). Personal control over the electric devises is important in order to meet the occupants‟ comfort.

Analysis Using Severity Index for Question 5-8 (Parameter Assessment)

Relative index ranking technique is a non-parametric technique widely used by construction management researchers for analyzing structured questionnaire response data involving ordinal measurement of attitudes AUDE (2006), Olomolaiye, P.O. et.al (1987), Holt, G.D (1997), Idrus, A. & M.Sodangi (2010). One form of this technique is the severity index analysis which uses weighted percentage scores to compare the relative importance of the criteria under study. The frequency analysis was first carried out to determine the frequency of responses which were then used to calculate severity indices by means of the formula below. In this study, the seven scale rating is used. Egamenn, M. & A.N. Mohamed (2006), Elhag,T.M.S & A.H. Boussabaine (1999), Ballal, T.M. (2000)

Severity Index (I) = [Σ a*i* . x*i*] / [7 Σ x*i*] × 100%

xi = variable expressing the frequency of the *i*
ai= constant expressing weight given to *i*
i = 1, 2, 3, 4, 5, 6, 7 as illustrated below
x7 = frequency of the „very high extend‟ response, corresponding to a7 = 7
x6 = frequency of the „high extend‟ response, corresponding to a6 = 6
x5 = frequency of the „moderate high extend‟ response, corresponding to a5 = 5
x4 = frequency of the „neutral‟ response and corresponding to a4 = 4
x3 = frequency of the „moderate low‟ response and corresponding to a3 = 3
x2 = frequency of the „low‟ response and corresponding to a2 = 2
x1 = frequency of the „very low, response and corresponding to a1 =1

Severity boundary lines: = Σ SI/ n n is the numbers of element or criteria involved

The Severity Index would enable the user to prioritize the criteria in the study. Criteria with highest severity index (%) will be ranked topmost while criteria with the least severity index (%) will be ranked at the bottom. For this project, the seven point scale was transformed to relative importance indices for each criterion, using the above method to obtain the ranks of the different criteria. These ranking enabled the researcher to cross-compare the relative importance of the criteria as perceived by the respondents. However, the mean and standard deviation of each individual criterion are not appropriate statistics to evaluate the overall rankings because they do not reflect any relationship between them. As such, all the numerical scores of the identified criteria were transformed to severity indices (in percentages) to determine the relative ranking of the criteria. The result for this project being analyzed according to main four parameters involved which are air quality, temperature, noise and light.

Air Quality

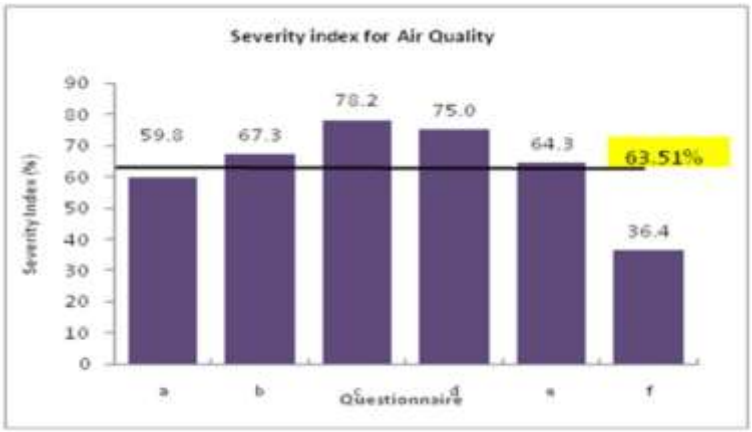

Figure 7 Overall Severity Index for Air Quality

Table 4 Overall Severity Index for Air Quality

Air Quality		
Survey Questionnaire	Severity Index (%)	Ranking
a) Effects of air quality of the building to the work performance	59.82	5
b) Air Freshness	67.32	3
c) Air Humidity	78.21	1
d) Air Smell	75.00	2
e) Air Movement	64.29	4
f) Control over ventilation	36.43	6
Overall SI for air quality	63.51	

The result on assessment of air quality aspects are presented in table above. From the result obtained in table, it shows the ranking according to the important element criteria to evaluate air quality of the building. Three topmost satisfied criteria are air humidity, smell, and air freshness. Based on the figure 12, criteria (a), and (f) are lower than the severity boundaries, thus these three elements need to be improved.

Temperature

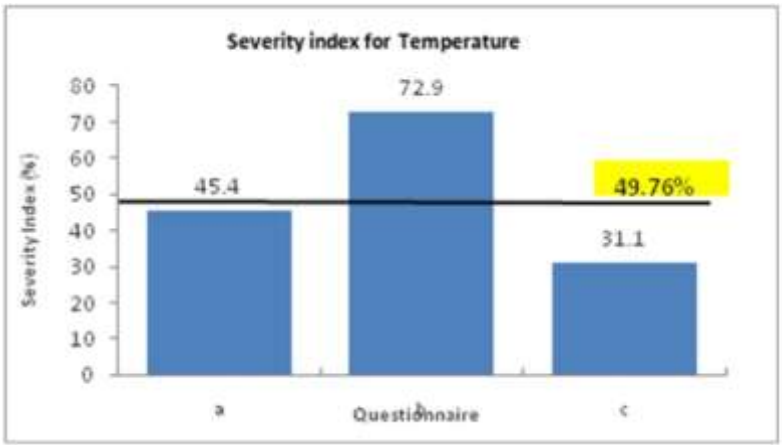

Figure 8 Overall Severity Index for Temperature

Table 5 Overall Severity Index for Temperature

Temperature		
Survey Questionnaire	Severity Index	Ranking
a) Effects of temperature of the building to the work performance	45.36	2
b) Level of temperature	72.86	1
c) Control over cooling	31.07	3
Overall SI for temperature	49.76	

Based on the bar chart, the control over cooling is not satified and below the boundary lines. Changes and way forward need to be planned in order to solve the problem and to give occupant the ability to adjust the temperature that suit with them. Controlling over the temperature is important because each person fell comfort differently reflect to their physical, gender, and ages.

Noise

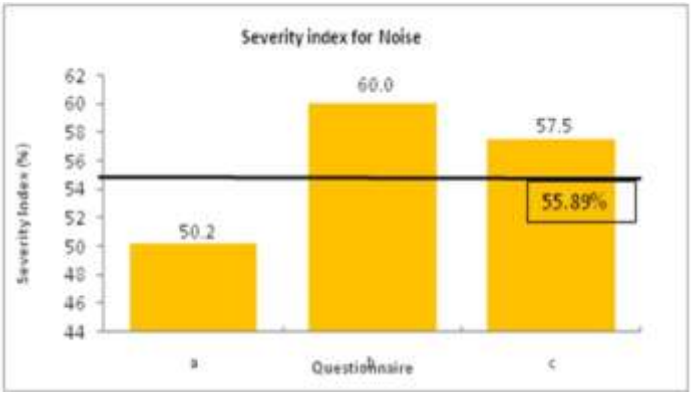

Figure 9 Overall Severity Index for Noise

Table 6 Overall Severity Index for Noise

Noise		
Survey Questionnaire	Severity Index	Ranking
a) Effects of distraction from noise of the building to the work performance	50.18	3
b) The significant distraction from noise outside the space	60.00	1
c) The significant distraction from background noise	57.50	2
Overall SI for noise	55.89	

Results show that noise is very significant to the work performance. From the severity index shown in the table, 50.18% indicates that the distraction from noise of building give impacts on performance. Both distractions of noise from outside and also background noise significant to the respondent.

Light

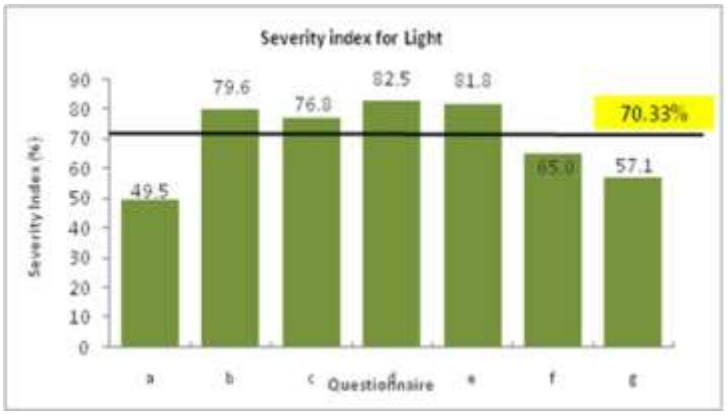

Figure 10 Overall Severity Index for Light

Table 7 Overall Severity Index for Light

Light		
Survey Questionnaire	Severity Index	Ranking
a) Effects of light of the building to the work performance	49.46	7
b) Level of natural light	79.64	3
c) Level of glare from sun/natural light	76.79	4
d) Level of artificial light	82.50	1
e) Level of glare from artificial light	81.79	2
f) The effectiveness of blinds/shutters in blocking out natural light	65.00	5
g) Control over artificial light	57.14	6
Overall SI for Light	70.33	

The high value of severity index shows that most of the respondent reported positive feedback regarding lighting. The three topmost satisfied criteria in lighting that affect the building performance are the level of artificial light, glare and level of natural light. There are aspects that need to be improving which are the effectiveness of shutters and control over artificial light.

Severity Index for all parameters

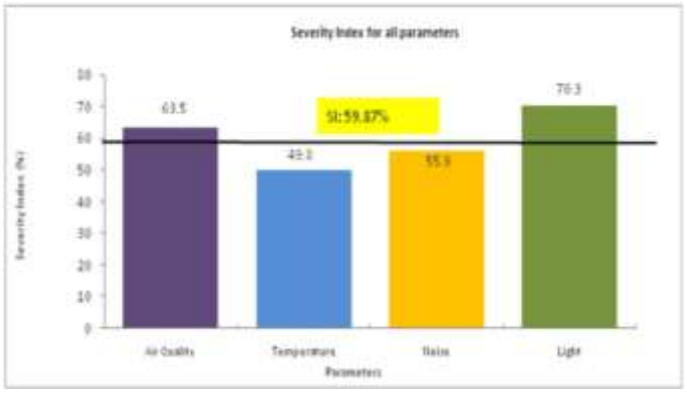

Figure 11 Overall Severity Index for all parameters

Table 8 Overall Severity Index for all parameters

Parameter	Severity Index	Ranking
Air Quality	63.51	2
Temperature	49.76	4
Noise	55.89	3
Light	70.33	1
SI boundary	59.87	

All four parameter have been gather in the bar chart to show which of the parameter are most affects occupants" satisfaction on the building performance. According to the table, the top ranking is light which is 70.33% followed by air quality. The SI boundary is 59.874%, thus noise and temperature is not passing the value. The overall POE will be verified by the results of IEQ and this is been included in further discussion. Improvement must be taken into consideration to make sure the noise level and thermal comfort meet the requirement standard.

Section C: Response of satisfaction and Recommendation

Do you satisfy with the indoor environmental quality of UTP building?

Table 9 Summary of Satisfaction Level

Rating		Staff		Students		Combination
1 -	Not satisfied	0	0%	1	2%	1
2		2	12%	2	3%	5
3		2	12%	10	16%	15
4		3	18%	14	22%	21
5		3	18%	13	21%	20
6		6	35%	20	32%	33
7 -	Very satisfied	1	6%	3	5%	5
EQ16: Level of satisfaction			77%		80%	79%

In overall, 79% of respondent satisfy with the indoor environmental quality of UTP building. Thus, this POE does not meet the EQ16 of GBI requirement. In this case, UTP management need to develop a plan for corrective action when the survey results indicate that more than 20% of occupants/workers are dissatisfied with the overall comfort in the building. This plan should include measurement of relevant environmental variables in problem areas. However, referring to the results on students" survey, it shows that level of satisfaction meets the requirement. Unfortunately, in this case the responses from the staff give big influent on the final results as staff spent more time in the building compare to student *Suggest improvements that can be made to improve the quality of indoor environment for UTP's building.*

There are 92 totals of responses on this question which is covers several aspects. Thus all of the responses had been classified according to the category to make it clear. Due to some repetition in the suggestion provided by the respondent, the filtration had done and

below is the summary of the responses. Miscellaneous include all response that are not related to indoor environmental quality are not be included in this report.

Table 10 Distribution of suggestion of improvement

Category	Responses
Air quality	27
Temperature	18
Noise	3
Light	7
Miscellaneous	37
TOTAL	92

Parameter: Air Quality

1 Have control over air conditioner
2 Improve air ventilation
3 Provide more air-conditioner to get more fresh air
4 Plant flowers around the buildings that give good smell.
5 Install fan and air con together
6 Improve the existing ventilation system
7 Oxygen pumping into the building
8 Fragrance in room should be applied
9 Improve air circulation, improve air conditioning so that can feel the existence of the air conditioning

Temperature/ Thermal comfort

1 Improve room temperature
2 Plant some small trees or flower in the class
3 During class, adjust the temperature to make the room more cold and suit to the occupant.
4 Provide full control for the air conditioner temperature
5 Control on the temperature inside the building
6 Control over HVAC output in the rooms
7 Effort should be made to install thermostat in each individual

Light

1 Adjustable light system in class
2 Improve lighting
3 Use white light and more energy saving light bulb
4 More natural light must be provided
5 Start changing the current lighting system with T8 and LED.

Noise

1 Provide better duct noise control
2 Revise on the design on glass wall that low in sound proof and distract concentration
3 Improve noise proof to reduce the distraction from next door

Rank of three top most satisfied parameter (Staff only)

Table 11 Rank of topmost satisfied parameters

	Rank: 1		Rank 2		Rank 3	
Air quality	4	24 %	8	47 %	3	18 %
Temperature	3	18 %	3	18 %	6	35 %
Noise	2	12 %	1	6 %	5	29 %
Light	8	47 %	5	29 %	3	18 %

In summary, the top three of satisfied parameter are:

1. Light
2. Air Quality
3. Temperature

This rank is not very reliable since only contributed by staff which is only 21% from overall respondents. However, this result still can take into account to verify with the IEQ assessment.

Study on Working Environment (Staff only)

Table 12 Problem/symptom in relation to working environment

				If Yes:	
				Do you think it has to do with your working environment ?	
Problems/symptoms	Yes, often (every week)	Yes, occasionally	No, Never	Yes	No
a) Fatigue	18 %	59%	24 %	53 %	47 %
b) Heavy headed	6%	47%	47 %	41 %	59 %
c) Headache	6%	53%	41 %	53 %	47 %
d) Nausea/ dizziness	6%	18%	76 %	53 %	47 %
e) Difficulty concentrating	12 %	53%	35 %	65 %	35 %
f) Itchiness, burning, eye irritation	0%	24%	76 %	59 %	41 %
g) Irritated, stuffed up or running nose	12 %	35%	53 %	59 %	41 %
h) Hoarseness, dry throat, cough	6%	47%	47 %	53 %	47 %
i) Dry or reddened facial skin	0%	18%	82 %	59 %	41 %
j) Flaking/ itchiness in the scalp/ears	0%	6%	94 %	53 %	47 %
k) Dry, itchy, red skin on the hands	0%	12%	88 %	59 %	41 %

Staff were been asked in the survey regarding the problems/ symptom of illness during last tree month. As seen in Figure 17, the leading illness symptoms experienced often is fatigue 18%, followed by difficulty in concentrating and running nose. 94% of respondent stated that never experienced flaking/ itchiness in the scalp/ears in last three month.

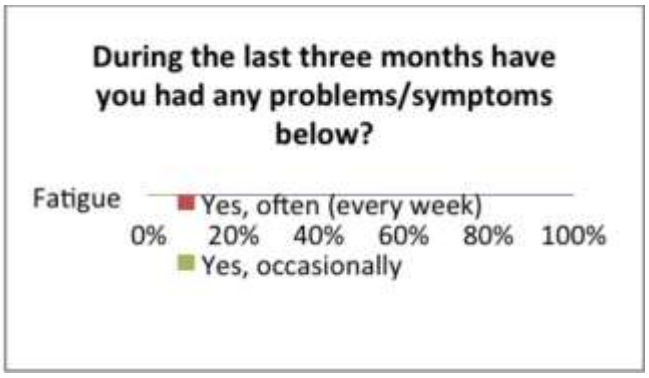

Figure 12 Problem/symptom in relation to working environment

Indoor Environmental Quality Assessment (IEQ)

Table 13 Overall Result of Indoor Environmental Quality Assessment

		Location					
Parameter	Standard	C3	C7	14-02-09	14-03-14	14-03-00	Environmental Lab
Temperature	23-26◦C, min: 22◦C	√	√	√	√	√	√
CO_2	≤1000ppm	√	√	√	√	√	√
Relative humidity	≤ 70% (55%- 70%)	√	√	√	√	√	√
Noise Level	<40dBAeq	X	X	√	X	X	X
Air Velocity	≤ 0.7 m/s	√	√	√	√	√	√
Light	300-500 lux	X	X	X	X	X	X

		Location					
Parameter	Standard	13-02-05	13-02-06	13-01-04	13-01-05	Concrete Lab	Geotech Lab
Temperature	23-26◦C, min: 22◦C	√	√	√	√	√	√
CO_2	≤1000ppm	√	√	√	√	√	√
Relative humidity	≤ 70% (55%- 70%)	√	√	√	√	√	√
Noise Level	<40dBAeq	X	X	√	X	X	X
Air Velocity	≤ 0.7 m/s	√	√	√	√	√	√
Light	300-500 lux	X	X	X	X	X	X

The measurement of IEQ is carried out to verify the result of POE and determine the exact value for each parameter. Based on the overall result obtained for indoor environmental quality assessment, out of six parameter been tested, noise level and light intensity does not meet the GBI and MS 1525 requirement. Reading for average temperature, relative humidity, CO^2 level and air velocity indicates that each element will contribute 1 point for GBI rating scores. According to POE result, two parameters which are temperature and noise did not pass severity index boundary, means the most unsatisfied parameter. However, IEQ shows that temperature of the UTP building meet the standard which is in range 23-26$\circ^C$. IEQ shows that noise level and illumination level for light are not compliance to standard. Noise level remains in unsatisfied level according to POE and also verified in filed measurement.

Noise

For noise level, only one room that pass the requirement. Based on the observation, the sources of the noise distraction for the lecture theatre (Pocket C) comes from the machine functioning in IT and Media Services (ITMS) control room. For the lecture room, lab and lecturer room, the distraction comes from the blowers of air cons that produce high level of noise. The contribution of outdoor noise to indoor noise levels is usually small. Beside, a sound level within a building caused by an outdoor source obviously depends on the source's intensity and the sound level reduction afforded by the building. Since the design of UTP‟s building is façade glass, it seem not afford sound reduction much. By the observation, if students talking while walk along the pathway outside the lecture room, still can distract people in the room.

Light

Regarding the light intensity level, most of the location of the assessment did not meet the MS1525 requirement. According to MS1525, lighting for working interior for general offices is between 300-400 lux, while for class room 300-500 lux. However, the readings taken shows the illumination levels exceed the recommended value. This is most probably due to the exposure of the room towards the natural light (sunlight).

Rooms that facing directly to the sun path record high illumination level because sunlight contains high intensity of illumination e that will affecting the reading taken in the room. This is also because the lecture rooms have no effective blinds or shutters and the design of UTP‟s building that built by façade glass allows the utilization of sunlight during the day. For the light in Pocket C, high intensity of light create thermal and too much glare affect the occupants‟ comfort. 94% of respondents claim that there is too much glare from artificial light. The assessments verify the result of POE.

Figure 13 Lecture room 13-02-06

By referring the figure above, lecture room 13-02-06 with switch off light condition shows the utilization of sunlight during the day. However, not all part of the room expose to the sunlight, thus during a day the light still need to be turn on. In that case, the illumination intensity does not compliance with the standard. There are also no shutter been install for some room. Hence, the excess of illumination provide heat and uncomforted condition to occupants

Light in lecture theatre also exceed the recommended illumination level. Respondents claim that too much glare provided by the light and it generates heat that makes occupants felt uncomfortable during the class lecture. By observation, the light in lecture theatre also makes shadow on work surface. Hence, study on characteristic of light that will be install need to take into attention.

CONCLUSION

In conclusion, based on the results of field measurement and post occupancy evaluation, it shows that some improvements need to be provided for the elements which are not passed the severity index boundary and verified by indoor environmental quality assessment. In nut shell, Universiti Teknologi PETRONAS have great potential to meet GBI certified level that will position university to high level. Out of six parameters only noise level and light illumination level need improvement to meet GBI requirement.

Management of UTP specifically Health safety and environment (HSE) department need to plan corrective plan and initiative to improve the current building performance in order to be certified as green building. Some recommendations are provided in this report in correlation to assist HSE department.

RECOMMENDATIONS

Parameter: Noise

Indoor noise levels often are influenced primarily by internal noise sources such as appliances, cooling and ventilating equipment, and people. However, many outdoor noises may still annoy people in the room more than indoor noises do. In this study, for lecture theater Pocket C, sound absorber should be installed to make sure the noise level requirement achieved. For other lecture room, the doors must to be ensuring close and air conditioned blowers should be covered with sound proof material. Due to the façade glass as wall of the building, additional shutters should be installing to reduce the distraction sound from outside.

Parameter: Light

Health and Safety department need to revise the illumination level for each light in the office and class room in general. Light with high intensity and exceed recommended amount create much glare and affect the occupants‟ comfort. Light that had been installed need to be suitable with the usage of the space, the area of work space and the heat energy produced to ensure its meet occupants‟ satisfaction and building performance. In utilization of sunlight during a day, there are still not have sufficient illumination that required user to switch on the light. Hence, the personal control over light should be implementing where user can adjust the amount of illumination intensity that is needed with the existing of natural light. This also promotes energy saving and UTP can reduce the electricity consumption and bills.

Personal control over temperature

According to post occupancy evaluation, up to 72% of respondents claim that occupants have no control over temperature which affect work performance and felt uncomfortable. Corrective plan need to be planned in order to solve the problem. The proper ventilation and cooling system control should be installed. The introduction of automated control for air-conditioning temperature with regards to the occupant present and activities will help to solve this situation. The occupant also can avoid distraction when they were in building by wearing proper clothes.

ACKNOWLEDMENT

The author sincerely express thanks to Universiti Teknologi PETRONAS for giving the assistances to perform the work of this research.

REFERENCES

Perez-Lombard, L., Ortiz, J. and Pout, C. (2008) *A review on building energy consumption information.* Energy and Buildings 40: 394-398

Fowler, K. and Rauch, E.. *Building Sustainability: Assessing Building Performance, Pacific Northwest National Laboratory*. Report prepared for the US General Services Administration. 2008

Heerwagen, J. and Zagreus, L. *Post Occupancy Evaluation of the Phillip Merrill Environmental Center.* Center for the Built Environment, University of California, Berkeley. 2005.

Rebecca R. et.al. *Post Occupancy Evaluation: Oregon Health & Science University Center for Health and Healing*. October 2009

PAM, A.*GBI Assessment Criteria for Non- Residential New Construction (NRNC).* Kuala Lumpur: Green Building Index Sdn. Bhd. 2009.

Hikmat H.Ali, Hind M.Almomani, Muna Hindeig: *Evaluating Indoor Environmental Quality of Public School Buildings in Jordan, Indoor Built Environment,*18(1),2009,66-76

Kim, Yong-Kyoung, Park, Ju-Yang, Yee, Jurng-Jae: *An Experimental Study on Evaluation ofDrainage Flow Performance and Noise in The United Plumbing System,* Architecture Institute of Korea, 26(4), 2010

Jang, Ha-Na, Kwon Oh-Jung, Kim Jin-Young: A Study on the Improvement for IAQ of the Officetel, Journal of the Korean Housing Association, 18(1), 2007, 123-130

Niklas Fransson, Daniel Vastfjall, Jeennie Skoog: In search of the comfortable indoor environment: A comparison of the utility of objective

L.T.Wong, K.W.Mui, P.S.Hui: A multivariate-logistic model for acceptance of indoor environmental quality(IEQ) in offices, Building and Environment, 43, 2008, 1-6

PAM, A.*GBI Assessment Criteria for Non- Residential New Construction (NRNC).* Kuala Lumpur: Green Building Index Sdn. Bhd. 2009

Malaysia, D.O.S. MALAYSIAN STANDARD *Code of Practice on Energy Efficiency and Use of Renewable Energy for Non-Residential Buildings (First Revision).* 2007. *MS 1525:2007*

AUDE. *Guide to Post Occupancy Evaluation,* Alastair Blyth & Mel Barlex,University of Westminster.2006 [14] Olomolaiye, P.O., K.A. Wahab and D.F. Price, 1987. Problems influencing craftsmen"s productivity in Nigeria. Build. Environ., 22(4): 317-323

Holt, G.D., 1997. Classifying construction contractors, a case study using cluster analysis. Build. Res. Inform.,25: 374-382.

Idrus, A. and M. Sodangi, 2010. Framework for evaluating quality performance of contractors in Nigeria. Int. J. Civil Environ. Eng., IJCEE-IJENS, 10(1): 34-39

Egemenn, M. and A.N. Mohamed, 2006. Clients" needs,wants and expectations from contractors and approach to the concept of repetitive works in the Northern Cyprus construction market. J. Build. Environ., 41: 602-614.

Elhag, T.M.S. and A.H. Boussabaine, 1999. Evaluation of construction costs and time attributes. Proceedings of the 15th ARCOM Conference, Liverpool John Moore University, 15-17 September, 2: 473-480.

Ballal, T.M., 2000. The Use of Artificial Neural Network for Modelling Buildability in Preliminary Structural Design. Ph.D. Thesis, Loughborough University of Technology.

Al-Hammad, A.M., 2000. Common interface problems among various construction parties. J. Perform. Constr. Fac., 4(2): 71-74