Correlating Visual Comfort with Green Building Index in an Open Plan Office Space

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Abstract: Indoor Environmental Quality (IEQ) is criteria used to rate green buildings and directly deals with comfort and health indicator of humans in green and high-performance buildings. The primary aim of building is for human comfort and satisfaction with each component. This paper is a result of an exploratory study carried out for an on-going PhD research. A cross-sectional survey of occupants in an open plan office for 44 post graduate students, in the Faculty of Built Environment (FAB) Universiti Teknologi Malaysia (UTM) was examined. The respondents completed a set of questionnaire centred on the experience on the four criteria for Indoor Environmental Quality (IEQ) as rated by the Green Building Index (GBI) Malaysia with focus on visual comfort. Measurements were taken at eight random locations within the workstation in relation to visual comfort. The questionnaire addressed issues such as visual privacy and colour rendering. Issues of visual discomfort were raised, irritability, headache, dry eyes, flickering from fluorescent and social density. The data generated showed a high probability of visual discomfort as the recommended average illuminace level for lighting for working interiors (300lux-400lux) was not attained from the data generated. This shows that there is a need for sensitization of stakeholders on the use of the GBI for new and renovated buildings to reduce the negative impact buildings would have on human and the environment in general.
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1. Introduction

Humans mostly spend their valuable time indoors either in the industrialized or the developing nation, and this requires adequate comfort without compromising the energy requirement of the environment they find themselves, this require lighting the space and the source of energy for various task performance (Pramod, Eino and Liisa 2006). Environmental space needs to meet various human requirements for any visual activity has a peculiar criteria for the task it need to perform, this all depend on energy usage and most developed countries and developing countries energy usage account for 20-40% of total energy usage, this have negative effects on us and our environment. Many countries have developed green building rating tool to rate buildings in terms of achieving and to curb the problem of sustainability. Most of the green rating tools need improvement as they are based on predicted (simulated) energy performance [Gifford 2008; Newsham, Mancini and Birt 2009; Scofield, 2009). More work in form of Research and development are needed to be carryout by employing Post Occupancy Evaluation (POE) on green buildings to improve; these will help in the construction of buildings that are sustainable and integrating all possible human interventions in them which will certainly lead to a more sustainable built environment (Nawawi and Khalil 2008; Meir, I. A., Garb, Jiao and Cicelsky 2009; Newshan, 2010 & Yeang, 2010). Office finishing and design pattern Play an important aspect in occupant satisfaction and performance, IEQ is one criterion to boost the income of a business for with improved indoor environment for workers in an office their productivity tend to increase. The present IEQ for LEED and GBI laid emphasis on the mechanical aspect for assessment other criteria like space layout, natural lighting and aesthetics can also contribute to environmental quality of the occupants that are neglected by GBI/LEED (Lee and Guerin, 2009). Little or no significance is experienced in the difference between green and conventional buildings from comparison between two (2) LEED office buildings in Hong Kong with evidence that little research have been carried out in Asia (Gou, Lau and Shen, 2011).

1.1 Malaysia Green Building Index (GBI)

The Malaysian Standards MS 1525:2007 and the newly launched SHRAE/USGBC/IESNA standard 189.1P which are referable standards used by GBI (Green Building Index) and LEED (Leadership in Energy and Environmental Design), mentioned

little about visual comfort except for standard 189.1, which only elaborate on the use of physical or computer model, minimum illuminance target; 300lux on work surfaces, 4.5m from facade, noon equinox and direct sunlight on work plane < 20% of occupied hours on equinox day. While the MS 1525:2007 recommends average illuminance level for working interior as 300-400 (lux) for general offices, shops and stores, reading and writing, drawing office, and recommendation of a suitable visual environment various task performance with no explicit on how to achieve the visual comfort of a particular task (Lee and Guerin, 2009; Gou, Lau and Shen, 2011; Majersik, 2009 & Department of Standards Malaysia, 2007). Although the use of Malaysian standard is voluntary, they are developed through consensus by committee's which comprise of balanced representation from the practitioner's, the governments and all works of life.

Table 1: Recommended average illuminance levels (Department of Standards Malaysia, 2007)

Task	Illuminance	Example of Application
Lighting for working interiors	200	Infrequent reading and writing
	300 – 400	General offices, shops and stores, reading and writing
	300 – 400	Drawing office
	300 – 500	Class room, Library
	100	Toilet
	300	Inquiry desk

1.2 Indoor Environmental Quality (IEQ)

This is one of the criteria that used to measure the rating of building; among other criteria, it is mainly concerned with four models assessing the comfort which are; thermal, indoor air quality, acoustic & visual and this are significant variables which affects occupant health, comfort, and satisfaction, the current standards used for achieving these variables are not evenly considered in term of points distribution and research less emphasis are place on visual comfort and in order to carry this POE possesses an inexpensive method that research can be carried out and can be used to access the non-physical dimension used in rating and an indirect way of assessing how green and conventional buildings are affecting occupants/users of space (Majersik, 2009; Department of Standards Malaysia, 2007; Abbaszadeh, Zagreus, Lehrer and Huizenga, 2006; Peretti and Schiavon, 2011 & Newsham, Brand, Donnelly, Veitch, Aries and Charles, 2009). IEQ is a vital criterion that determines the outcome of a green building. This is to seek POE at an early stage with effect of lighting which is lighting at workspace and its visual comfort. LEED tend to concentrate on environmental sustainability while economics/social human sustainability is not included in the criteria like in a choice of between natural and artificial light which result in low level of illuminance in workspace of occupants therefore POE is required to diagnose various occupants comfort and performance level in regards to building usage (Lee and Guerin, 2009).

2. Visual Comforts and Visual Task

Vision and light are two compactable phenomenon's, the human visual system provides a large part of the contact people have with the external world, since it is used to translate light, color, shapes to the brain. Therefore, for the eye to function and a user of space to have an effective satisfaction in his/her environmental field visual comfort and visual task performance is of a priority. Task visibility and Visual comfort can be described in large parts by the concepts of glare and contrast, both of which are affected by the field of vision of the viewer. Measurements vary in individual about the field of vision and the ages of the individual also count (Choi, Loftness and Aziz 2009; Robbins, 1936 & Breedlove, et al., 2007).

Daylighting can be defined as the conscious usage of glare-free natural daylight to light a building's interior. and it is under-utilized in most architectural design due to lack of information of its usefulness and depending on overoptimistic energy savings (as in simulations and blind usage) that are really met in open plan offices (Goodman, 2009).

Lighting is of a paramount concern to the design of office space as in a typical new building, it consumes up to 25% of the amount of energy required and this indirectly affects visual comfort which is one of the models of IEQ (Reinhart, 2002 & Iversen, Nielsen, and Svendsen, 2008). The use of natural light is indeed an inevitable practice internationally, for it saves energy in buildings which involves in bioclimatic passive solar design. Although, sustainability in the context of sustainable architecture has been narrowed to 'low energy' but energy performance boils down to Energy Efficiency and IEQ. Research has shown that visual comfort relate to daylighting research significantly as it contributes to well-being and performance of the users (Frontczak, Schiavon, Goins, Arens, Zhang, and Wargocki, 2011 & Newsham, Marchand, Svec, Veitch, 2002). Access to Natural daylight and fenestration with pleasant views assist in the reduction of stress levels in office environment, research has also shown that most people find natural lighting from daylighting better than fluorescent, incandescent lighting, help in psychological comfort and increase their productiveness and it has advantages in our health and well-being (Hwang and Kim, 2010).

Daylighting is an element used to improved occupants psychological health and productivity as office buildings required mental labour than physical labour, this implies that office environment should be

related to the health of the occupants and in turn could reduce occupants productivity rate probably due to building related illness (BRI) lighting environment can influence an occupants safety, level of fatigue, comfort as well as work efficiency (Abdelatia, Marenne and Semidor, 2010). Research in green building required baseline and this is difficult to achieve in Asia region for fewer green buildings exist. There have been some problem across most green buildings with daylighting and glare control as a repetitive one (Gou, Lau and Shen, 2011) and occupants comfort is neglected for energy savings.

3. Method

A cross sectional research survey of occupants in a post graduate office in Faculty of built Environment B07, Universiti Teknologi Malaysia. Participants completed a set of questionnaire concerning their experience in the research office, with an overview of IEQ and a focus on visual comfort. Physical measures were taken at 8-points to determine the illuminace and luminance level of the work surface and office space. The survey took place on the 28th May, 2011 at 10am, on a Saturday when the users of the space are less to avoid disturbance of the users of the space. Four equipment's were used to take the various measurements they are: a measurement tape, a digital camera, a lux meter and a luminance meter, figure 1 & 2; show the digital camera and the lux meter used in collecting data.

The space width was found to be 13200mm, space depth 19350mm and ceiling height 2700mm and the partition type is wooden cubicles. The space floor plan is shown in figure 5, the 8-points determining the illuminance and luminance level are depicted by the circular spot.

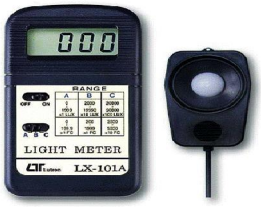
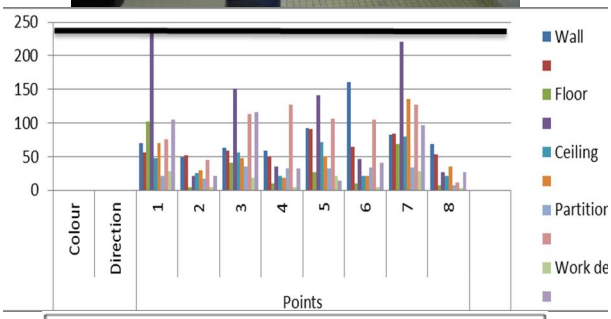


Figure 1. The luminance meter used to determine Luminance in the office space

Figure 2. Digital camera use for taking photographs



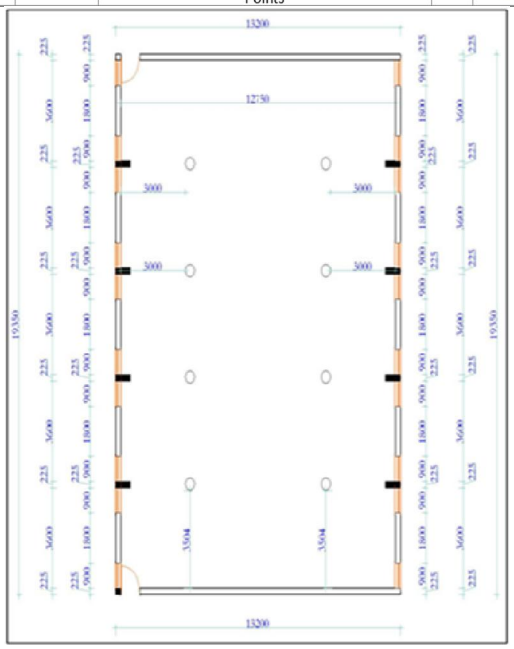


Figure 5. Floor plan of the postgraduate office room B07 Faculty of Built Environment UTM

Table 2. Lighting performance indicator (adopted from Dubois 2011)

# Performance indicator	Interpretation
1 WORK PLANE ILLUMINANCE	
< 100 lx	Too dark for paper and computer work
100-300 lx	Too dark for paper work / acceptable for computer work
300-500 lx	Acceptable for paper work / ideal for computer work
> 500 lx	Ideal for paper work / too bright for computer work
2 DAYLIGHT FACTOR	
< 1 %	Unacceptably dark, negligible potential for daylight utilisation
1-2 %	Acceptable, small potential for daylight utilization
2-5 %	Preferable, large potential for daylight utilization
> 5 %	Ideal for paper work, too bright for computer work, total daylight autonomy

Window Height	900mm	**Window Width**	**900mm**
Window cill Height	1100mm	**Window Frame Size**	
Window Glazing	Type	Clear	
Internal Shading	Type	Vertical Blinds	
	Geometry	Rectangular	
External Shading	Type	Roof Eaves	
	Geometry	Angular	

4. Result and Discussion

Dubois, (2001) and the Malaysian Department of Standards, (2007) adequately outline the acceptable lighting performance indicators through various conditions as highlighted in Table 1 and Table 2 respectively. During the first part of the data collection with natural lighting, the white wall surface at 2.3" exhibited the highest flux average of 61 while the work desk of colour blue exhibited 14 which showed the effect of chosen colour schemes within the space. Also, the gray coloured floor by virtue of the angle of the window eaves highlighted in table 3, received more natural light than other parts of the space resulting in the highest surface flux of 110 with least luminance flux of 57 lux. The total average in table 2 and Figure 4 shows that only at point one was the required flux met at 250 with a close measure at point 7. This average was however recorded for work desk only while all other surface fell short of the required standard.

Surface reflectance according to (LEED, 2010), the effective surface reflectance for wall, floor, ceiling, partition and work desk are 75%, 30%, 85% 50% and 50% respectively. The averages of surface reflectance for wall, floor, ceiling, partition and work desk of the Post graduate room is shown in table 5 only the floor surpass the average requirement of the surface reflectance.

Certainly for now most green buildings are deficient in lighting satisfaction, although few research have been conducted to ascertain this fact, but these is at the expense of lighting quality. For instance, in LEED-NC, 50 points are need out of 110 for silver certification but only a point allocated for daylight, view and personal control therefore there will be little different between LEED certified buildings and conventional buildings, this also applies to GIB Malaysia Non Residential New Construction (NCNR) category out of 66 points require out of 100 for silver as well only 2 point for external views 2 points for personal control and a point for daylighting (Dodo & Mohd Zin, 2011). Lighting is of a paramount concern to the 66 points require out of 100 for silver as well only 2 point for external views 2points for personal control and a point for daylighting (Dodo & Mohd Zin, 2011). Lighting is of a paramount concern to the design of office space as in a typical new building, it consume up to 25% of the amount of energy required and this indirectly affect visual comfort which is one of the model of IEQ. The use of natural light is indeed an inevitable practice internationally for it saves energy in buildings which involves in bioclimatic, passive solar design although sustainability in the context of sustainable architecture has been narrowed to 'low energy' but energy performance boils down to Energy Efficiency and Indoor environment quality in which research work in the later has been emphasize toward thermal comfort and visual comfort neglected. Researchers have shown that visual comfort relate to daylighting research significantly as it contributes to well-being and performance of the users; as expressed by (Alambeigi, 2013) and (Shemirani et al., 2011).

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