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Relationship between Indoor Environmental Quality (IEQ), Occupant's Satisfaction and Productivity in GBI Rated Office Building using SEM-PLS

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ABSTRACT

Indoor environmental quality is getting extra attention since most people these days spend most of their time indoors. This initial study aims to examine the association between Indoor Environmental Quality (IEQ), occupant's satisfaction and productivity in an office building. The survey was conducted in an office building that is Green Building Index (GBI) in the heart of Kuala Lumpur, Malaysia. This office building was awarded the Platinum Provisional Certification by the GBI Association Malaysia. A questionnaire was administrated to 120 occupants working in the rated green office building, where respondents were asked to select their preferences based on a seven-point Likert scale of agreement and satisfaction. Analysis was conducted using PLS-SEM: SMART PLS Version 3.2 to examine the reliability and validity of the questionnaire. Results indicated that there is a significant relationship between the Indoor Environmental Quality (IEQ), occupant's satisfaction and productivity in an office building especially with regards to visual comfort. Results highlighted the importance of the Indoor Environmental Quality (IEQ) for productivity.

Keywords: Indoor Environmental Quality (IEQ), Green Building Index (GBI), office building, occupant's satisfaction, productivity

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INTRODUCTION

Driven by environmental needs, Green Building Index (GBI) was founded and developed by the Pertubuhan Akitek

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Malaysia (PAM) and the Association of Consulting Engineers Malaysia (ACEM) in 2009. The Malaysian GBI is envisioned to promote sustainability in built environment and enhance awareness among developers, architects, engineers, planners, designers, contractors and the public about environmental issues. Green Building Index (GBI) is adopted from the Leadership in Energy and Environmental Design Standard (LEED) rating system. The GBI rating tool provides an opportunity for developers and building owners to design and construct green, sustainable buildings that can provide energy savings, water savings, a healthier indoor environment, better connectivity to public transport and the adoption of recycling and greenery for their projects and reduce our impact on the environment (GBI, 2015). The Green Building Index is Malaysia's initial comprehensive rating system for assessing the design and performance of Malaysian buildings. It is based on six criteria mentioned here: "Energy Efficiency", "Indoor Environment Quality", "Sustainable Site Planning & Management", "Materials and Resources", "Water Efficiency" and "Innovation". Ratings are categorised as: e "Platinum", "Gold", "Silver" and "Certified" that are given based on the marks obtained by the assessed building (GBI, 2015).

There are 15 areas of assessment for Indoor Environmental Quality (IEQ) item in the Non-Residential New Construction (NRNC) Tool. Each of the 15 areas contributes certainly mentioned point for a total score of the Indoor Environmental Quality (IEQ) item. The 15 areas are divided into four main variables, namely; Variable 1: Air Quality, Variable 2: Thermal Comfort, Variable 3: Lighting, Visual and Acoustic Comfort and Variable 4: In conjunction with the Post Occupancy Evaluation (POE) requirement, it is a must for building occupant's to meet at least 80% of the satisfaction level. If the building fails to comply with this requirement, a corrective plan needs to be developed for the building to obtain final certification from Malaysian GBI. Therefore, the need to develop a comprehensive and systematic Post Occupancy Evaluation (POE) survey and databases such as Building User Survey (BUS) Methodology, Centre for the Built Environment (CBE) survey and the Building Occupants Survey System Australia (BOSSA) is important. It can be done through evaluating and recognizing the requirement for Post Occupancy Evaluation (POE) that match with the requirement stipulated by the Malaysian GBI. It is also crucial to consider the aspects of climate, environment, regulations and public's perception in developing the Malaysia Post Occupancy Evaluation (POE) on Indoor Environmental Quality (IEQ) item. It is hoped that the comprehensive survey and database can help in motivating the Provisional Certification GBI buildings to obtain its Final Certification and drive more future research in this field. It is expected the framework of Post Occupancy Evaluation (POE) can be used to evaluate an occupant's satisfaction at any office building in Malaysia.

Indoor environmental quality can be defined as "the measurement of the key parameters affecting the comfort and well-being of occupants" or the "elements to provide an environment that is physically and psychologically healthy for its occupants" (Garnys, 2007). The National Institute for Occupational Safety and Health in the United States of America has established a definition of Indoor EnvironmentQuality (IEQ) which includes the integrated physiological and psychological influences of thermal, acoustic and luminous environments and air quality on occupants (Li, You, Chen, & Yang, 2013). Clements-Croome and Baizhan (2000) stated that the indoor environmental quality comprises of a range of components such as humidity, indoor air quality, temperature, and ventilation, lighting, noise and workspace density. Sarbu and Sebarchievici (2013) believed that the main environmental factors that define the indoor environmental quality are the thermal comfort, indoor air quality, acoustic comfort and visual comfort. It is supported by Hodgson (2008) as cited in Aminuddin, Rao and Hong (2012) who highlighted that the four primary criteria emphasised in green building rating tools are: (1) indoor air quality; (2) acoustics; (3) visual comfort (lighting); and (4) thermal comfort. However, many believed that even though the fact that acoustics is one of the main criteria for indoor environmental quality (IEQ), it is often overlooked and neglected. Similarly, Chandratilake and Dias (2015) stated that primary indoor environmental quality (IEQ) parameter includes the occupant health and safety, thermal comfort, daylight, visual quality, acoustic and indoor air quality. Prakash (2005) added ergonomics as one of the factors that need to be taken into account in providing a comfortable indoor environment to the end users. Apart from that, indoor environmental quality also comprises of few other aspects such as the spectrum of the paints (Prakash, 2005), electric lighting, daylight, views, individual control, and indoor contaminants by materials and tenants as the components of the indoor environmental quality in a building. (GBCA2009b). Subsequently, Frontczak and Wargocki (2011), from the results of his research, has recommended that when developing systems for governing the indoor environment, the type of building and outdoor climate including seasons should be taken into account. Findings from his research indicated that thermal comfort is ranked by building occupants to be of greater importance compared with visual, acoustic and air quality. However, the ranking was different in different countries and depended on the building whether it is private or public. However, for this pilot study discussion is focused on the aspects of the reliability and validity of the proposed questionnaire as an instrument in data collection.

Hypothesis and Research Model

Figure 1 portrays the conceptual research model for this study. It is hypothesized that four factors influence occupant's satisfaction. These factors include; Thermal Comfort, Acoustic Comfort, Visual Comfort and Indoor Air Quality (IAQ). The proposed initial conceptual model for the study is as presented below:

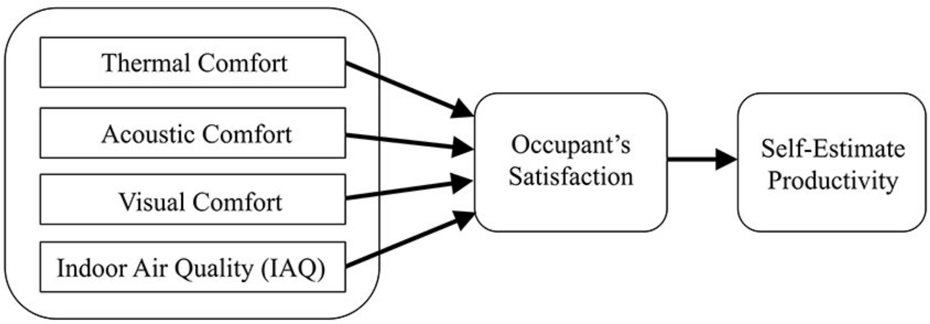

Figure 1. Conceptual research model

Subsequently, this study has two hypotheses that are tested in this initial study which is as follows:

H1. Indoor Environmental Quality (IEQ) has a positive relationship with Occupant's Satisfaction.

H1a. Thermal Comfort has a positive relationship with Occupant's Satisfaction.

H1b. Acoustic Comfort has a positive relationship with Occupant's Satisfaction.

H1c. Visual Comfort has a positive relationship with Occupant's Satisfaction.

H1d. Indoor Air Quality (IAQ) has a positive relationship with Occupant's Satisfaction.

H2. Occupant's Satisfaction has a significant positive influence to Self-Estimate Productivity.

METHODS

The selected building is a government building located in the heart of Kuala Lumpur Malaysia with an occupancy rate of over 700 occupants and had been occupied and fully operated for less than two years. This beautiful and modern design green office building was awarded the Platinum award by the GBI Malaysia in its Provisional Stage.

This study employed a cross-sectional research design that enable the integration of the literature review and the real data survey that utilises both the subjective and objective measurement of data collection

(Azman et al., 2014). The initial stage of this study will test the reliability and validity of the instruments (subjective measurement) through a hands-on survey of occupants. The unit of analysis of this study are the occupants in the rated Green Building Index (GBI) office building. The study employs a non-probability purposive sampling since it is not possible to obtain the list of all the elements of the building population due to privacy considerations. The non-probability purposive sampling facilitates the selection of respondents. A total of one hundred questionnaires were distributed by hand to occupants of the selected GBI office building, and of this number 81 questionnaires were received representing approximately 81% of response rate.

Subjective Measurement

The main data collection of this research will be measured using two instruments, namely: objective and subjective measurement. Objective measurement o is the data collected using fieldwork while the subjective measurement is data collected through the questionnaire. However, for this initial study, only subjective measurement is taken into account to identify the reliability and validity of the instrument as well as to determine and to arrive at preliminary results on the hypotheses.

The survey questionnaires used in this study have four sections. The first section of the questionnaire focuses on the independent variable (IV) viz., the Indoor Environmental Quality (IEQ) and its four dimensions; (1) Thermal Comfort, (2) Acoustic Comfort, (3) Visual Comfort and (4) Indoor Air Quality (IAQ). All 20 items in the first section are adapted from the CBE and BOSSA post occupancy evaluation as well as from the literature review (CBE, BOSSA). The second section of the survey relates to occupant's satisfaction as the indirect variable. The third part of the questionnaire inquires occupants' perception towards productivity levels which is measured using three items adapted and modified from CBE and BOSSA. These items in the three sections were measured using a 7-item scale. The last section of the survey focuses on the demographic variables of the respondents as listed in Table 1.

RESULTS

SPSS 22 and Smart PLS 3.2 were employed to assess the reliability and validity of the survey questionnaires. The demographic profile of the respondents was analysed using the SPSS version 22 while the measurement and structural model of the research framework were analysed using the SmartPLS 3.2. The significant advantage of using the SmartPLS 3.2 in determining study reliability and validity is that this method delivers latent variable score thus avoiding the problem of small sample size and efficiently handling complex models with many variables (Henseler, Ringle, & Sinkovics, 2009).

Table 1
Demographic profile

Variable	Valid Percentage
Gender	
-Female	51.9
-Male	48.1
Age	
-Under 30 years	27.2
-31 to 50 years old	61.7
-Over 50 years old	11.1
Posting	
-Administrative	43.2
-Technical	11.1
-Professional	28.4
-Managerial	14.8
-Other	2.5
Years Working in the Building	
-Less than 6 months	29.6
-7 to 12 months	18.5
-1 to 2 years	51.9
-2 to 5 years	0
-More than 5 years	0
Work Area Proximity to:	
-External Glass Wall/Window	66.6
-Atrium	2.5
-Courtyard	1.2
-Not Applicable	29.6

Demographic Profile of the Respondent

Based on Table 1, the percentage of female and male respondent were roughly equal, with female group score being 51.9% (female) and male score at 48.1%.Majority of respondents were between ages of 31 to 50 years old. Table 1 also indicates that most of the respondents were working in the administration area and most of them worked in the building between 1 to 2 years. This finding was equal to the duration of building occupancy of fewer than two years. Table 1 also shows that majority of respondents work area or sitting location is close to the external glass wall or windows.

Measurement Model Analysis

Table 2 summarizes the results of the measurement model after a few adjustments were made. Originally, the model consists of 20 items that were divided into: seven items for thermal comfort, four items of the acoustic comfort, five items for visual comfort and lastly four items for indoor air quality (IAQ). However, four items were deleted from the thermal comfort section, and one item from visual comfort was brought forward to the thermal comfort section to increase the composite reliability of the independent variable. As for the indirect variable of the model; Occupant's Satisfaction, the original number of items was four and was then reduced to two items in order to increase the reliability of the variable. The last variable of the model is the dependent variable of Self-Estimate Productivity that measures how the building occupants perceived their productivity based on their satisfaction levels of the Indoor Environmental Quality (IEQ) aspect in the building. The variable originally consists of three items, however, in order to increase its reliability value, one of the item is removed from the construct. The model was analyzed using SmartPLS 3.2 algorithm function with a total of 6 variables that comprises of 20 items. Results of the model are presented in Figure 2:

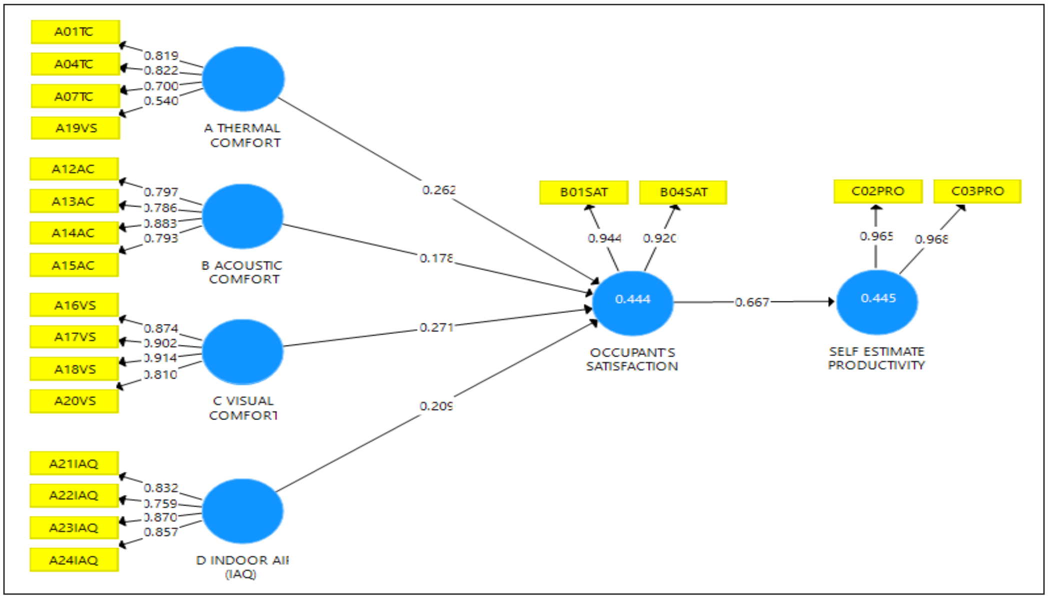

Figure 2. SmartPLS algorithm value of the measurement model

In order to test the goodness of the proposed conceptual model and rectify its validity as an instrument for real study data collection they need to be tested for reliability and validity. According to Sekaran and Bougie (2013), reliability is a test to measure the consistency of the instruments while validity is a test that indicates the wellness of the developed instrument in measuring a particular concept of the study.

Table 2
Measurement model analysis result

Construct	Item	Convergent Validity		Internal Consistency Reliability		Discriminant Validity	
		Cross Loading	AVE	Cronbach Alpha	Composite Reliability	HTMT	VIF
		>0.50	>0.50	0.60-0.90	0.60-0.90	Confidence Interval Does Not Include 1	<5.00
Thermal Comfort	4	0.540-0.822	0.532	0.698	0.816	Yes	1.602
Acoustic Comfort	4	0.786-0.883	0.665	0.835	0.888	Yes	1.067
Visual Comfort	4	0.810-0.914	0.767	0.898	0.929	Yes	1.364
Indoor Air Quality (IAQ)	4	0.759-0.870	0.690	0.850	0.899	Yes	1.821
Occupant's Satisfaction	2	0.920-0.944	0.869	0.850	0.930	Yes	1.000
Self-Estimate Productivity	2	0.965-0.968	0.934	0.930	0.966	Yes	

Table adapted from Hair et al. (2014)
*AVE: Average Variance Extracted; HTMT: Heterotrait-Monotrait Ratio; VIF: Collinearity Statistic

Reliability

Reliability of the model can be accessed using two values; the Cronbach's alpha coefficient of above 0.6 in assessing the inter-item consistency and through composite reliability where value ranged from 0.7, or greater is considered as acceptable (Fornell & Larcker 1981). In this study, as per Table 2 indicates that the composite reliability of the model measurement values ranged from 0.698-0.930 for Cronbach's Alpha value and range of 0.816-0.966 for composite reliability as portrayed in Table 2. The values prove that it is acceptable to measure the instruments consistently.

Validity

The primary purpose of the validity test is to measure fitness and is divided into convergent validity and discriminant validity tests. Convergent validity can be assessed by looking at the results of measurement model's factor loading, composite reliability and also its average variance extracted (AVE) (Hair et al., 2014). Table 2 shows that the factor loading of each item in the construct exceeded the endorsed value of 0.5 as stated by Hair et al. (2014). Although the cross-loading value of items in the first construct (Thermal Comfort) was quite small, it still passes the minimum requirement value of 0.50. This low loading value may be due to the small sample size of the respondents in the pilot study. Subsequently, Table 2 also further confirms the validity of the model by indicating the value of composite reliability of the model that ranged from 0.816-0.966, which surpassed the recommended value of 0.7 (Hair et al., 2010). The model's average variance extracted (AVE) values also exceed the expected value of 0.5 (Fornell & Larcker, 1981, Barclay, Higgins, & Thompson, 1995, Hair et al., 2014) with the range of 0.523-0.934 that reflects the overall amount of variance in the items for the latent construct. Thus, the result for convergent validity is acceptable for this model.

The next test that needs to be taken into consideration is the discriminant validity test that explores the degree to which accurate measure of one variable is not a reflection of another variable in the model. According to Cheung and Lee (2010), discriminant validity test can be indicated by the weak correlation between items in a different construct. This test can be identified by looking at the collinearity statistic of the Varian Inflation Factor (VIF) value of the constructs. Table 2 rectifies that all constructs in the model obtain VIF values of less than 5. It can be concluded that there are no collinearity issues between the constructs in the proposed conceptual model. To further examine the status of model discriminant validity, as suggested by Henseler et al. (2014), it is best to assess the discriminant validity in PLS-SEM by looking at the HTMT criterion value to auxiliary confirm that the items across construct do measure different construct in the model. It is identified by looking at the fact that the confident interval value of HTMT statistic must not comprise the value of 1 for an entire combination of the construct and also by assessing the value of

HTMT below that 0.90 (Hair et al., 2014) as presented in Table 3 Table 3 shows the value of HTMT of the entire construct is less than 0.90 which indicates minimal discriminant validity for the model.

Table 3
Varian Inflation Factor (VIF) value

Variables/Construct	TC	AC	VC	IAQ	SAT	PRO
Thermal Comfort (TC)						
Acoustic Comfort (AC)	0.280					
Visual Comfort (VC)	0.521	0.235				
Indoor Air Quality (IAQ)	0.800	0.278	0.546			
Occupant's Satisfaction (SAT)	0.658	0.354	0.580	0.625		
Self-Estimate Productivity (PRO)	0.289	0.381	0.398	0.402	0.739	

Based on the above discussion it can be concluded that all the four constructs of the Indoor Environmental Quality (IEQ) are valid to measure individual constructs based on their factor estimations and statistical significance.

Structural Model Analysis

In order to test the hypotheses a structural model was tested and analysed. As shown in Table 4, out of the five variables thought to influence occupant's self-estimate productivity in a green office building only four were significant. Results indicate that thermal comfort, visual comfort and indoor air quality (IAQ) are positively related to occupant's satisfaction where the p-value is less than 0.05. However, one of the independent variables that is acoustic comfort was found to be not significant. Subsequently, as for the indirect variable of occupant's productivity, the result specifies significant direct effect on the dependent variable (self-estimate productivity) of the model.

Table 4
Structural model analysis result

Hypothesis	Relationship	Coefficient	p-value/ t-value	Result
H1A	Thermal Comfort → Occupant's Satisfaction	0.262	0.030/ 2.177	Supported
H1B	Acoustic Comfort → Occupant's Satisfaction	0.178	0.126/ 1.531	Not Supported
H1C	Visual Comfort → Occupant's Satisfaction	0.271	0.007/ 2.702	Supported
H1D	Indoor Air Quality (IAQ) → Occupant's Satisfaction	0.209	0.050/ 1.967	Supported
H2	Occupant's Satisfaction →Self-Estimate Productivity	0.667	0.000/ 9.684	Supported

DISCUSSION

This study emphasizes the importance of Indoor Environmental Quality (IEQ) in providing office occupants an environment that could increase their productivity. The study attempted to highlight the interaction between the six main variables of the research:

1. Thermal Comfort
2. Acoustic Comfort
3. Visual Comfort
4. Indoor Air Quality (IAQ)
5. Occupant's Satisfaction
6. Productivity

The findings of this pilot study showed that the occupant's satisfaction on the aspect of Indoor Environmental Quality (IEQ) may lead to higher productivity in an office building. This result is parallel with findings of Haynes (2008), Gou & Lau, (2013) and also Vimpari and Junnila (2014).

It (the study) suggests that the Indoor Environmental Quality (IEQ) variables of the thermal comfort, visual comfort and indoor air quality (IAQ) contributed to occupant's satisfaction. Meanwhile, occupant's satisfaction was found to have a positive relationship on occupant's self-estimate productivity. However, surprisingly, there is no significant relationship between acoustic comforts with occupant's satisfaction. The result may be due to the small number of respondents. Thus, currently, the main data collection of this study has collected a large number of respondents which hoped to encourage and contribute to research findings that are more substantial.

CONCLUSION AND FURTHER WORK

This study tested a conceptual framework based on the indoor environmental satisfaction literature. The instrument used in this study fulfilled the acceptable requirements for reliability and validity analyses. The outcome of the path model analysis confirmed that Indoor Environmental Quality (IEQ) is significantly correlated with Occupant's Satisfaction and Productivity.

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