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Association between Indoor Environmental Quality (IEQ), Occupants Productivity and Perceived Productivity in Malaysian Green Office Buildings

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Abstract

The indoor environmental quality (IEQ) can be describe in general as the measurement of the internal environment and parameters affecting the comfort of building occupants. This research study aims to examine the relationship between Indoor Environmental Quality (IEQ), occupant's satisfaction and productivity in selected green rated office buildings. The survey was conducted at four (4) rated Green Building Index (GBI) office buildings located in the heart of Kuala Lumpur and Putrajaya, Malaysia. These selected office buildings was awarded with Platinum and Gold Provisional Certification respectively by the GBI Association Malaysia. There are twenty-five (25) items in Section A of the questionnaire while there are twelve (12) items on the respondent's demographic profile and work place criteria that were allocated in section B of the questionnaire. The questionnaire was administrated to 350 occupants working in the rated green office buildings with responsive rate of 86%. The respondents were asked to select their preferences based on a seven-point Likert scale of agreement and satisfaction for Section A and multiple answer question for Section B. Descriptive analysis of this main study was conducted using the SPSS version 22. Meanwhile, the measurement and structural model analysis of this study was performed using the PLS-SEM: SMART PLS Version 3.2. There are four aspects of assessment in this measurement model that include indicator reliability, internal consistency reliability, convergent validity, discriminant validity, and multicollinearity evaluation. As for the structural model of this study, an analysis was conducted to verify the research hypothesis of this study. Hence, result of this main study indicated that there is a mix relationship between the Indoor Environmental Quality (IEQ) main variables with occupant's satisfaction and productivity in green rated office building. These results highlighted the importance of the Indoor Environmental Quality (IEQ) dimensions of the thermal comfort perceiving occupant's satisfaction in office building. Thus, also verified that there is a significant association between occupant's satisfaction and perceived productivity in green rated Non-Residential New Construction (NRNC) building.

Keywords: Indoor Environmental Quality (IEQ), Green Building Index (GBI), Office Building, Occupant's Satisfaction, Productivity

Introduction

Earlier research by (Lebowitz et al., 1985), found that people in developed world spend almost 75-90 percent of their time inside a building. The similar finding was found by (Singh, 1996) and (Klepeis et al., 2001) who believed that research suggests people tend to spend 80-90 percent of their time indoors. These facts highlighted the importance of building indoor environment quality improvements and the need for validating the related well-being and productivity benefits available in rated green buildings (Singh, Syal, Korkmaz, & Grady, 2011). Thus, with most people carry on 80-90percent of their lives inside buildings, the green rated building must able to satisfy the objective and subjective requests linked to vital functions of the occupants in existing and future buildings. Later, there will be an increasing focus on energy uses and indoor environmental quality in these rated green building in ensuring the optimum indoor environmental quality achieved in the post-occupancy period (Wolkoff & Kjaergaard, 2007). (Chen et al., 1998) stated that the indoor environment is crucial for people's health and welfare, because 90 percent of typical person's time spent indoors. Consequently, their production also related to the indoor environment. He also pointed that satisfaction level and expectation of occupants in a built environment comprises of the illuminations, acoustics, air quality, diet, thermal comfort and social environment, habitually reflect the situation which surrounds them by their physiological and mental sensations such as sight, hearing, smell, taste, touch and mentality. Hence, the green construction is aimed at reducing environmental impact and improving the safety, health and productivity of a building's final occupants (John & Michael, 2007). The main aims of this green construction are to create facilities and building that are sustainable with huge attention focuses on the satisfaction and sustainability of the end users and end use of the green building. According to (Kibert, 2008), sustainable design can be defined as "application of sustainability principles to building design". Subsequently, now a day, building designers attempt to enhance better indoor environmental quality with proper choice of sustainable materials and green design that are comfortable for occupants at any time of day, in any climate and all year round. Henceforth, a successful design and construction of building enclosure for building might guarantee the accomplishment of basic building enclosure externally and internal of the building comprises of the acoustics and air control, sustainable structural and enclosure design, heat and moisture control, and finally ultimate indoor environmental quality that fulfil the requirement of a building to be certified by sustainable rating standard as a green building.

Accordingly, over the past decade, the sustainable building rating system (SBRS) for green buildings has been developed worldwide to promote the construction of green buildings in the industry. According to (Liang et al, 2014), among the numerous efforts in the emerging green building is the establishment of green building certification systems as one of the most prominent and systematic approach toward promoting sustainability in construction. Thus the transition from traditional practices to sustainable design and construction will require action on many fronts and support from the prominent organization (Hanna, 2011). Benefits of these systems are they can guide the development of construction industry towards best practice and improving the quality of building for tenants and occupants. The sustainable building rating system (SBRS) is a concept of sustainable practice, and environmental responsibility which normally is an elective standard as opposed to a mandated regulation involving multiple constituents (building owner, design professionals, construction professionals, and code

officials). It is a crucial tool to measure and evaluate green building in most of the country worldwide including Malaysia. It is believed that these sustainable building rating system (SBRS) can provide and enhance frameworks for building performance criteria which enable building construction to be more accurate and precise about the movement towards sustainable working process.

In Malaysian green development context, the Green Building Index (GBI) was founded and developed by the Pertubuhan Akitik Malaysia (PAM) and the Association of Consulting Engineers Malaysia (ACEM) in 2009 as one of the accelerations in Malaysia sustainable development. 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. The Green Building Index (GBI) is always dynamic, constantly adapted and adopted from other rating systems. Green Building Index (GBI) is closely adopted from the Leadership in Energy and Environmental Design Standard (LEED) rating award and its criteria, although both are used in a different geographical zone and under different climatic conditions. 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 which are based on six criteria, which are "Energy Efficiency", "Indoor Environment Quality", "Sustainable Site Planning & Management", "Materials and Resources", "Water Efficiency" and "Innovation" with four categories of rating which are "Platinum", "Gold", "Silver" and "Certified" that are given based on the marks obtained by the assessed building (GBI, 2015). However, this study focused only on the aspect of the Indoor Environmental Quality (IEQ) criteria of Non-Residential New Construction (NRNC) buildings in Malaysia. Consequently, 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. These 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: Post Occupancy Evaluation that can be identified and measured through the objective and subjective measurements as conducted in this research study.

Hypothesis and Research Model

Fig.1 portrays the conceptual research model for this study. It is hypothesized that four factors influence occupant's satisfaction which leads to perceiving of productivity by occupants in a building. 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:

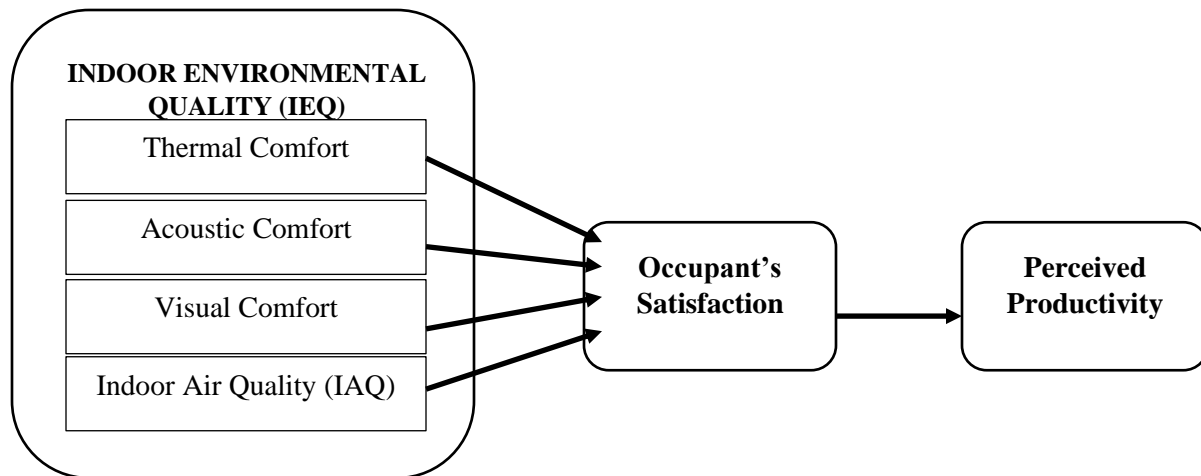


Fig.1: Conceptual Research Model

Subsequently, this study has two main hypotheses that are tested in this 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 on Perceived Productivity.

Method

The criteria for building selection for the main data collection study where the building must be rated by the Green Building Index (GBI) Malaysia. It must be an office building (full or semi-government) and is in the city of Kuala Lumpur or Putrajaya, Malaysia. Therefore, four GBI rated office buildings was chosen to be the location of this research study with the following criteria:

Table 1: Case Study Buildings

Building	Location	GBI Rating	Occupancy (Approximate Quantity)
Building A	Putrajaya	Platinum	300
Building B	Putrajaya	Gold	400
Building C	Kuala Lumpur	Platinum	800
Building D	Kuala Lumpur	Gold	700

This study employed a cross-sectional research design that enable the integration of the literature review and the real data survey that utilizes both the subjective and objective measurement as the main procedure of data collection that will hinder and reduce the possibility of research bias and bringing the best accuracy in collected data (Azman et al 2014). The unit analysis of this study is the occupants in the rated Green Building Index (GBI) office buildings in

Malaysia that includes the administrative, technical person, professional, and others that work daily at the selected building. Thus, this 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 its private and confidential policy. The non-probability purposive sampling facilitates in choosing the right respondents for the survey and eliminates those who did not fit the criteria from the sample. Hence, as for this study, a total of 350 questionnaires were distributed among the occupants in the selected GBI office buildings by hand and through online survey. However, only 324 questionnaires were returned and proceed for analysis where 22 of the returned questionnaire were found to be outliers in the study. Nevertheless, with the total of 302 respondents proceed for the analysis, it is still acceptable for this study as the number of appropriate returned questionnaire calculated by G*Power was 180.

Subjective Measurement

The main data collection of this research will be measured using two instruments, namely, the objective and subjective measurement. The objective measurement of the student refers to the data collected using fieldwork while the subjective measurement is the collection of data by using questionnaire. However, this paper focused on the findings of the subjective measurement of the research study that conducted by using questionnaire survey.

The survey questionnaires used in this study consist of four sections. The first section of the questionnaire focuses on the independent variable (IV) of the study which is the Indoor Environmental Quality (IEQ) that comprises of 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 is focused on the aspect of occupant's satisfaction as the indirect variable between the independent variable and the dependent variable of the study. The items in this section are taken from different satisfaction literature. The third part of the questionnaire inquired on the occupants' perceptions towards their perceived productivity and was measured by 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 focused on the demographic variables and work place criteria of the respondent as listed in Table 2.

Result and Discussion

SPSS 22 and Smart PLS 3.2 were employed to assess the measurement and structural model of the survey questionnaires data and answering the research hypothesis. The demographic profile of the respondents is analyzed using the SPSS version 22 descriptive analysis, while the measurement and structural model of the research framework were analyzed 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 et al. 2009).

Table 2: Demographic Profile

Profile	Sub-Profile	Frequencies	Percentage (%)
Age	Under 30 years	71	23.5
	31 to 50 years old	202	66.9
	Over 50 years old	29	9.6
Gender	Female	184	60.9
	Male	118	39.1
Type of Work	Administrative	99	32.8
	Technical	92	30.5
	Professional	89	29.5
	Managerial	3	1.0
	Other	19	6.3
Years Working in Building	Less than 6 months	21	7.0
	7 to 12 months	127	42.1
	1 to 2 years	92	30.5
	2 to 5 years	35	11.6
	More than 5 years	27	8.9
Green Building Awareness	Yes	299	99.0
	No	3	1.0
Floor Location	Lower Level 1 – 15	278	92.1
	Higher Level 16 – 40	24	7.9
Normal Work Area	Private office	37	12.3
	Private office shared with other occupants	42	13.9
	Open plan office with high partitions (higher than 1.5m)	68	22.5
	Open plan office with high partitions (higher than 1.5m)	127	42.1
	Open plan office with low partitions (lower than 1.5m)	24	7.9
	Open plan office with low partitions (lower than 1.5m)	4	1.3
Other	Open plan office without partitions		
	Other		
	Current Workspace Arrangement		
	Fixed location	297	98.3
	No fixed location	5	1.7
Normal Work Duration	Less than 6 months	21	7.0
	7 to 12 months	127	42.1
	1 to 2 years	94	31.1
	2 to 5 years	35	11.6
	More than 5 years	25	8.3
Hours Spend in Workspace	Less than 10 hours	81	26.8
	11 to 30 hours	63	20.9
	More than 31 hours	158	52.3

Work Area	External Glass Wall	268	88.7
Location	External Glass Window	-	-
	Atrium	2	0.7
	Indoor Garden	-	-
	Balcony	-	-
	Not applicable	32	10.6
Workspace	Yes	270	89.4
Near Facade	No	32	10.6

Demographic Profile of the Respondent

These statistics described the demographic profiles of respondents who participated in the survey. Table 2 described the respondents' background information. Based on the analysis, the response rate was 86%. Among participants involved in this study, 66.9% were from the range 31 to 50 years old. Interestingly, female respondents more inclined to participate in this study at 60.9% than male respondents at 39.1%. Respondents who worked in the administrative section have the highest participation at 32.8% then followed by those in technical section at 30.5%. Majority of the respondents have been attached with the company between 7 to 12 months (42.1%) and almost all of them were aware that they are working in a green building (99%). The workstation for most respondents were at a lower level (92.1%) with an open plan office with low partitions (42.1%) and then followed by those with high partitions (22.5%). The workspace arrangement was designed at a fixed location for most respondents (98.3%). In their normal working area, employees who have been at their work location have served between 7 to 12 months (42.1%) and then followed by those who were in their 1 to 2 years in their normal working area (31.1%). Majority of the respondents spend in their workspace for more than 31 hours in a week (52.3%). The location of the normal working area for most of the respondents was near by the external glass wall (88.7%) and atrium (0.7%).

Measurement Model Analysis

The research framework in this study is tested using partial least squares approach. Smart-PLS 3.2 (Ringle, Wende, & Becker, 2015) is used to assess the measurement and structural model for this study. This statistical program assesses the psychometric properties of the measurement model and estimates the parameters of the structural model. As discussed in the previous chapter, Henseler, Ringle, & Sinkovics (2009) suggest four aspects of assessment in this measurement model. The analyses include indicator reliability, internal consistency reliability, convergent validity, discriminant validity, and multicollinearity evaluation. The following subsections present the findings for each of the analysis used to evaluate the validity of the measurement model for this study. Figure 2 portray the SmartPLS Measurement Model of the research study that consist of six (6) research variables with total of 21 items.

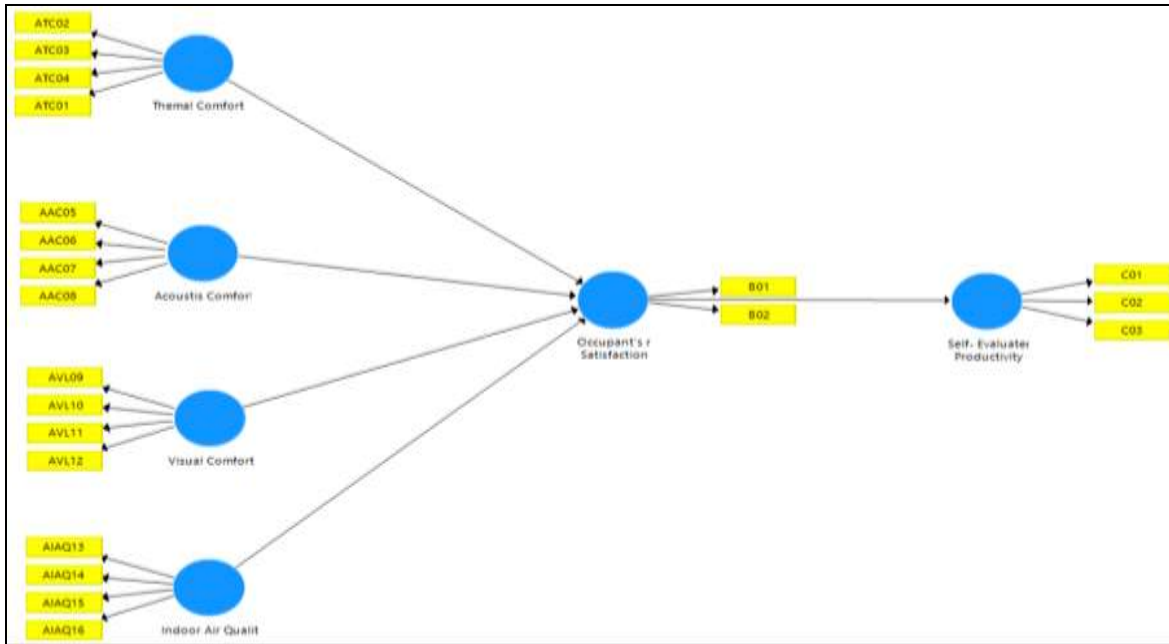


Fig.2: SmartPLS Measurement Model

a) Indicator Reliability

Indicator reliability of the measurement model is measured by examining the items loadings. Loadings with 0.70 or higher are considered highly satisfactory (Chin, 1998; Hair, Ringle, & Sarstedt, 2011; Henseler et al., 2009). Nevertheless, according to Hair et al., (2011), for exploratory study designs the items loading value of 0.40 is regarded as acceptable, whereas those less than 0.40 should be dropped. The cut-off value taken for outer loading in this study is 0.40 and above. As could be seen in Table 3, the loading value for items in the questionnaire survey measurement exhibited loadings exceeding 0.700; ranging from a lower bound of 0.833 to an upper bound of 0.961. This result indicated that the loadings have demonstrated satisfactory indicator reliability.

Table 3: 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	0.833-0.912	0.785	0.909	0.936	Yes	2.329
Acoustic Comfort	4	0.785-0.902	0.711	0.864	0.908	Yes	1.778
Visual Comfort	4	0.858-0.951	0.818	0.925	0.947	Yes	2.222
Indoor Air Quality (IAQ)	4	0.914-0.943	0.869	0.950	0.964	Yes	2.471
Occupant's Satisfaction	2	0.929-0.943	0.876	0.859	0.934	Yes	1.000
Perceived Productivity	3	0.912-0.961	0.873	0.927	0.954	Yes	

Table adapted from Hair et al. 2017

*AVE: Average Variance Extracted; HTMT: Heterotrait-Monotrait Ratio; VIF: Collinearity Statistic

b) Internal Consistency Reliability

Composite reliability (CR) is considered a better measure of internal consistency because it employs the standardization of different item loadings when PLS-Algorithm is applied. A measurement model has satisfactory internal consistency reliability when the CR of each construct higher than 0.70 (Henseler et al., 2009). For exploratory study, construct reliability within the range between 0.60 to 0.70 is considered acceptable (Hair et al., 2011). Higher CR indicated that the construct is highly satisfied in its reliability. Thus, based on Table 3, the value of CR ranges was all above the appropriate value of 0.70 ranges from 0.908 to 0.964. Thus, the results indicate that the items used to represent the constructs have highly satisfactory internal consistency reliability.

c) Convergent Validity

Convergent validity refers to the amount of variance captured by a construct from its relative items due to measurement errors (Henseler et al., 2009). In this study, the measurement model's convergent validity is assessed by examining its average variance extracted (AVE) value. Convergent validity is adequate when constructs have an AVE value of at least 50 percent or more variance from the item loadings is explained by the construct to which it is assigned to. Table 3 shows that all constructs have AVE ranging from 0.711 to 0.876, which exceeded the

recommended threshold value of 0.5. This result shows that the study's measurement model has demonstrated an adequate convergent validity.

d) Multicollinearity Assessment

The multicollinearity assessment was conducted to ensure the correlation between exogenous construct and endogenous construct are not highly correlated or in other words, almost similar among each other. The testing is being reflected through variance inflation factor test (VIF). When a correlation between an independent variable and dependent variable generate an output of less than 5.0, this indicates that the constructs are free from serious collinearity issues (Hair et al., 2014).

e) Discriminant Validity

Discriminant validity refers to the extent to which the construct does not correlate with other measures which are different from it (Hair et al., 2014). This study employed discriminant criterion suggested by Henseler, Ringle, & Sarstedt (2015) by using Heterotrait-monotrait (HTMT) approach to confirm discriminant validity. According to them, discriminant validity is achieved when the correlation value between constructs are less than one. However, this study follows a more conservative threshold of not exceeding one (1) as stated in Table 3 which indicates a clear distinction between constructs. If the value found to be more than the stated threshold, it shows that there is a discriminant validity problem occurs in the measurement model. On the other hand, value less than specified threshold indicates adequate discriminant validity and the testing could be continued to the structural model evaluations. Thus, this study result confirms that discriminant validity is met via HTMT assessment.

Structural Model Analysis

In order to verify the hypotheses of the study, a structural model was tested and analysed by using SmartPLS 3.2. As describe in Table 4, out of the four variables hypothesized to influence occupant's satisfaction in a green office building, only one was significant. Results indicate that only the thermal comfort variable is positively related to occupant's satisfaction where the p-value is less than 0.05. Though, the rest of the independent variables which are the acoustic comfort, visual comfort and indoor air quality (IAQ) were found to be not significant with the occupant's satisfaction. Subsequently, as for the indirect variable of occupant's productivity, the result specifies significant direct effect of occupant's satisfaction on the dependent variable (perceived productivity) of the structural research model.

Table 4: Structural Model Analysis Result

Hypothesis	Relationship	p-value	t-value	Result
H1A	Thermal Comfort → Occupant's Satisfaction	0.025	2.252	Supported
H1B	Acoustic Comfort → Occupant's Satisfaction	0.385	0.870	Not Supported
H1C	Visual Comfort → Occupant's Satisfaction	0.211	1.253	Not Supported
H1D	Indoor Air Quality (IAQ) → Occupant's Satisfaction	0.421	0.805	Not Supported
H2	Occupant's Satisfaction → Perceived Productivity	0.000	5.086	Supported

To validate the proposed hypotheses and the structural model, the path coefficient between two latent variables is assessed. From the analysis of path coefficients in Table 4, it shows mixed results where several paths supported the hypothesis and the remaining paths are not supported. The t-values are higher than minimum cut-off significance value which is at least 0.05 or 5%. Hypothesis results of the study as the following:

- a) Hypothesis 1 – Occupant's Satisfaction is influenced directly only by Thermal Comfort ($\beta = 0.159$; $t = 3.366$; $p < .001$), Conversely, Visual Lighting, Acoustic Comfort, and Indoor Air Quality were the only variables that did not have significant effect on Occupant's Satisfaction. As a result, solitary hypothesis H2a are supported.
- b) Hypothesis 2 – There is a positive significant relationship between Occupant's Satisfaction and the Self-Estimate Productivity. In other words, Occupant's Satisfaction has a strong direct influence on Self-Estimate Productivity. Results from the path analysis indicates significance level at ($t = 5.086$; $p < .000$).

Hence, this questionnaire survey data finding of the main data collection indicate a disagreement with the pilot study result of the intended study conducted by the researcher. The previously published pilot result of this study shows that out of the four independent variables testing in the pilot survey, three of the variable were found to be significantly related to occupant's satisfaction except acoustic comfort (Hamimi, Hanim & Mazran, 2017). However, the result for the second hypothesis of this main data finding shows similar outcome with the pilot result where the occupant's satisfaction was found to has a positive relationship with the dependent variable of this study (Hamimi, et.al 2017). These mix results between the pilot and main survey of this study probably happen because of the different in the number of respondents answering the survey as well as the additional buildings (as mentioned previously in method section) involved in the main survey compared to one building in pilot survey.

Conclusion

This study stresses on the importance of the Indoor Environmental Quality (IEQ) aspect in providing office occupants with a satisfaction that will increase their perceived productivity in

green rated office building. Indoor Environmental Quality (IEQ) do play a significant role in determining occupant's satisfaction and productivity in the green office building. Therefore, this research study is to highlight the interaction between the six main variables of the research namely the Thermal Comfort, Acoustic Comfort, Visual Comfort, Indoor Air Quality (IAQ), Occupant's Satisfaction and Perceived Productivity. Subsequently, this research study delivers several implications of the sturdiness of research methodology and analysis by using the SEM SmartPLS in architectural field, and some empirical contribution on the aspect of indoor environment in hot and humid country. Hereafter, in terms of empirical contribution, 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 in parallel with finding of previous studies by (Haynes, 2008). Lastly, it is hoped that in the aspect of the research methodology robustness, the designed survey questionnaires used in this study can be used as a comprehensive Post Occupancy Study (POE) in measuring occupant's satisfaction in GBI rated buildings in obtaining, maintaining and upgrading its given certification level.

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