INDOOR ENVIRONMENTAL QUALITY AND OCCUPANTS' PRODUCTIVITY: GREEN CERTIFIED OFFICE BUILDINGS IN SRI LANKA

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ABSTRACT

There is a potential link between indoor environment and occupants' productivity, which has identified in previous literature. Especially, there is an effect of the quality of indoor environment, where, people spend 90% of their time indoors. Indoor Environmental Quality is become a growing concern to ensure occupants' health, wellbeing, and personal productivity. However, the deficiency of research in this area gave an importance to conduct this study. Accordingly, this research is to determine the relationship between Indoor Environmental Quality and occupants' productivity in green buildings. Survey approach was selected under quantitative phenomenon, as this research is focused to determine the relationship between variables quantitatively. Both questionnaire survey and semi-structured interviews were conducted among occupants in green certified office buildings in Sri Lanka. The survey data was analysed using nonparametric statistical analysis techniques; significance testing and Spearman's Correlation. SPSSv.20 software was used in data analysis. The Indoor Environmental Quality factors identified through literature were evaluated to identify significant factors influencing occupants' productivity. According to the test statistics, seven significant factors were identified as the first stage of data analysis where they showed statistically significant correlation to the major Indoor Environmental Quality dimensions. As the second stage of analysis, the relationship between Indoor Environmental Quality factors and occupants' productivity was determined. As the test results showed, air quality and acoustical partitioning factors confirmed a statistically significant weakly positive monotonic correlation whilst system control showed strongly positive monotonic correlation to the occupants' productivity in green buildings. The test results were further discussed by stating the qualitative findings and extant literature. As the outcome of this research, the relationship between significant Indoor Environmental Quality factors and occupants' productivity was reviewed and evaluated. As per the findings of the research, facilitating more provisions on air quality and acoustic quality would effect to ensure the productivity improvements of green building occupants.

Keywords: *Green Buildings; Indoor Environmental Quality; Occupants' Productivity; Sri Lanka.*

1. INTRODUCTION

In recent years, the topic of Indoor Environmental Quality (IEQ) seems as a growing concern where, it was identified as a major factor influencing occupants' health, wellbeing and productivity. Specially, much more attention has focused on the indoor environment in offices in light of growing concern about worker productivity. Further, occupants who are satisfied with the overall environmental quality of their workspace are widely assumed to be more productive (Leaman and Bordass, 2007). Indoor environment mainly includes indoor air quality, thermal quality, visual quality and acoustical quality. The improvement the quality of all these four would ensure the improvement of occupants' comfort, satisfaction and productivity (Clausen and Wyon, 2008). According to a study by Khalil and Husin (2009), building occupants are looking for comfortability to be productive in their workplace. Further, occupants prefer to have comfortability in using and utilizing the facilities and services as it must be fit

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for purpose of the user. In light of facilitating a high quality indoor environment for the building occupants, green building concept is gaining momentum. As many studies found, occupants are more favourably disposed to green buildings due its benefits. Specially, green buildings serve their major expectation of obtaining a comfortable workplace (Leaman and Bordass, 2007; Abbaszadeh *et al.*, 2006 cited Deuble and Dear, 2012). The occupants who satisfied with the overall quality of their working environment are widely assumed to be more productive (Leaman and Bordass, 2007).Even though many previous researches have conducted in the similar research setting, there is a deficiency of the research on the relationship between IEQ factors and occupants' productivity improvements. Further, most of them have focused only on single aspects of the built environment. Thus, this research is aimed to determine the relationships between IEQ factors and occupants' productivity in green buildings.

2. LITERATURE REVIEW

2.1. INDOOR ENVIRONMENTAL QUALITY (IEQ)

The indoor environment is where people spend 90% of their time (Kosonen and Tan, 2004). As the majority of people spend most of their time indoors, there is a continuous and dynamic interaction between occupants and their surroundings that produce physiological and psychological effects on the person (Lan and Lian, 2009). The term Indoor Environmental quality (IEQ) is referring to "the environmental qualities within a building, used especially in relation to the health and comfort of building occupants" (Hobday, 2011). According to a study by Kamaruzzaman *et al.* (2011), it is essential for buildings to have a good quality indoor environment, as it affects the productivity and health of the occupants of the building. IEQ refers to all aspects of the indoor environment that affect the health and well-being of such occupants (Levin, 1995). According to a studies by Prakash (2005), Portman *et al.* (2006 cited Lee *et al.*, 2009) and Lee (2010), IEQ is one of five categories of the LEED (Leadership in Energy and Environmental Design) building assessment system, developed by the Green Building Council of the United States of America including sustainable site, energy and atmosphere, water efficiency, materials and resources, and indoor environmental quality. Henceforth, IEQ generally encompasses factors such as temperature, humidity, ventilation, indoor air quality, day lighting and lighting quality, thermal comfort and access to views. Furthermore, Day lighting and thermal comfort contributed to better IEQ, and had a positive effect on occupant's perception of productivity and performance (Prakash, 2005; Lan and Lian, 2009). As further verified by Atsusaka (2003 cited Chan *et al.*, 2009), enhanced daylight and reduced toxicity in indoor environments can increase employee productivity by up to 16%. Kim and Dear (2011) declared when a building's lighting is perceived as comfortable there is a positive improvement in occupant overall workspace satisfaction (Kim and Dear, 2011).

2.2. INDOOR ENVIRONMENTAL QUALITY IN GREEN BUILDINGS

The quality of the built environment is one of the main goals in many green certification systems. This is because green building certification schemes require building designers and managers to consider the impact of the indoor environment on the health and wellbeing of the office worker. Further, once the evaluation and assessment of the environmental impact of a building is carried out before it is built and when only the representation of the building is available, environmental impacts of that building could be prevented. The first assessment tool was the Building Research Establishment Environmental Assessment Method (BREEAM) (Baldwin, 1998 cited Lacouture *et al.*, 2008) and, the most representative and widely used green assessment tools are Leadership in Energy and Environmental Design (LEED), Comprehensive Assessment System for Building Environmental Efficiency (CASBEE) and Green Star. Although the existing methods and tools have an extended use, LEED has established strong credibility among the experts by increasing its affiliates (Pulselli *et al.*, 2007 and Ding, 2008 cited Lacouture *et al.*, 2008). The following Table 1 shows the Indoor Environment Quality parameters available in green buildings. The indoor environment is one of the major criteria in many green certification systems such as, LEED, and CASBEE etc, which is required to ensure by building designers and managers to obtain the green certification for buildings.

Table 1: IEQ Parameters in Green Buildings

IEQ Factor	LEED	BREEAM	Green Star	CASBEE
Thermal Quality	Controllability of Systems	Local Temperature Control		Room Temperature Setting Variable Loads And Following-Up Control Zoned Control Temperature and Humidity Control
Visual Quality	Low-Emitting Materials Day Lighting	80% Adequately Day Light Window Antiglare Ballets Illuminance Levels Independent Lighting Control	Daylight Daylight Glare Control High Frequency Ballets Electric Lighting Levels	Daylight Factor Openings By Orientation Daylight Devices Glare From Light Fixtures Daylight Control Illuminance Level Uniformity Ratio Of Illuminance Lighting Controllability
Indoor Air Quality	Indoor Chemical and Pollutant Source Control Minimum IAQ Performance Construction IAQ Management Plan	Smoking Clean Carpets	Air Change Effectiveness CO_2 And VOC Monitoring And Control Hazardous Materials	Type Of A/C Co_2 Monitoring Control of Smoking
Acoustic Quality	Controllability of Systems	Noise	Internal Noise Levels	Background Noise Equipment Noise Sound Insulation of Openings Sound Insulation of Partition Walls Sound Absorption

Source: Boonstra and Pettersen (2003); Haapio (2008); Wallhagen, (2010)

2.3. GREEN BUILDINGS IN SRI LANKA

Similarly in Sri Lanka, most of modern buildings have tended to be green certified building to obtain its vital benefits because of indoor environment quality is an important aspect which has received practically no attention in built environments (Ileperuma, 2000). Further, facilitating a high quality working environment for the building occupants is one of the major concerns of obtaining a green certification rather stays as a traditional building. GREEN$^{SL®}$ Rating System of Green Building Council Sri Lanka (GBCSL) has been introduced, with the main aim of fundamentally changing the built environment by creating energy efficient, healthy, productive buildings that reduce or minimise the significant impacts of buildings on the environment (GBCSL, 2010). The Green Building Council of Sri Lanka (GBCSL) came into existence as a result of an emerging trend towards applying the greener concepts for building environment. Moreover, it is uniquely supported by both industry and government institutions across the country. Further, green Buildings in Sri Lanka show a higher completion rate in comparison to other countries in the world. Specially most of office buildings have turned their buildings to green with the expectation of obtaining its ultimate benefits, especially, energy efficiency and IEQ improvements.

Figure 1 shows IEQ parameters considered in GREEN$^{SL®}$ National Green Rating System.

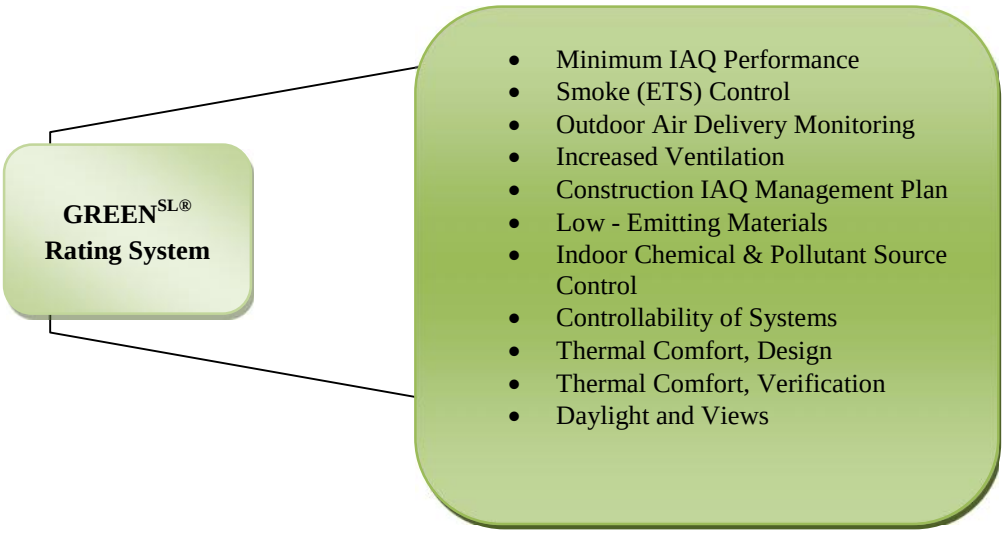

Figure 1: IEQ Parameters in GREEN SL®

2.4. OCCUPANTS' PRODUCTIVITY IN GREEN BUILDINGS

A number of case studies suggest that productivity gains through better quality office environments may be possible. According to case studies by Urban Catalyst Associates (2005) occupants 'productivity is the most significant benefit of green buildings, even though the value of improved occupant productivity and healthier built environments is difficult to calculate. According to the Jones Lang LaSalle's Global Sustainability Perspective (2011), green buildings and their attention to high quality indoor environments provide therefore an ideal background for such considerations. Whilst green developers and builders create healthier working, learning, and living environments, it is not only reducing utility bills, operation and maintenance cost but also increasing occupants' productivity.

2.5. OCCUPANTS' PRODUCTIVITY IN OFFICE ENVIRONMENT

Rolloos (1997 cited Hameed and Amjad, 2009) defined the occupants' productivity as, "productivity is that which people can produce with the least effort". Productivity is also defined by Sutermeister (1976 cited Hameed and Amjad, 2009) as, "output per employee hour, quality considered." However, there is no clear definition of productivity in the office environment. It is because that the office can consist of different jobs and tasks, making it difficult to compare or aggregate and thus, there is a great variation among them (Sullivan*et al.*, 2013). Measuring productivity of occupants in an office environment is a great challenge as it consists of the variety of different jobs and tasks. Among the productivity measurement methods available, most of them are based on quantitative data on operations. As Hadi (1999 cited Miller *et al.*, 2009) believes, productivity measures should be split into three sections, such as, quantifiable and tangible measures, indirect measures, and organisational measures. The technique of perceived productivity was selected as the best approach to evaluate occupants' productivity in this study. Further, it is a widely used rating technique, being relative simple, quick and cheap. Considering the measures and scales used in similar previous studies, five points Likert (ordinal) scale was developed to rate perceived productivity of occupants and the influence of IEQ factors.

2.6. IEQ FACTORS INFLUENCING OCCUPANTS' PRODUCTIVITY

According to a study by Kamaruzzaman *et al.* (2011), it is essential for buildings to have a good quality indoor environment, as it affects the productivity and health of the occupants of the building. Once most of the numerous studies have been verified the relationship between built environment and occupants' productivity, several IEQ factors influencing occupants' productivity were identified by critically reviewing the previous literature (Clements-Croome, 2000; Bartlett and Howard, 2000; Heerwagen, 2000;

Mahdavi and Unzeitig, 2004). Accordingly, 27 IEQ factors influencing occupants' productivity were identified in relation to the thermal quality; visual quality, IAQ and acoustic quality (refer Table 2).

Table 2: IEQ Factors Influencing Occupants' Productivity

Major IEQ Dimensions	Sub Factors
Thermal Quality	Personal Control on Ambient Conditions Temperature Opening Windows Personal Thermal System Control
Visual Quality	Provisions of Day Lighting Radiation and Electromagnetic Fields Electric Lighting Quality Glare Controllable Task-Lighting Illuminance Controllable Lighting Installations Lighting Intensity Colour Personal/Task Lighting Proximity to a Window View to Outdoor Environment
Iaq	Indoor Air Temperature Air Quality Dust Odour Air Freshness Air Movement
Acoustic Quality	Background Sound Level Acoustical Partitioning Sound Privacy System Controls Sound Absorption Materials

As this research aimed, the relationship between the identified factors and occupants' productivity was evaluated. The following section describes the methodology adopted in this study.

3. RESEARCH METHODOLOGY

The survey approach was selected for this study under the quantitative phenomenon as this research aimed to identify the relationship between IEQ and occupants' productivity improvements in green buildings.

A questionnaire survey was conducted among occupants in green certified office buildings in Sri Lanka. Here, the occupants of green certified office buildings in Sri Lanka were selected as the population sample to collect the data. Considering the minimum sample of 30 and, the importance of having a large sample to generalise the survey findings to whole selected population, '100' was selected as suitable sample size for this study. Accordingly, 100 occupants of green certified office buildings in Sri Lanka were selected randomly to distribute questionnaires. 65 questionnaires were returned from the distributed 100 questionnaires.

Although questionnaires may be used as the only data collection method, it may be better to link them with other methods in a multiple-methods research design (Saunders *et al*., 2009). Hence, semi-structured interviews were conducted with ten selected building occupants and professionals in green buildings in order to further prove the validity of research findings. Hence, the test results of correlation were analysed along with the facts which were obtained from the interviews conducted.

3.1. SIGNIFICANCE TESTING AND CORRELATION ANALYSIS

The ordinal data collected from the questionnaire survey were evaluated and analysed by using significance testing and correlation analysis.

As this research requires testing the relationship between built environment factors and occupants' productivity in green buildings, Significance testing was used. It is useful technique to test the likelihood of the relationship (or one more extreme) occurring by chance alone, if there really was no difference in the population from which the sample was drawn (Robson 2002). If the probability of the test statistics or one more extreme having occurred by chance alone is very low (usually $p<0.05$ or lower), there is a statistically significant relationship. This refers to rejecting the Null hypothesis whilst accepting the hypothesis.

Where,

H_0 : $p = 0$ (Null hypothesis)

H_1 : $p \neq 0$

The relationship is not statistically significant when the probability (p-value) is higher than 0.05 (Gardner, 2007).

Statistical significance was tested by setting the significant level to 0.05 to reduce the occurrence of Type I errors. The level of significance of each factor was considered when determining the critical built environment factors, which showed probability less than 0.05.

Correlation analysis is used where a change in one variable is accompanied by a change in another variable, but it is not clear which variable caused the other to change (Saunders, Lewis and Thornhill, 2009).As the survey of this research was designed with five point Likert scale (ordinal scale), Spearman's Correlation was selected as an appropriate method to analyse the data. Statistical analysis was done by using Statistical Package for the Social Science (SPSS) v20 software.

Spearman's Correlation

$$\text{Spearman's coefficient of correlation } (r_s) = 1-\left[\frac{6\sum d_i^2}{n(n^2-1)}\right] \quad \text{(Eq.01)}$$

where, di = difference between ranks of ith pair of the two variables

n = number of pairs of observations

$$t_{cal} = r_s \frac{\sqrt{n-2}}{\sqrt{1-r_s^2}}$$ Distributed "t" with "n-2" degree of freedom

r_s - Rank Correlation Coefficient

d_i - Difference between each rankings

n - Number of objectives

Null Hypothesis H0 : $^{\circ} = 0$ (There is no correlation between rankings)

Alternative Hypothesis H1 : $^{\circ} \neq 0$ (There is a correlation between rankings)

" $^{\circ}$ " is the standard symbol of Correlation Coefficient. In this hypothesis " $^{\circ}$ " is the Rank Correlation coefficient (Crawshaw and Chambers, 2001).

The correlation between IEQ factors and occupants' productivity was evaluated and the significant factors were determined based on the strength and the significance of correlation.

As Saunders et al (2009) mentioned that, the correlation coefficient could take on any value between -1 and +1. A value of +1 represents a perfect positive correlation. The value of -1 represents a perfect negative correlation. Correlation coefficients between -1 and +1 represent weaker positive and negative

correlations, a value of 0 meaning the variables are perfectly independent as illustrated in following Figure 2.

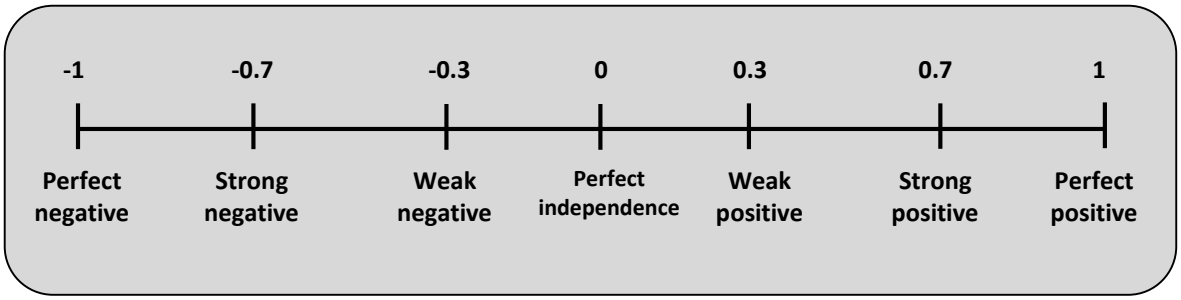

Figure 2: Values of the Correlation Coefficient
Source: Saunders *et al.* (2009)

Considering the rule of thumb in social science research and the evaluation criteria introduced by Saunders *et al.*, (2009), it was considered in this study to interpret the strength of the monotonic correlation of research variables as illustrated in following Table 3.

Table 3: Interpretation of Correlation in This Study

Size of Correlation	Interpretation
0.70 to 1.00 (-0.70 to -1.00)	Perfect correlation
0.30 to 0.70 (-0.30 to -0.70)	Strong correlation
0.00 to 0.30 (0.00 to -0.30)	Weak correlation
0.00	Perfect independence

Source: Saunders *et al.* (2009)

The correlation test results of built environment factors and its interpretation are presented subsequently.

4. RESULTS AND DISCUSSION

4.1. SIGNIFICANT INDOOR ENVIRONMENTAL QUALITY (IEQ) FACTORS

The research analysis was conducted to explicate the potential relationships between the built environment factors and the occupants' productivity in green office buildings. As the first step, significant IEQ parameters were determined by testing the correlation between major IEQ dimensions and the sub factors identified.

Table 4: Significant IEQ factors

	Spearman's Correlation	Sig. (2-Tailed)	N
Thermal Quality			
Opening Windows	.285*	.022	65
Visual Quality			
Controllable Lighting Installations	.260*	.037	65
Personal/Task Lighting	.248*	.047	65
View to Outdoor Environment	.388**	.001	65
Indoor Air Quality			
Air Quality	.253*	.042	65
Acoustic Quality			
System Control	.281*	.023	65
Acoustical Partitioning	.248*	.047	65

* Correlation is significant at the 0.05 level (2-tailed). ** Correlation is significant at the 0.01 level (2-tailed).

The above Table 4 illustrates the significant factors selected for subsequent analysis. Among the other thermal quality related factors, opening windows showed a significant correlation to the major dimension. As further correlation coefficient, it was determined as weakly positive monotonic correlation, thus, selected (Spearman's rho= .285, p= .022).

Controllable lighting installations, personal lighting and view to outdoor environment factors were selected as significant visual quality factors influencing occupants' productivity. Among those, first two factors showed a weakly positive correlation to the visual quality with the correlation coefficient (Spearman's rho) of .260 and.248 respectively (where the Probability values (p-values) are .037 and .047 subsequently). However, according to the evaluation, view to outdoor environment showed a strong positive correlation, as it owned .388 of correlation coefficient (p= .001). According to the sounders' *et al.* (2009), the correlation coefficient values from 0.3 to 0.7 are considered as strong positive correlations, thus selected.

Air quality was selected as another significant factor which showed significant and weakly positive monotonic correlation to the IAQ (Spearman's rho= .253, p= .042). Under the acoustic quality, system control (Spearman's rho= .281, p= .023) and acoustical partitioning (Spearman's rho= .248, p= .047) were determined as significant factors as they showed significant weakly positive correlation to the acoustic quality. Accordingly, seven significant IEQ factors, such as, opening windows,Controllable lighting installations, personal lighting, view to outdoor environment, air quality, system control and acoustical partitioning were determined whilst others are rejected based on the statistical significance of the strength of correlation.

4.2. THE RELATIONSHIP BETWEEN INDOOR ENVIRONMENTAL QUALITY (IEQ) AND OCCUPANTS' PRODUCTIVITY

The significant built environment factors were selected as independent variables whilst occupants' productivity was concerned as dependent. The relation between dependent and independent variables was evaluated by performing rank correlation test.

4.2.1. ASSESSMENT OF CORRELATION

The following Table 5 illustrates the correlationsassessed between significant IEQ factors and occupants' productivity in green buildings, as per the test results of Spearman's Correlation. The test results were extracted from SPSS v.20.

Table 5: Rank Correlation Teat Results of IEQ Factors

	Spearman's Correlation	Sig. (2-tailed)	N
Occupants' Productivity			
Opening Windows	.091	.473	65
Controllable Lighting Installations	.065	.607	65
Personal/Task Lighting	.006	.964	65
View To Outdoor Environment	.022	.862	65
Air Quality	.258*	.038	65
System Control	.347*	.005	65
Acoustical Partitioning	.257*	.039	65

According to the test results of Spearman's Correlation, opening windows showed statistically insignificant correlation to the occupants' productivity (p=.473), even though it showed weak positive monotonic correlation (Spearman's rho=.091). Similarly, controllable lighting installations, personal lighting and view to outdoor environment confirmed a weak positive correlation to occupants' productivity, with the correlation coefficient values of .065, .006 and .022 respectively. However, none of them showed a statistically significant correlation where respective p-values are .607, .964 and .862. Thus, all those four factors were rejected.

As per the test statistics of Spearman's Correlation, three IEQ factors were determined as critical factors influencing occupants' productivity in green buildings where they showed statistically significant correlation to the occupants' productivity with the high statistical significance. Among those, air quality showed statistically significant weakly positive monotonic correlation to occupants' productivity (Spearman's rho= .258, p=.038), whilst, system control showed strongly positive monotonic correlation with the high significance (Spearman's rho=. 347, p= .005). Acoustical partitioning was identified as another critical factor influencing occupants' productivity with the statistically significant weakly positive monotonic correlation (Spearman's rho= .257, p= .039).

4.2.2 DISCUSSION OF SURVEY WITH INTERVIEW RESULTS

From the overall assessment, significant IEQ factors were selected. According to the test statistics, three factors were selected as significant which showed statistically significant weak and strong monotonic correlation to occupants' productivity in green buildings. However, none of the factors were generally perceived as perfectly (positive or negative) correlated factors.

This confirm in the extant literature and the findings of the qualitative inquiry, that indeed the potential of selected IEQ factors. Therefore, the factors which showed statistically significant correlation to the major dimension were selected for subsequent analysis even though the strength of the relationship was at moderate and weak levels.

As Hinkle et al., (1998) further verifies that, "a small correlation coefficient is just as good as a high correlation, because such most relationships are a long way from perfect" (Hinkle *et al.*, 1998)

"Typically, a single independent variable in social research seldom accounts for more than 25% to 30% of the variance in a dependent variable, and often for as little as 2% to 5%" (Knoke *et al.*, 2002, p.132)

Further, the overall assessment of the strong or weak correlation to influence occupants' productivity also confirms that indeed of having a varying significance to influence occupants' productivity. The following Table 6 indicates the overall assessment of the significant built environment factors.

Table 6: Significant IEQ Actors Influencing Occupants' Productivity in Green Buildings

IEQ Factor	Statistical Significance (P-Value)	Coefficient of Correlation (Spearman's Rho)	Strength of Correlation			
			Perfect	Strong	Weak	Perfect Independence
Air Quality	.038	.258*			√	
System Control	.005	.347*		√		
Acoustical Partitioning	.039	.257*			√	

The discussion of test results along with the qualitative findings and the extant literature is presented subsequently.

4.2.3. AIR QUALITY AND OCCUPANTS' PRODUCTIVITY

According to the test statistics of probability and Spearman's Correlation, air quality was identified as critical IEQ factor influencing occupants' productivity. Air quality showed a significant and weakly positive monotonic correlation to the occupants' productivity (Spearman's rho=.258, p=.038). As it confirms, the slightly improvement of air quality in green buildings would slightly increase the occupants' productivity. The results would be further verified by qualitative findings. As stated by Human Resource Manager in o green building B, "*it is really comfortable to work in green buildings with the high quality indoor air provided. We are maintaining required air quality standards to provide*

workers a comfortable environment. And, the complaints from our workers are considerably less and they also work very efficiently." It is further proved by an Engineer in Green Building C as *"there is an optimum use of natural air inside the building with the less use of air conditioning. However, our workers have changed them suited to work in this green environment. I also work very happily thus; personal productivity is at high level."*

As it is further proved by the study of Heerwagen (2000), the improved air quality is likely to have a greatest impact on wellbeing and personal productivity. Further, studies using self-assessments of productivity have found strong relationships to air quality factors. Among those, air quality was identified as a critical factor influencing occupants' productivity in green buildings by testing the literature existed on the relationship between air quality and occupants' productivity.

Nonetheless, the existing studies have shown a strong association between Indoor Air Quality, Sick Building Syndrome symptoms and work performance (Heerwagen, 2000; Atkin and Brooks, 2000). Accordingly, a significant effect of air quality to enhance occupants' productivity in green buildings could be identified. Hence, it creates an importance to introduce further provisions on IAQ, which will enhance the occupants' productivity, as they work with comfort and greater satisfaction in green working environment. Hence, air quality requires a further consideration, as it showed significant relationship to occupants' productivity in green office buildings. Hence, the existing provisions of air quality in GREEN$^{SL®}$ National Rating System could also be important to revise by adopting new provisions and strategies, such as, the implementation of air quality standards of Occupational Safety and Health Administration (OSHA) and Illinois Department of Public Health (IDHP) to fulfill the IAQ requirement of green buildings etc.

4.2.4. ACOUSTIC QUALITY AND OCCUPANTS' PRODUCTIVITY

Noise is distracting the concentration on work or study and provides less than ideal working and learning environments, thus influencing occupants' productivity. Among the other acoustic quality related factors, system control and acoustical partitioning were identified as the significant factors which showed statistically significant correlation to the acoustic quality in green buildings. In the correlation analysis, system control and acoustical partitioning factors (independent variables) were evaluated with the occupants' productivity (dependent variable).As SPSS output showed, both of them proved a significant association to the occupants' productivity, where, system control showed strongly positive monotonic correlation (Spearman's rho=.347, p=.005) whilst acoustical partitioning showed weakly positive monotonic correlation (Spearman's rho=.347, p=.005). The monotonic correlation of both factors confirms the improvement of occupants' productivity in green buildings with respect to the provisions provided on acoustic comfort in green buildings.

Hence, the provisions of system control and acoustical partitioning can increase to ensure occupants' productivity improvements. As stated by Quantity Surveyor in Green Building C *"we are working here very happily as the environment is comfortable with this natural environment than our previous building. However, it would be beneficial to further concern on controlling the noise generated inside and outside of the building."* It is further proved by Branch Manager in Green Building A as *"Green building is a new concept and we have introduced to this new building. Environment is really comfortable to work and, it increases our productivity as you asked from me. But, I would like to highlight one area that needs to be improved further. The noise generated inside the building is really disturbing to our day to day works. As I think, more provisions should be introduced to reduce that noise generation."*

According to the previous productivity related studies, acoustic quality has a potential link to occupants' productivity (Mahdavi and Unzeitig, 2004),Clements-Croome, 2002; Kim and Dear, 2011). A study by Frontczak and Wargocki (2010) further proved that noise is distracting the concentration on work or study and provides less than ideal working and learning environments. Further, it could be from internal sources such as, building systems, office works and workers etc. and from background noise generating sources. One of main reasons is that the design techniques that are utilized in green buildings to improve energy efficiency, sustainability, and other IEQ aspects of buildings tend to worsen acoustic defects. Often design team members are simply not aware of the impact of their design decisions on the acoustics of the building (Hodgson, 2008). Henceforth, major consideration should be given on the acoustic quality in

green buildings. According to the research findings, system control and acoustical partitioning have potential relationship to occupants' productivity. Hence, the rating system should provide relevant provisions to ensure acoustical quality in green buildings. The provisions and strategies are required to enhance the controllability of systems to reduce the noise generated. Office spaces could also design with acoustical partitioning to reduce both internal and external noises. Use of sound absorbers, acoustical ceiling over building system installed areas; acoustical tiling can be identified as further provisions to enhance acoustic quality in green buildings.

Accordingly, the relationship between indoor environment quality and occupants' productivity was tested and determined. Based on both statistical and qualitative findings, air quality, system control and acoustical partitioning were identified as the significant IEQ factors influencing occupants' productivity in green buildings. Further, the relation between those factors and occupants' productivity was identified and further improvements on green buildings were suggested.

5. SUMMARY

In light of growing concern on facilitating a quality indoor environment for building occupants, green building became momentum. Most of organisations tend to be green from their tradition work setting so as to obtain its ultimate benefits. Specially, much more attention has focused on the indoor environment in offices as it was identified as a major factor influencing occupants' productivity. Indoor environmental quality mainly refers to the thermal quality, visual quality, IAQ and the acoustic quality. By reviewing key literature, 27 IEQ factors influencing occupants' productivity were identified. As the purpose of this research, correlation analysis was performed to identify significant factors influencing occupants' productivity. According to the test results of Spearman's Correlation, seven significant factors were determined such as, opening windows, air quality, controllable task lighting, personal lighting, and view to outdoor environment, system control and acoustical partitioning. As the second stage of analysis, the relationship between IEQ and occupants' productivity was determined. As the test results showed, air quality and acoustical partitioning factors showed a statistically significant and weakly positive correlation whilst system control showed strongly positive monotonic correlation to occupants' productivity in green buildings.

Thus, facilitating more provisions specially to ensure air quality and acoustical quality would effect to ensure productivity improvements of green building occupants.

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