DIFFERENTIATING GREEN BUILDINGS FROM CONVENTIONAL BUILDINGS: ENVIRONMENTAL PERFORMANCE PERSPECTIVE

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ABSTRACT

In the current situation, where people concerns about sustainability environment, building occupants seek to be comfortable and productive in their workplace. Occupants with local control over their environment generally have an improvement in their work effort and productivity. However, work productivity of occupants can be de-motivated and interrupted due to poor environmental conditions. Thus, the intervention to ensure a healthy working environment should always be the first step towards improving productivity. In the governing concern on improving occupant's working environment, Green Building movement is fast becoming a necessity. It is therefore impressive that there is already emerging national consensus on the definition of a green building and a rapidly increasing number of green projects in both the public and private sectors. Green buildings can be defined in various ways however, giving definition compared to 'conventional' buildings is a supplementary problem. There is no doubt that the term has a very positive connotation. Further, green buildings generate lot of benefits to people and the environment. However, no evidence that the level of occupant comfort and satisfaction are greater in 'green' rather than conventional buildings.

Hence, this study was aimed to identify facts for differentiating green buildings from conventional buildings in terms of environmental performance. The available literature was reviewed and preliminary investigation was conducted in selected green rated and non-green buildings. The indoor environment quality criteria which is developed based on GREENSL® rating system was evaluated in selected buildings to identify differences between green and conventional buildings. According to the results of literature survey and preliminary investigation, green buildings showed high environmental performance compared to conventional buildings in terms of indoor air quality, thermal comfort and lighting quality whilst there was a less satisfaction with acoustic comfort in green buildings. However, the success of green buildings depends on the quality and efficiency of the installed green systems. The rating system can be used as the common language and standards of measurement to define green buildings, differentiating from conventional buildings.

Keywords: *Conventional Building; Environmental Performance; Green Building; GREENSL® Rating System.*

1. INTRODUCTION

An unsatisfactory physical environment can lead to occupant dissatisfaction. In the current situation, where people concerns about sustainability environment, building occupants seek to be comfortable and productive in their workplace. Further, occupants demand to have priority in terms of comfortability to use and utilise the facilities and services as it must be fit for purpose of the user (Khalil and Husin, 2009). In the governing concern on improving occupant's working environment, Green Building (GB) movement or sustainable development is fast becoming a necessity (Prakash, 2005; Singh *et al*, 2009). The benefits of GBs related to indoor environmental quality improvements are the reduction on health costs and the increase on occupants' productivity through their perceived satisfaction towards work areas (Ross and Lopez-Alcala, 2006; Edwards, 2003; Kats, 2003; Ries, 2006 cited Lacouture *et al*., 2008). It is therefore impressive that there is already an emerging national consensus on the definition of a green building and a rapidly increasing number of green projects in both the public and private sectors. Many buildings are fast moving into green buildings from their traditional phenomenon due to its social, economical and

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environmental benefits. Especially green building design makes sure that the buildings are more efficient, productive and healthy due to enhanced indoor environments. Further, green building practices are perceived by many construction industry professionals to be part of the solution to problems regarding indoor environment of buildings. Even though, green buildings can be defined in various ways, giving correct definition to the term 'green' is supplementary problem compared to 'conventional' buildings. However, there is no doubt that the term has a very positive connotation. Further, green buildings generate lot of benefits to people and the environment. However, no evidence that level of occupant comfort and satisfaction are greater in 'green' rather than conventional buildings.

Hence, the purpose of this study was to identify the facts on differentiating green buildings from conventional buildings in terms of environmental performance. The GREENSL® rating system was used as the basis to evaluate environmental performance. The following section reviews the secondary data relating to the environmental performance in green buildings.

2. LITERATURE REVIEW

2.1. GREEN BUILDING

A study by Edward (1998 cited Karkanias *et al*., 2010) mentioned that the concept of green building has applied in most of the countries as to reduce the impact of buildings on environment and human health. According to a study by Kohler (1999), giving correct definition to the term 'green' is supplementary problem. However, there is no doubt that the term has a very positive connotation, but it is not quite clear why day lighting and acoustic protection should specifically refer to `green' buildings (Rees, 1992 cited Kohler, 1999).

The term 'green building' can be defined in various ways as mentioned in Table 1.

Table 1: Definitions of Green Buildings

Year	Source	Definitions
2000	Batuwangala	'a building, which is designed, built, operated, maintained or reused with objectives to protect occupant health, improve employee productivity, use wisely natural resources and reduce the environmental impact.'
2009	Edwin, Qian and Lam	'the practice of creating and using healthier and more resource-efficient models of construction, renovation, operation, maintenance and demolition.'
2012	Deuble and Dear	'green buildings (also referred to as green-intent buildings) by definition, aim to reduce their environmental impact by using less energy in both their construction and operation. Thus, buildings featuring natural ventilation capabilities are typically defined nowadays as green buildings.'
	Rashid, Spreckelmeyer, and Angrisano	'an any building with a Leadership in Energy and Environmental Design (LEED) certification from the USGBC is considered a green building.'
2013	Gou *et al.*	'as those featuring natural ventilation capabilities, i.e. low-energy or free-running buildings, are now at the forefront of building research and climate change mitigation scenarios.'

Through the various definitions, green building can be identified as a new building philosophy, encouraging the use of more environment friendly materials, and implementation of techniques to save resources and specially the improvement of indoor environmental quality, among others (Thormark, 2006 cited Lacouture *et al*., 2008). It offers an opportunity to create environmentally efficient buildings by using an integrated approach of design so that the negative impact of building on the environment and occupants' is reduced

(Ali *et al*., 2009 cited Hikmat *et al*., 2009). Henceforth, green building practices are perceived by many construction industry professionals to be part of the solution to problems regarding indoor environment of buildings (Hashim *et al*., 2011).

Green Certification

The success of green buildings depends on the quality and efficiency of the installed green systems. If the building lacks these essential features, it will neither accomplish the environmental goals nor generate the estimated benefits. Thus, the market requires a common way to differentiate green buildings from traditional buildings through the use of standard, transparent, objective, and verifiable measures of green, which assure that the minimum green requirements have been reached (Lacouture *et al*., 2008). Hence, a range of green building rating systems, protocols, guidelines and standards has been developed in the past 20 years that respond to the need to evaluate and benchmark levels of building achievement in the green revolution (Yudelson, 2008, 2010 cited Gou *et al*., 2013). Wallhagen (2010) further verified that the green assessment tools can also be used to produce guidelines, benchmarks, ratings and incentives to construct buildings with low environmental impact and to work as environmental management tools. Further, green rating tools establish common language and standards of measurement to define green buildings differentiating from traditional buildings (Yudelson, 2008, 2010 cited Gou *et al*., 2013).

The first of such tools 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, Green Building Index (GBI) - Malaysia, Green Mark - Singapore, Hong Kong Building Environmental Assessment Method (HK-BEAM) and The Pearl Rating System for Estidama (Sustainability) (Roderick *et al*., n.d.; Boonstra and Pettersen, 2003; McKay, 2007). Similarly in Sri Lanka, there is a local rating system called GREENSL® introduced by the Green Building Council in Sri Lanka (GBCSL). The Green Building Council of Sri Lanka (GBCSL) came into existence as a result of an emerging trend towards applying the greener concepts for built environment (GBCSL, 2011).

2.2. ENVIRONMENTAL PERFORMANCE IN GREEN BUILDINGS

The success of the project depends on the implementation of environmental criteria (Lippaiova and Sebestyen, n.d.). As Lippaiova and Sebestyen further mentioned that the aim of green management is to satisfy the demands of users and the natural environment. Previous studies show that the environmental performance can be enhanced by moving to green from conventional buildings. According to a study by National Research Council Canada (2012), the strongest driver for the green building movement is the goal of reducing building energy use. As it further mentions another large credit category in green building rating systems is indoor environment quality (IEQ) in most of the green rating systems.

Further, the environmental conscious criteria are also the part of the quality criteria as the indoor environmental quality has positive effects on productivity and health (Lippaiova and Sebestyen, n.d.).Thus, 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.

Table 2 shows that the level of consideration of few green building certification systems on indoor environment. Indoor environment is one of major criteria in many green certifications systems such as, LEED, and CASBEE, which is required to ensure by building designers and managers to obtain the green certification for buildings.

Table 2: Indoor Environment Quality Criteria in Green Assessment Tools

	% of IEQ						
CRITERIA	**LEED**	**BREEAM**	**CASBEE**	**Green Star**	**GBI Tool**	**Green Mark**	**GREEN SL**
Management	04	16	05	09	39	-	04
IEQ	21	16	23	19	11	04	13
Energy	23	15	18	18	23	56	22
Transport	06	13	00	19			
Water	10	05	03	12	12	09	14
Materials	18	11	12	19	09		14
Land use	08	08	19	06	-	-	-
Environment protection	10	15	20	07	-	26	-
Innovation	-	-	-	-	06	-	04
Sustainable sites	-	-	-	-	-	-	25
Social and cultural awareness	-	-	-	-	-	-	04
Other features	-	-	-	-	-	05	-

Source: Boonstra and Pettersen (2003); Haapio (2008); Wallhagen (2010); InBuilt (2010); GBCSL (2011); BCA Green Mark (2013)

The superior indoor environments offered by green buildings will lead to more satisfied occupants with higher levels of well-being, and thus to better outcomes for the organisations that employ them. There is abundant evidence that better indoor environments do lead to such positive outcomes (Newsham *et al*., 2008; Newsham *et al*, 2009b, Thayer *et al*., 2010 cited NRCC, 2012).

Table 3: IEQ Parameters in Green Buildings

IEQ factor	**LEED**	**BREEAM**	**Green Star**	**CASBEE**	**GREENSL®**
Temperature and humidity	Controllability of systems	Local temperature control		Room temperature setting Variable loads and following-up control Zoned control Temperature and humidity control	Low - Emitting Materials Indoor Chemical and Pollutant Source Control
Acoustic	Controllability of systems	Noise	Internal noise levels	Background noise Equipment noise Sound insulation of openings Sound insulation of partition walls Sound absorption	Controllability of Systems
Ventilation	Environmental tobacco smoke control CO_2 monitoring Ventilation efficiency	Operable windows Air intake Fresh air	Ventilation rates	Ventilation rate Natural ventilation performance Consideration for outside air intake Air supply planning	Monitoring Increased Ventilation

IEQ factor	LEED	BREEAM	Green Star	CASBEE	GREENSL®
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	Minimum IAQ Performance Smoke (ETS) Control Outdoor Air Delivery Construction IAQ Management Plan
Day Lighting and Lighting 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	Daylight and Views
Thermal Comfort	Thermal comfort	Thermal comfort	Thermal comfort	-	Thermal Comfort,
Access to Views	Views	Desks location	External views	-	Daylight and Views

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

As the above Table 3 presents that several measures relating to environmental performance can be identified. However, indoor air quality, acoustic quality, day lighting and lighting quality and thermal comfort were selected as main aspects to evaluate environmental performance in green and conventional building through preliminary investigation. The environmental performance evaluation framework was developed based on key literature findings as mentioned in following Figure 1.

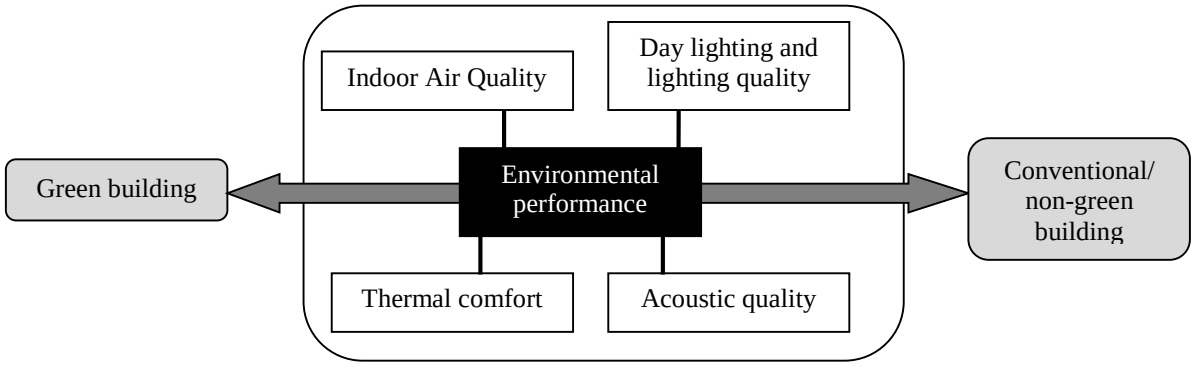

Figure 1: Environmental Performance Evaluation Framework

3. RESEARCH METHODOLOGY

The research was designed as two stages; literature survey (Stage - i) and preliminary investigation (Stage - ii). As the first stage, a comprehensive literature survey was conducted by referring key research papers in the areas of green buildings, IEQ parameters in several green building criteria and environmental performance factors. The environmental performance evaluation framework is developed based on key literature findings (refer Figure 2).

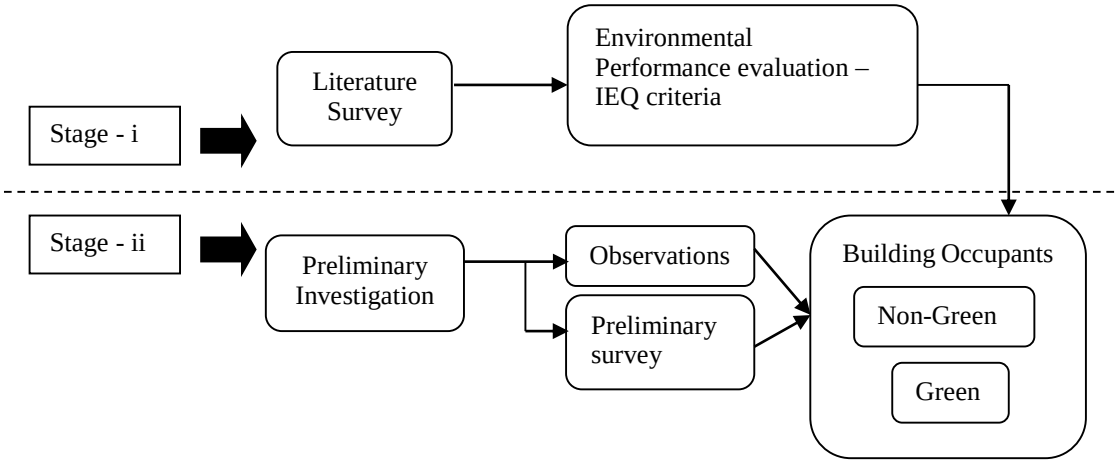

Figure 2: Stages of Research Design

The second stage of the research consists of a preliminary investigation thus; observations and preliminary survey were conducted with occupants in selected green and non-green buildings in Sri Lanka. Buildings to conducting preliminary investigation were selected based on green certification. Hence, the buildings with green certification were selected as green buildings, whilst buildings which have not obtained green certification were selected as non-green/conventional buildings. A sample of 30 occupants of green and non-green buildings was randomly selected and surveyed to collect the data. Observations and preliminary survey was done considering IEQ parameters in GREENSL® rating system as the evaluation criteria. It was used as the basis to evaluate and identify environmental performance features and major differences between green and non-green buildings.

The data collected through preliminary investigation were evaluated to identify environmental performance features in green buildings compared to conventional/non-green buildings. Following section 4 describes the analysis and findings of primary data collected through preliminary investigation.

4. RESEARCH FINDINGS AND DISCUSSION

As this research paper is based on preliminary investigation conducted at the beginning of this research study, this section is intended to present key research findings relating to the difference between green and non-green buildings in terms of the environmental performance.

As the researcher observed, the buildings with green certification had been implemented several IEQ measures as it is a major requirement to obtained credits for environmental performance. Hence, green buildings have been improved their indoor environments considering IEQ measures given in the local rating system. IAQ and ventilation, thermal comfort, day lighting and lighting quality and the acoustic quality factors were considered in data analysis to find major differences in between green and non-green building environments.

4.1. IAQ AND VENTILATION

According to the preliminary investigation, most of the occupants of green buildings had high satisfaction with air quality compared to non-green/conventional buildings. Most of them are preferred to work near operable windows with natural ventilation, as the building has been provided automatic air quality and polluter controlling features. Further, smoking areas which have been designed at the exterior is one of the other positive features in green buildings.

Compared to non-green buildings, green buildings facilitate high quality environment with quality indoor air as it gains maximum benefit from natural ventilation with the required controls on contaminants. Therefore, green buildings rated significantly higher satisfaction for IAQ and ventilation. This is due to the implementation of many strategies to enhance IAQ and to maximally use natural ventilation by facilitating comfortable environment to building occupants as mentioned in Figure 3.

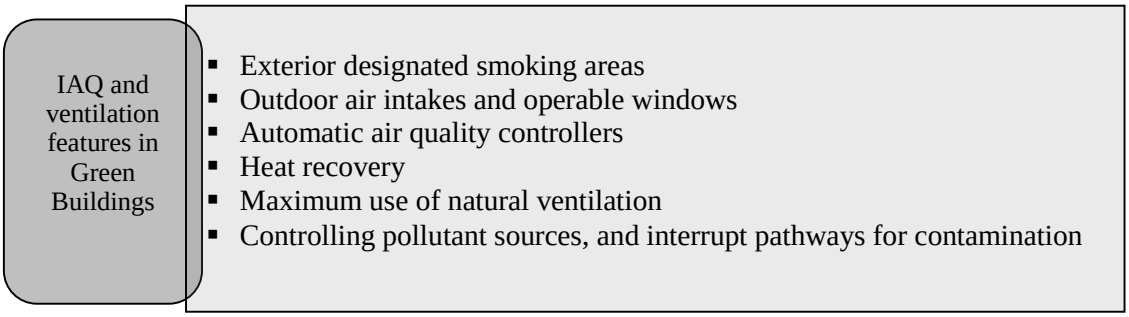

Figure 3: IAQ Features in Green Buildings

4.2. THERMAL COMFORT

The green buildings have been designed consisting comfortable thermal environment by applying several strategies as mentioned in Figure 4. In addition, occupants of green buildings indicated that they were less likely to prefer a change in thermal conditions. However, individual controllers had been made them more comfortable within the working environment in green buildings.

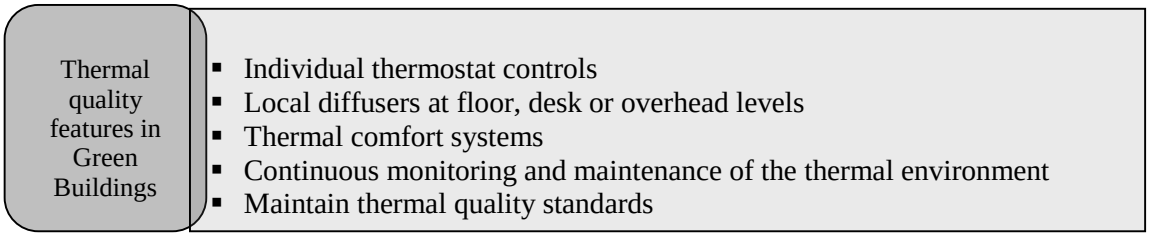

Figure 4: Thermal Quality Features in Green Buildings

Further, compared to conventional work setting, green buildings have designed with monitoring and controlling systems to maintain thermal quality standards. Most of the occupants stated that they have not felt uncomfortable in thermal environment while they are working. Thus, the data collected through preliminary investigation shows that compared to conventional/non-green buildings; there are highly satisfied occupants with thermal comfort in green buildings.

4.3. DAY LIGHTING AND LIGHTING QUALITY

Even though green buildings have been implemented several strategies to enhance the lighting quality and visual comfort, the investigation did not show a big difference or considerable improvement in green buildings compared to non-green buildings. However, occupants were satisfied with their access to view of outside environment in green buildings rather in conventional buildings.

It is because that the green buildings have lighting conditions closer to recommended practice, and provide more access to daylight, than conventional buildings. Further, green buildings have designed with following day lighting strategies (refer Figure 5) to make occupants more comfortable in their working environment compared to non-green buildings.

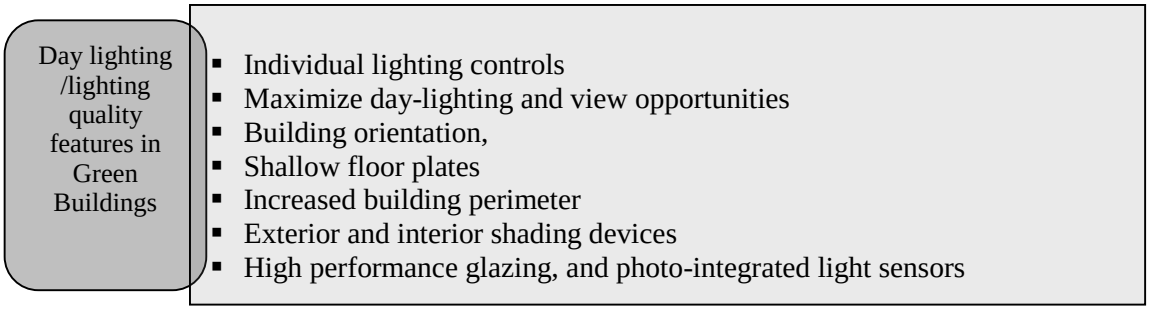

Figure 5: Day Lighting and Lighting Quality Features in Green Buildings

4.4. ACOUSTIC QUALITY

According to the preliminary investigation, one design feature of the IEQ that continuous to be a problem is acoustic. Even though green buildings had high satisfaction in terms of IAQ and thermal comfort compared to conventional buildings, it showed considerable decrease in satisfaction of acoustic comfort in green buildings. As the design features of green buildings have been considered the maximum use of natural ventilation and day lighting with the access to view outside environment to facilitate comfortable environment to building occupants, it has created high background noise levels in green buildings than conventional buildings. Most of the occupants said that they are always feeling uncomfortable with background noises generated. Thus, most of them feel uncomfortable to work near operable windows. In addition, the use of glass in the building enclosure is also driven to make acoustically uncomfortable indoor environment as it lead to decrease sound isolation between interior spaces even though interior glass partitions help to transmit day light into building.

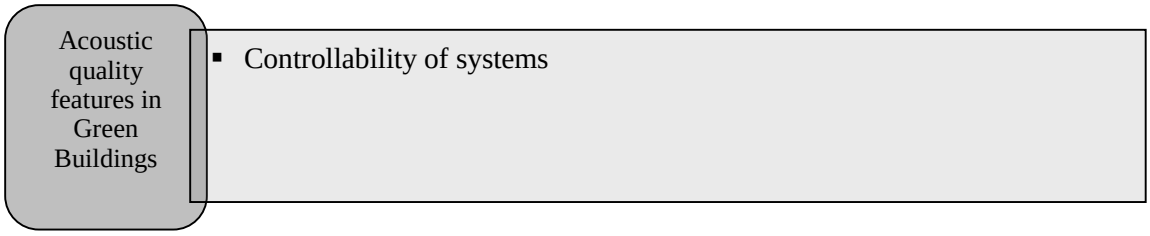

Figure 6: Day Lighting and Lighting Quality Features in Green Buildings

However, no additional features have been introduced in green buildings to ensure acoustic quality within the building environment. The only strategy introduced by the local rating system is making provisions to ensure controllability of systems within the building premises (refer Figure 6). Green buildings are required to implementing additional strategies to reduce acoustic quality issues beard by the occupants.

When considering the environmental performance in green and conventional buildings, there are several similarities and differences can be identified in terms of IAQ, thermal comfort, acoustic quality and the visual comfort. Green buildings shows highly positive response towards thermal comfort and IAQ compared to conventional buildings. Hence, in green buildings, satisfaction with thermal comfort and IAQ has been increased greatly. Lighting quality also should be further considered whilst the satisfaction of occupants on acoustic quality declined considerably. Further, the overall scoring of building occupants for environmental performance is much higher in green buildings compared to conventional buildings.

5. SUMMARY

As the major purpose, this study was aimed to evaluate green and non-green built environments in order to differentiate such two building categories in terms of environmental performance features. As the results of preliminary investigation, occupants of green buildings were more satisfied with IAQ and thermal comfort compared to conventional buildings. Further, there is no big difference has been shown in occupants' satisfaction on lighting quality in both green and conventional buildings. Green occupants had been more satisfied to work connected with outside environment. However, the satisfaction on acoustic quality in green buildings declined slightly with high background noise due to maximum use of open areas and glass interiors. Thus, careful and coordinated design as well as good acoustic strategies should be implemented throughout the design process by introducing them through local green rating systems. The credit allocation for acoustic quality aspect in GREENSL® can be increased out of 13 IEQ credits. By considering the research findings, green buildings show high environmental performance differentiating from conventional buildings. However, it was rare for all green buildings to perform better environmental performance than their conventional buildings. It is because that the success of green buildings depends on the quality and efficiency of the installed green systems. Therefore, the rating system can be used as the common language and standards of measurement to define green buildings differentiating from conventional buildings.

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