FACTORS AFFECTING THE INDOOR ENVIRONMENTAL QUALITY IN SRI LANKA: GREEN VS. CONVENTIONAL HOTEL BUILDINGS

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ABSTRACT

The hotel building sector is now using sustainable design and construction practices thereby helping to prevent environmental pollution. Green building practices are capable of promoting a healthy and comfortable indoor environment for hotel occupants (including guests and staff). Some criticism has been made by occupants of green buildings on the accuracy of the certification process and the performance of LEED certified buildings. Therefore, this study is aimed at identifying the key factors affecting the Indoor Environmental Quality (IEQ) of green buildings compared to that of conventional hotel buildings by evaluating building performance. Firstly, a literature survey was conducted to identify the importance of IEQ in green buildings and the methods of evaluating IEQ performance. Subsequently, key and sub factors relating to IEQ performance identified from the literature review were validated through expert interviews. A questionnaire survey and semi structured interviews were used as data collection techniques by making use of two green buildings and two conventional buildings. The data was analysed using Mann-Whitney U-test and "Nvivo 10" software. The analysis revealed that green hotels provide an overall IEQ performance that is higher than that of conventional hotels. However, factors such as lighting, acoustics and the degree of personal control that occupants have on the indoor environment were comparatively less satisfactory in green hotels. The paper also discussed the reasons for the low satisfaction of IEQ in respect of these factors. Finally this study confirms that the hotel industry needs to consider a climate responsive design to ensure a better IEQ and pay attention to post occupancy evaluation throughout the life cycle of a building.

Keywords: *Green buildings; Indoor Environmental Quality (IEQ); Occupants' Satisfaction; Sustainability.*

1. INTRODUCTION

IEQ refers to the quality of a building's indoor environment in relation to the health and wellbeing of those who occupy the space within it (Mallawaarachchi *et al*., 2012). Indoor air quality, thermal comfort, acoustics, day light and lighting quality are the factors that determine the indoor building performance in the building sector (Parkin, 2000). Industrial, commercial, residential and hospitality sectors are responsible for polluting the environment as they satisfy the occupants and end users of their buildings to reap economic and financial benefits (Tzschentke *et al*., 2004). These industries are adopting green building practices to generate a healthy environment for the occupants of their buildings, increase the quality of indoor environment and improve social, economic and environmental sustainability for the benefit of both present and future generations (Walker *et al*., 2007). The hotel industry plays a vital role in the economy and sustainability and is gradually becoming an issue with business and guest interests (Chan and Chan, 2004). The comfort of the guests and their willingness to return are factors that have a significant impact on the success of the hotel sector and the have to adopt green design and construction practices to save energy, water, and other resources thereby helping to prevent the pollution of the environment at increasing costs, and with economic, social and environmental responsibility (Schor, 2008).

The hotel industry being an environmentally responsible industry, the evaluation of its building performance is essential to identify how their services and buildings assist to achieve the business goals and occupants' needs (Fischer, 2009). According to Mallawaarachchi et al. (2012), most of the industries

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use several assessment tools and techniques. Among them, the U.S. Green Building Council's LEED rating system act is leading green certificate rating systems. LEED certification has progressively contributed to decreasing IEQ and increasing energy savings during the year 2009 through new construction practices. According to Krik (2005), the reduction of credits in the IEQ category can increase to ensure resource conservation, which could be a reason for a conflict between guest comfort and green building practices in hotels. Therefore occupants of green certified buildings has low satisfaction and comfort (McLennan, 2004; Boecker *et al.*, 2009). IEQ experts state that to create healthy spaces in LEED certified green buildings, industries need to look forward to appropriate and applicable green practices. It is derived that there is necessary to improve green building practices that can be implemented throughout a building life cycle to minimise environmental impact, increase social and economic benefits and enhance guest satisfaction and comfort (Cassidy, 2003).

In both developed and developing countries, the previous studies have majorly examined on office, university and factory buildings, and there has been almost no studies on the user satisfaction of other buildings. In Sri Lanka, a previous research has focused on "IEQ evaluation in green certified office and factory buildings" (Samaranayake and De Silva, 2010) to identify the key factors that affect the indoor environmental quality of green buildings and appropriate and suitable green building practices that will facilitate the highest LEED rating while providing a comfortable and a healthy environment for the occupants in the hospitality sector. Considering the statistics on hotel sector in Sri Lanka, the economic indicators expect a growth of 22.3% (Central Bank of Sri Lanka, 2013). Maintaining guest satisfaction and creating a healthy work place are major considerations of the hotel buildings. Nowadays, a majority of hotel buildings in Sri Lanka have been able to attain the LEED certification (Green buildings) which governs the standards of the facilities, especially the higher environmental responsibility. Still, a proper comparison between Green hotel buildings and conventional hotel buildings for maintaining better indoor environmental quality has not been done. Hence, this research study focuses on identifying the key factors that affect the indoor environmental quality of green hotel buildings compared to conventional hotel buildings through the evaluation of building performance. Further, identifying the key factors implies the importance and the impact on the quality of indoor environment of hospitality green buildings. In order to achieve the aim, the following objectives were formulated.

- To identify evaluation methods of IEQ performance of hotel buildings in Sri Lanka
- To identify significant key and sub indicators relating to IEQ performance in green and conventional hotel buildings in Sri Lanka
- To evaluate the current performance of IEQ in relation to the identified significant indicators in green and conventional hotel buildings
- To propose strategies to enhance IEQ of green hotel buildings in Sri Lanka

2. THE CONCEPT OF SUSTAINABLE DEVELOPMENT

Buildings have a huge effect on climate change, generation of waste, indoor and outdoor environmental pollution (Zimmermann *et al.*, 2005). According to Douglas (1996), the term 'Sustainable Development' can be explained as a mode of improving the quality of life and allowing people to live in a healthy environment under enhanced social, economic and environmental conditions. Green building is a new trend in the construction industry (Kubba, 2012). According to USGBC (2009), the key features of green buildings are sustainable sites, water efficiency, energy and atmosphere, materials and resources, indoor environmental quality and operation and maintenance. A green building has to have high efficiency in the use of energy, water and materials, and a reduced impact on the health of its occupants and its environment throughout its life-cycle.

2.1. INDOOR ENVIRONMENTAL QUALITY

The concept of IEQ is a major factor of concern for ensuring "sustainability" (Catalina and Iordache, 2011). Increased positive health effect is a priority in the design of buildings as people spend on average, 90% of their time indoors. The effect of indoor air on people is hundred times more than that of outdoor air. Air, thermal, lighting and acoustic qualities significantly affect IEQ (Mahbob *et al.*, 2011). A good IEQ performance will enhance work place conditions and this in turn will reduce complaints from end

users (Catalina and Iordache, 2011). Apart from physical and environmental factors, performance factors such as office layout, amount of space, privacy, office furniture and furnishings, cleaning and maintenance, access and ability of having personal control over indoor air quality have a greater influence on IEQ performance (Lombardi, 2011). In any type of building overall occupancy satisfaction is quite important, as otherwise there can be building sick syndrome, absenteeism and high turnover and low occupants comfort (Lai and Yik, 2009). Thus, buildings have a responsibility to facilitate better indoor environmental quality for their occupants and therefore the maintenance and evaluation of IEQ factors over a life cycle of building has become very necessary.

2.2. IEQ EVALUATION METHOD

Preiser (1995) has stated that for the evaluation of environmental performance of buildings, several environmental methodologies and methods are presently in place. Potbhare *et al.,* (2009) have stated that Sri Lanka has adapted to the sustainable building culture and green building rating systems for the built environment are recognized as a standard for sustainable building design and construction practices. The primary goal of LEED is to support green building practices in order to deliver environmentally responsible healthy environments for building occupants. According to Amarathunga and Barldry (1998), there are objective and subjective measurement evaluation techniques. Among those, Post Occupancy Evaluation (POE) is the appropriate technique to evaluate occupant's satisfaction and comfort. POE is a measurement of building performance throughout the life cycle of a building from its initial to end phase". Marans (1984) has stated that POE is a formal evaluation of a building by its occupants after it has been completed, in order to identify areas that do not meet users' requirements.

2.3. AN OVERVIEW OF HOTEL SECTOR

The hotel industry is playing a key role in the economic development of Sri Lanka (Bocker *et al.,* 2009). The main goal of hotel buildings is the improvement of the guest's satisfaction which will lead to the productivity of the workers. Most of the guests and customers arrive from foreign countries and there are guidelines regarding the provision of health, safety and welfare of the workers. As a result of this, most of the hotels in Sri Lanka have good ventilation systems and the IEQ is regularly monitored by health and environmental officers of the Government (Saheed, 2005). However, issues relating to IEQ performance can be seen in large and luxury hotel buildings as a result of improper lighting, acoustic, thermal factors and IAQ (Birt and Newsham, 2009). Some of the visitors have complained about IEQ related issues. Dustiness of the indoor environment is still there. Dust is normally generated by fabrics and there is a probability of dust being inside the hotel due to the low number of exhaust fans used (Samaranayake and De Silva, 2010).

2.4. IMPORTANCE OF IDENTIFICATION OF IEQ EVALUATION FOR HOTEL BUILDINGS

Several sectors are seeking to be environmentally responsible due to both economic and financial requirements, and to satisfy their own personal ethics they tend to introduce green building practices (Tzschentike *et al.,* 2004). The hotel industry plays a major role in the economy of the country and issues of sustainability in the hotel industry are becoming increasingly relevant to business and consumer interests (Chan and Qian, 2009). Guest satisfaction, intention to return, and the likelihood to recommend hotels are important factors for the success of the hotel industry. Hoteliers are increasingly motivated towards adopting green design and construction and investments in environmental technology can have a direct positive impact on guest experience and occupancy (Schor, 2008). Consequently to meet the requirements pertaining to the targeted tourist arrivals, hotel buildings are expected to increase their green features and capacity to achieve this targeted number of tourist arrivals. Hotel buildings can increase their potential by creating guest comfort and a stable indoor environment. Thus, the evaluation of IEQ performance of hotel buildings is very important (Levin, 1995). Considering the outcome of previous studies, some proponents argue that a green building will enhance indoor environmental quality and improve occupants' productivity to a higher degree compared to conventional buildings. On the contrary, some researchers have found that in green buildings air quality is very satisfactory while other three indicators are same and that there is a low satisfaction level compared to conventional buildings due to

the use of sustainable practices and products as well as poor rating of some of the green building IEQ variables. When past research is reviewed, mixed questions such as whether green buildings provide a comfortable, satisfying and productive work environment to their users arise. The following hypotheses in respect of green building performance, relative to conventional buildings was therefore developed.

H0: The occupants' satisfaction with IEQ performance in the LEED certified hotels is similar to that of non-LEED certified hotels.

3. METHODOLOGY

In order to attain the aim of identifying the key factors that affect the indoor environmental quality of green buildings compared to conventional buildings through the evaluation of building performance, the case study approach was followed. Initially, a preliminary interviews series were carried out to analyse and identify the main and sub indicators relating to IEQ performance of hotel buildings. Subsequently, a detailed survey was conducted through a questionnaire survey to identify the satisfaction and comfort level of guests and staff occupying a set of selected green buildings and conventional buildings in Sri Lanka. Interviews with key professionals were carried out to identify the problems and complaints regarding IEQ performance in buildings.

3.1. SELECTION OF CASE STUDIES

Table 1 presents the details of selected cases.

Table 1: An Overview of Different Categories of Buildings

Description	Green Building (Part I)	Conventional Building (Part I)	Green Building (Part II)	Conventional Building (Part II)
	CASE A1	CASE A2	CASE B1	CASE B2
Type of building	Hotel	Hotel	Hotel	Hotel
Duration	6 Years	5 years	5 years	8 years
Number of stories	5 stories	11 stories	5 stories	6 stories
Floor area	40,300 m^2	36,025 m^2	100,000 m^2	90,000 m^2
Star rating	Gold	-	Silver	-

In order to measure users' satisfaction with respect to the indoor environmental performance of each type of buildings, a survey was developed based on the expert interviews and literature review survey. The POE tool was used for measuring occupants' opinions and satisfaction with the IEQ performance of buildings. Building users across the two types of buildings were asked to rate their satisfaction levels for each indicator on a 5-point Likert scale (1 being very dissatisfied to 5 being very satisfied). Participants were selected randomly from each pair of buildings (green and conventional) for the paper based survey and to identify the complaints and causes, interviews were conducted with six key professional working in two green certified hotels.

3.2. QUESTIONNAIRE SURVEY

Mann Whitney U test was used to identify the difference between the occupants satisfaction with IEQs of the two buildings. The IEQ performance of the two types of buildings was compared using median and average median of factors. To determine whether the null hypothesis can be rejected or not, the decision rule was applied. This contributed to the hypothesis that occupants' satisfaction related to green buildings (x) is equal to that of non-green buildings (y). This assumption will be confirmed, at a 95% confidence level, for the null hypothesis (H0) or its rejection (H1):

H0: x = y if p-value is greater than 0.05 in which case the occupants' satisfaction with IEQ is similar for both hotels.

H1: x ≠ y if p-value is less than 0.05 in which case the occupants' satisfaction with IEQ is different for the two hotels

3.3. SEMI-STRUCTURED INTERVIEWS

The semi-structured interview was expected to compare the questionnaire survey results of occupants. A cross case analysis was carried out separately for green hotels in order to compare complaints about the IEQ factors. The factors identified under each theme were structured and supported by 'NVivo 10' computer software.

4. RESEARCH FINDINGS AND ANALYSIS

4.1. SIGNIFICANT KEY AND SUB INDICATORS RELATED TO IEQ IN GREEN AND CONVENTIONAL BUILDINGS

Respondents identified eight (8) indicators in addition to the IEQ indicators identified from the literature review and removed six (6) of them while, combining four (4) of them to make in to two (2) and modifying another two (2). In addition, the indicator 'odour' was dropped as the respondents were of the view that it was covered under the indicator 'smell'. Further, 'relative air velocity' was modified as 'air movement'. The 'day lighting factors' that came under the key indicator 'lighting' were removed by the respondents and 'glare' that also came under' lighting; was divided into two as 'natural light glare' and 'artificial light glare'. At the expert interviews, blinds/shutters that are effective in blocking natural light were added as a sub factor. 'Surface temperature' and 'thermal resistance of clothing' that were grouped under the key factor 'thermal comfort' were dropped. The sub factors 'overhearing private conservation' and 'equipment and mechanical noise' were modified as 'background noise'. The respondents also wanted to revise 'outdoor traffic noise' as 'noise from outside'. In addition 'person control' was added as a factor which could influence the IEQ performance and 'view to outside', 'provision of ventilation', 'cleaning and maintenance', 'sufficient and comfortable furnishing' and 'sleeping quality' were considered as important key factors of IEQ in the green buildings of the hotel sector.

According to the findings of the expert survey, there are forty five (45) IEQ sub indicators. Most of the IEQ experts agreed that the post occupancy evaluation method has a higher preference in evaluating occupants' satisfaction of IEQ performance of green hotel buildings.

Table 2: Evaluation of the Current Performance of IEQ in Green and Conventional Buildings

Evaluation Methods	A	B	C	D	E	F	G	H	I	J
Physical Measurement	×	√	×	×	√	√	×	×	×	×
Post Occupancy Evaluation	√	√	√	√	√	√	√	√	√	√

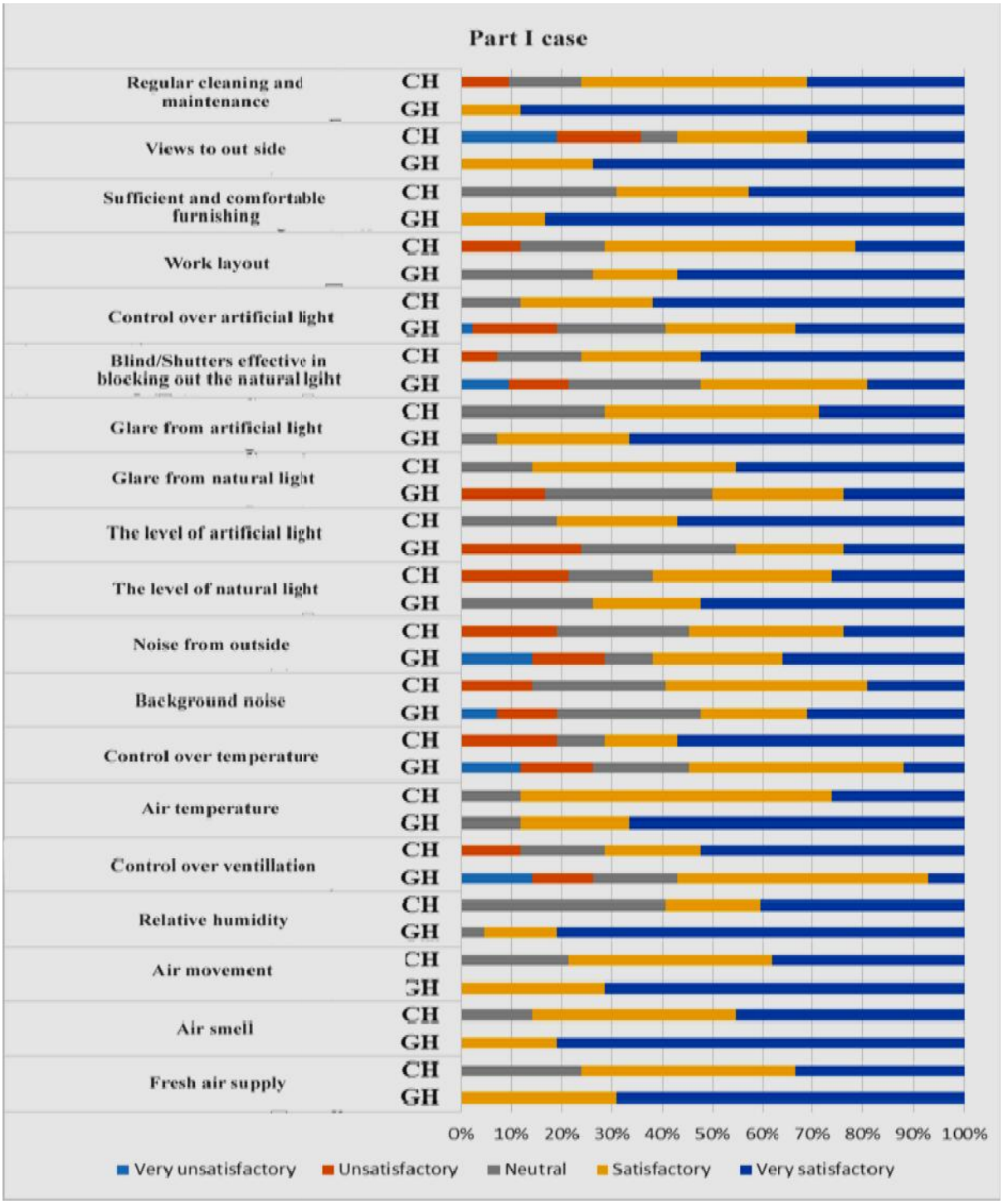

Figure 1: Distribution of Occupant's Satisfaction on Identified IEQ Factors Relating to Buildings: Part I

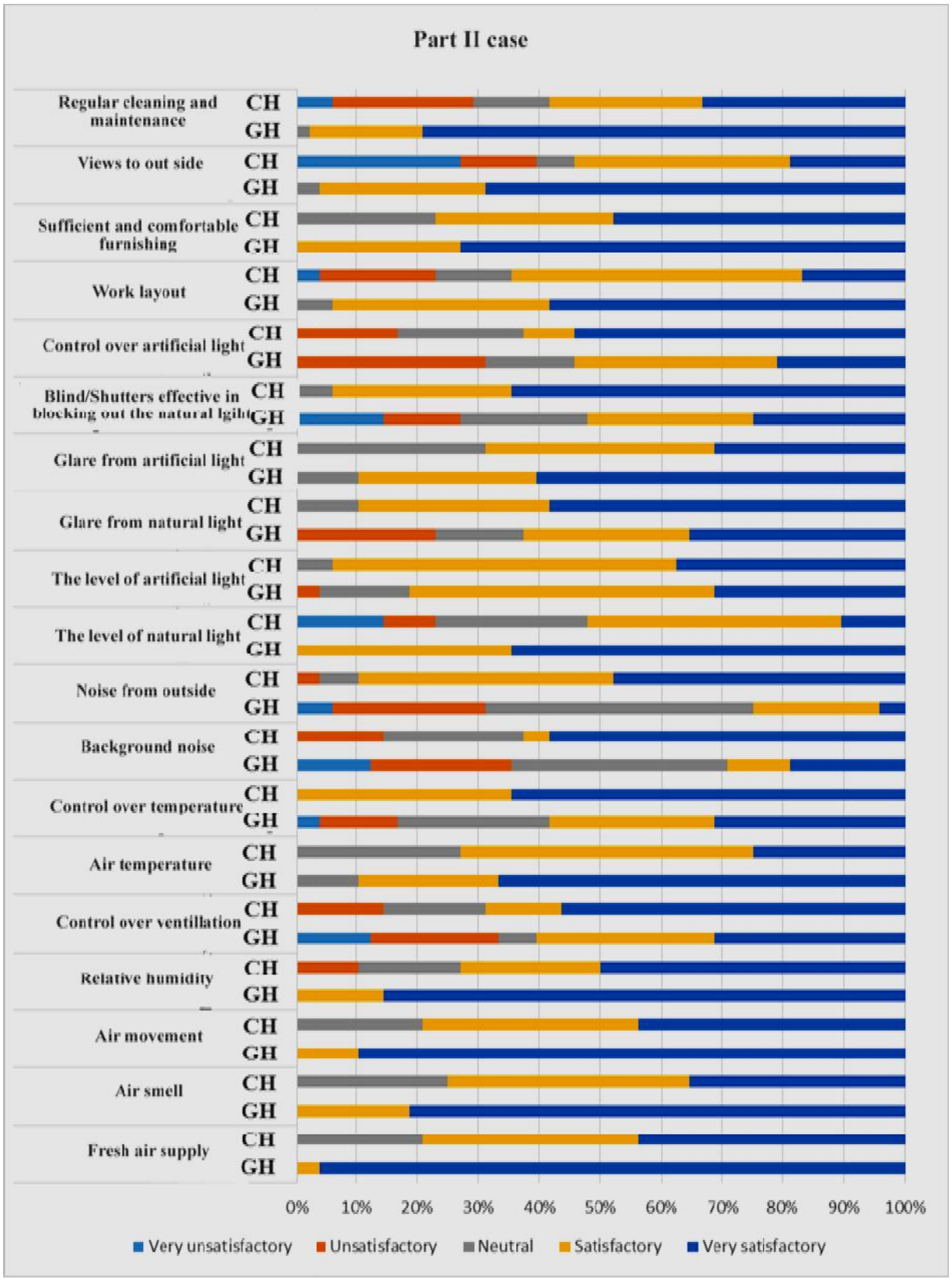

Figure 2: Distribution of Occupant's Satisfaction on Identified IEQ Factors Relating to Buildings: Part II

Figures 1 and 2 indicate the distribution of occupant's satisfaction on identified IEQ factors relating to buildings coming under Part I and Part II categories. The average median scores of the air quality, thermal comfort, work layout, sufficient and comfortable furnishing, view to outside and regular cleaning and maintenance have positive signs in both green and conventional hotels, which means that on average

these factors are satisfactory in both types of buildings. However the median of each factor is higher for green hotels. The key professionals working in green buildings indicated that green buildings specifically exhibited lower air pollution and higher air filtration, avoided the use of volatile organic compounds for cleaning purposes and maintained preventive maintenance schedules. BMS had been installed to control CO_2 and RH levels and the main key feature of LEED certified hotel buildings is the implementation of IAQ management, temperature recording and low admission of heat through walls from outside, windows and electronic light appliances due to good thermal design. Therefore the null hypothesis is rejected and the alternative is accepted which means that green hotels have higher levels of IAQ than conventional hotels.

On the other hand in both the green and conventional hotels, the average median scores of the acoustic quality, lighting quality and the ability to have personal control on the indoor environment have positive signs, which means that on average these factors are satisfactory for both groups. However the median of each factor is slightly lower for green hotels than for conventional hotels. Also 50% of the representatives of the management of both buildings when interviewed stated that there was too much darkness, lack of artificial light and reflections on the computer screens caused by lower levels of ambient electric lighting, façade glass and ineffective blocking of natural light by blinds/ shutters and requested more daylight. Eighty three percent (83%) of the respondents of both buildings stated that there is a lack of privacy for conversations, excessive echoing of voices or other sounds making occupants to complain, because of the low partitions that allow day light and opening of windows to allow natural ventilation. Therefore the null hypothesis is rejected and the alternative is accepted which means that green hotels have lower levels of IAQ than conventional hotels.

Table 3: Identification of Occupant's Satisfaction of Well-Being

		Part I			Part II		
		Never	**Occasionally**	**Often**	**Never**	**Occasionally**	**Often**
Common cold/ running nose	GH	75%	25%	00%	82%	18%	00%
	CH	60%	28%	00%	72%	28%	00%
Headache	GH	53%	47%	00%	83%	17%	00%
	CH	36%	64%	00%	64%	36%	00%
Influenza	GH	76%	24%	00%	76%	24%	00%
	CH	78%	14%	00%	86%	14%	00%
Difficulty in concentrating	GH	69%	25%	04%	25%	69%	04%
	CH	62%	38%	00%	38%	62%	00%
Fatigue	GH	64%	24%	04%	62%	38%	00%
	CH	27%	77%	00%	23%	77%	00%
Nausea	GH	76%	18%	00%	76%	18%	00%
	CH	80%	20%	00%	65%	35%	00%
Itchiness/ eye irritation	GH	84%	16%	00%	53%	35%	00%
	CH	82%	18%	00%	60%	40%	00%
Dry throat/coughs	GH	82%	18%	00%	82%	18%	00%
	CH	76%	20%	00%	76%	24%	00%

According to Table 3 with regard to occupant's satisfaction of well-being in the Part I and Part II categories of buildings, headache, influenza, nausea, eye irritation, common cold, dry throats/cough, sick building syndromes are at satisfactory levels in both types. However occupants stated that due to high level of back ground and outside noise there is occasional health issues. This implied that the occupants of green hotels were concerned about perceived healthiness. Also the management of the green buildings have not received any complaints regarding headache, influenza, nausea, eye irritation, common cold and flaking/itchiness. This implied that occupants of green hotels' had a high perception of healthiness.

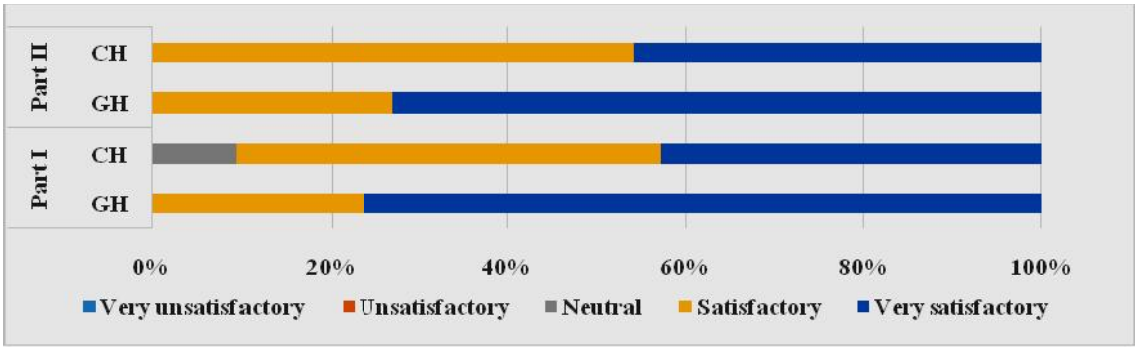

Figure 3: Comparison of Part I and Part II: Distribution of Occupant's Satisfaction on Identified IEQ Factors Relating to Buildings

This statement was validated by the questionnaire survey that provided the average median of overall satisfaction of IEQ in Part I (GH=5, CH=4) and Part II (GH=5, CH=4) buildings. Green buildings exhibited higher levels of overall satisfaction of IEQ. Even though the occupants of green hotels have a slightly lower level related to acoustic quality and lighting quality when compared to conventional hotels it will not affect the overall satisfaction of IEQ in the hotels. On other hand, the occupants are highly satisfied with fresh ventilation and temperature, aesthetic appearance, size of workspace, and access to the view of outside. Occupants of green buildings were less likely to prefer a change in thermal conditions, and took fewer actions to improve their thermal comfort. Green building occupants had higher ratings of satisfaction with access to the view of outside. The result of this study suggest that, on the whole, both green and conventional hotels deliver an indoor environment that was acceptable to most people (with the exception of acoustic quality), although however the indoor environments in green hotels were of higher quality.

5. DISCUSSION

H0: The occupant's satisfaction with IEQ performance in the LEED certified hotels is similar to non-certified hotel buildings.

H1: The occupant's satisfaction with IEQ performance in the LEED certified hotels is higher than that in Non-LEED certified buildings. Furthermore it was found that even though the building met the recommended standards, occupants occasionally complained about noise and lighting quality.

Both the green and the conventional buildings provide an environmental quality which can be accepted by most of the occupants according to the research. It is apparent that certain factors are not much satisfactory. The differences between green and conventional buildings could be identified here with the help of the factors that have been used in the research. Comparatively the IEQ in green hotels was higher. However this does not mean that there is no necessity to enhance green buildings further. Certain factors of IEQ were superior in green buildings. This may indicate that there is no necessity for a simple cause-and-effect while considering the results of the individual design credits and the post occupancy performance. As mentioned earlier, acoustics and lighting should be ensured at the design stage. It is recommended that an acoustics and lighting credit be created to counter balance design choices affected by other credits. There are acoustic credits in some green rating systems, and suggestions for a LEED credit. However, these existing and proposed credits do not place specific emphasis on reducing the spread of acoustics related issues.

6. SUMMARY

The aim of the research was to identify by evaluating building performance the key factors that affect the indoor environmental quality of green buildings as compared to conventional buildings. Air quality, thermal, lighting and acoustic qualities, external view, provision of ventilation, cleaning and maintenance and furnishings were identified as these key factors. Furthermore the ability to have personal control on

the indoor environment and blinds/shutters effective in blocking natural light were identified as key and sub factors affecting the IEQ in buildings. Overall satisfaction, job satisfaction and wellbeing of staff were high. As far as environment/ physical factors were concerned, air quality and thermal comfort were at a high level, and performance factors such as the view of outside, cleaning and maintenance, work layout were also at a high level. In LEED certification, air quality and air quality management and maintenance are the factors that are mostly considered. In green hotels there is good ventilation, glass walls are made available to enable viewing outside and, more space is provided for occupants to work and live. On the contrary in green hotels when compared to conventional buildings, lighting quality is at an average level and acoustics are at a very low level which according to the key professionals are some of the causes and problems of dissatisfaction related to IEQ factors in green buildings. Complaints made by those who were dissatisfied with lighting point to problems with day lighting and electric lighting levels which could be due to inadequate provision of controls over lighting. Complaints made by those who were dissatisfied with the acoustic quality in their work places point to problems with sound privacy, and distracting noise arising from people's conversations and telephone ringing. According to the occupants and experts who were interviewed, there are certain design decisions and operational practices that are generally known to affect IEQ which are commonly used in green buildings. These strategies include improving ventilation, removing indoor pollutants, using green material, giving occupants personal control over operable windows, air-conditioning, or under floor air distribution systems, employing daylight, and reducing ambient light levels by using task lighting.

It is recommended that a modification to these credits that enhance the importance of a particular reduction be justified. In order to do that, the joint design process has to be as important as specific and creditable actions, suggesting that a credit be developed that improves such action. Perhaps this credit could reward documented interdisciplinary design team meetings, or record of all implemented measures intended to enhance the building performance, credit-eligible or not, or a particular mechanism that facilitates on-going accomplishment review and continuous improvements. Hence, the Hotel Buildings can achieve a green rating with very few specific IEQ credits.

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