

## Occupant Satisfaction on Indoor Comfort in a Green Building

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**Abstract:** Sustainable Development was innovated, as a new concept to act against the repercussions of the climate change and Sustainable Built Environment performs a pivotal role with total commitment within this innovation. Many international organizations have focused their interest on this new phenomenon and as one of these organizations; USGBC (United States Green Building Council) established the LEED (Leadership in Energy and Environmental Design) certification program, for buildings to be performed as truly as green buildings. Therefore, it is important to find out; the occupants of these green buildings are truly satisfied with their workplace environment. As a result, Indoor Environmental Quality of LEED platinum rated green building was deeply evaluated, questioning the occupants, focusing on the aspect of thermal comfort as the person's psychological state of mind. Though, the building was within its extended comfort zone, from the analysis, it was found that, among all the variables, less number of occupants were satisfied with the thermal comfort and significant number of dissatisfied occupants were located in a specific area of the workplace and that justified, there should be some external factors which already exist, around the workplace, which are affecting the thermal comfort of the occupants. Therefore, this research emphasized that designers, need to think beyond the standards and guidelines, when ensuring the occupant satisfaction within new sustainable construction methodologies.

**Keywords:** Green Buildings, LEED, Post Occupancy Evaluation, Occupant's satisfaction, Thermal Comfort.

### 1. INTRODUCTION

As Rachel (1962) stated, in her book "Silent Spring" the man has used his significant powers, to alter the nature to make his life more comfortable and as a result, today the world is facing to many global issues and climate change has become the most critical threat that the world is facing today. However, it is very important to understand that climate change is not just another issue in this complicated world of proliferating issues. Climate change is THE issue, which unchecked, will swamp all other issues (Gelbspan, 2005). Therefore, many entities have started to pay their attention towards the climate change and recognizing these risks, governments and other entities around the world are acting now to limit potential damage from climate change rather than waiting and having to take more costly, reactive measures in the future (Pew Center, 2009).

"Sustainable Development" was innovated to overcome the daunting challenges of climate change. According to, United Nations World Commission on Environment and Development (1987), "Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs. It contains within it two concepts: the concept of needs, in particular the essential needs of the world's poor, to which overriding priority should be given and the idea of limitations imposed by state of technology and social organization on the environment's ability to meet present and future needs. The adaption of principals of sustainable development will play an important role in this context especially, with respect to the creation of built environments and sustainable or green building plays a pivotal role in sustainable development. (Kiberi, 2008). Sustainable buildings are designed and constructed to high environmental standards and thereby; minimize energy requirements, reduce water consumption, use materials which are of low environmental impact; low embodied energy and resource efficient, reduce wastage, conserve / enhance the natural environment and safeguard human health and wellbeing. (Clark, 2010) and (Bhamra & Lofthous, 2007).

According to Kiberi (2008), and U.S. Green Building Council (2010), [LEED](#) (Leadership in Energy and Environmental Design) is one of the building performance assessments to buildings to be performed as truly as green buildings, which was established by the USGBC; (United States Green Building Council) as one of the organizations that concern about the sustainability. According to the USGBC and its LEED

program, green buildings reduce the negative impacts of buildings on occupants and the environment in five general categories: sustainable site planning, safeguarding water and water efficiency, energy efficiency and renewable energy, conservation of materials and resources, and indoor environmental quality (Yudelson, 2007).

However, it is important to find out, that after fulfilling such important and critical requirements stated in the LEED certification process, whether LEED certified building can truly satisfy the occupants of the building and POE (Post Occupancy Evaluation) has to be carried out to find out the occupant satisfaction in the building. "POE" is a process of systematically evaluating the performance of buildings after they have been built and occupied for some time (Federal Facilities Council, 2001). According to Kumar et al (2009), Shove (1975) and Egan (2004), the best aspect to be evaluated during the POE was identified as the "Thermal Comfort" and it was defined in British Standard BS EN ISO 7730 as: "That condition of mind which expresses, satisfaction with the thermal environment". So the term "Thermal Comfort" describes a person's psychological state of mind and is usually referred to in terms of whether someone is feeling too hot or too cold.

The most suitable LEED platinum rated green building was selected, after conducting careful analysis on the buildings which, were stated in the LEED rated green buildings in Sri Lanka and detail study of the selected building was carried out and captured it as a sustainable design. The selected building was housed for apparel manufacturing process and it was located in Thulhiriya and according to the Department of Meteorology, Sri Lanka (2010), the mean annual temperature is 28.0 °C, neutrality temperature 26.3 °C, altitude (h) above mean sea level (m)  $h < 100$  in the selected location.

## 2. OBJECTIVES AND METHODOLOGY

The key objective of this research is to justify, whether the occupants in LEED rated green buildings are truly satisfied with respect to the thermal comfort in their workplace.

The following methodology was developed to achieve the objective of the research:

All relevant drawings and documents, which were submitted for LEED certification was carefully analyzed, observing and comparing with the complex and cross checked with the interview held with the maintenance engineer, which was structured according to the aspects that were specified in LEED for New Construction Version 2.2 handbook (2005). Further, a pilot survey was carried out with all the occupants of the entire complex including all three production floors. The first section of the questionnaire was covered the general information of the respondent such as age, gender, job title and nature of the work. The second section was designed to find out the occupant's overall satisfaction on the building using the Lickert scale technique (Corbetta, 2003) and the variables that analyzed were; general satisfaction on the building, general satisfaction on workroom, overall ventilation, thermal comfort, level of artificial lighting, views, acoustic quality, office furniture, machinery, equipments, finishing material, cleanness and maintenance, attention and concentration to work, awareness and communication, interactive behaviors and wellbeing. The sample questionnaire was stated in Appendix A<sup>2</sup>.

Once, deciding on the appropriate floor, a simple and straightforward reference key was established to use during data recording and data analyzing, after careful study on the layout plan of the selected floor and analysis was concentrated on the orientation of the building, orientation of the interior, openings, production lines, cutting and administration area, walkways, positions of the staff, machinery placements, etc.

Detailed questionnaire survey, which was designed specifically, focused on the thermal comfort, was carried out with entire occupants of the selected floor. The questionnaire consisted with three main sections. The first section consisted with the general information of the respondent; the second section was focused on thermal comfort enclosing 4 sub sections based on temperature, humidity, air velocity and overall satisfaction. The final section was to comment on the indoor environmental quality of the work place. The sample questionnaire was stated in Appendix B<sup>3</sup>.

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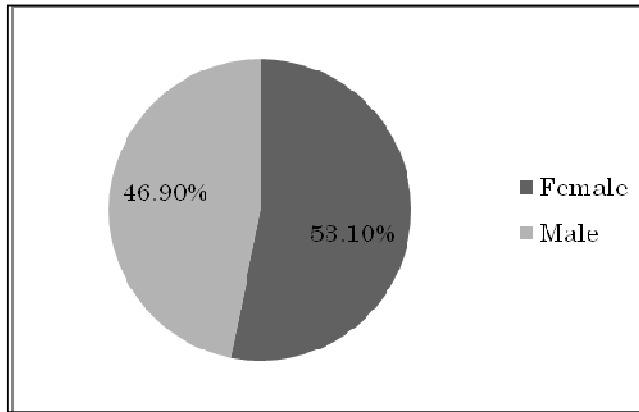
<sup>2</sup> Appendix A is available with the corresponding author to be obtained.

<sup>3</sup> Appendix B is available with the corresponding author to be obtained.

### 3. DATA ANALYSIS AND FINDINGS

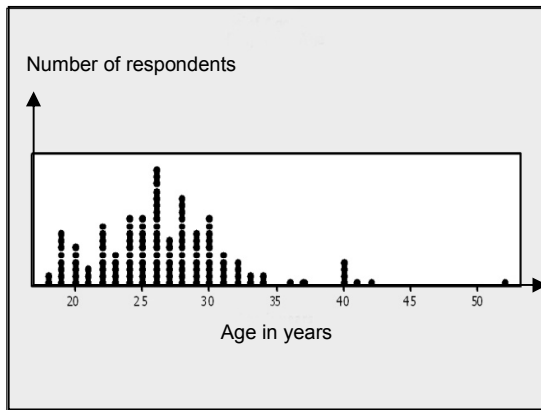
Previously recorded drawings, documents, data together with the interview held with the maintenance engineer, proved, that the complex was constructed according to original drawings concentrating to maximize the passive features and tried it's best to perform the complex efficiently using those passive features and the complex has fulfilled the requirements that needed for LEED platinum award.

Based on the pilot survey that was carried out in all three floors, when analyzed the sample according to the gender, majority represented the females and that was 53.1 % from the sample, as illustrated in Figure 1.

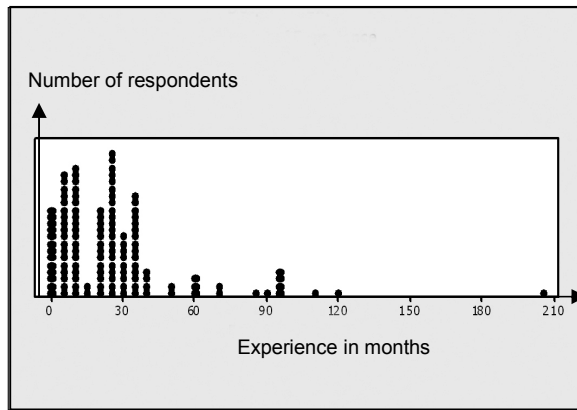


**Figure 1: Composition of the sample with reference to the gender**

With respect to the quantitative aspects; most common age group of the sample spanned from 19 to 34 years, as in Figure 2 and the majority of occupants in the sample has experience of 2 years, as in Figure 3 and it was represented on X axis in months.

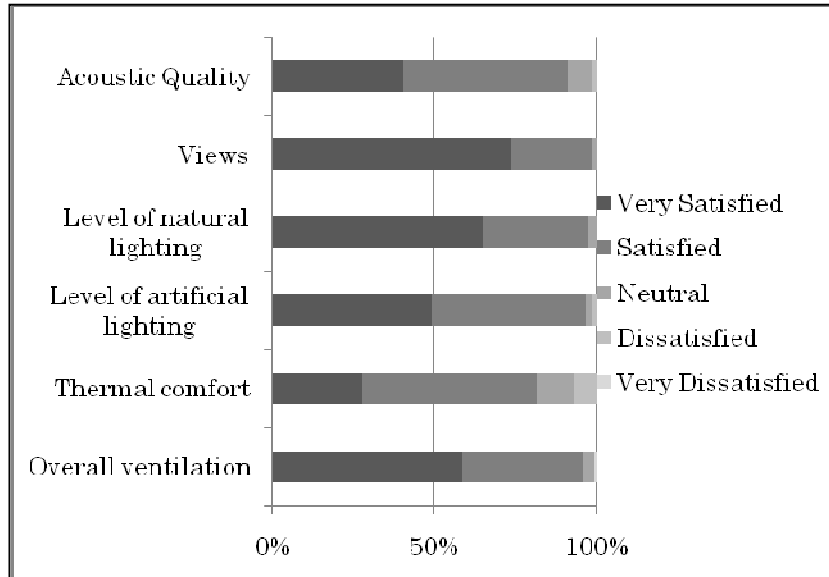


**Figure 2: Data description with reference to age**



**Figure 3: Data description with reference to experience**

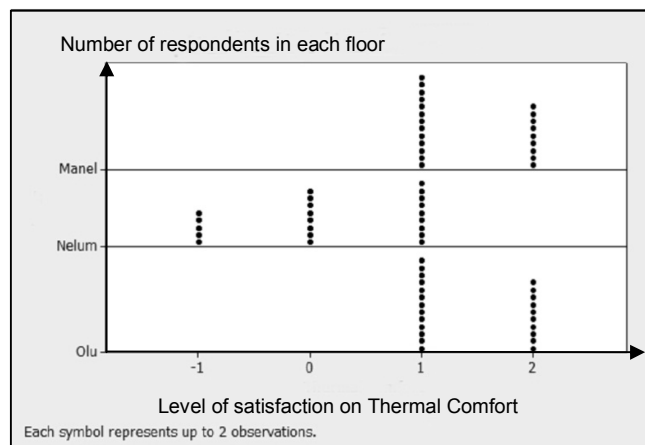
Based on the second section of the questionnaire, the findings can be illustrated as in Figure 4.



**Figure 4: Occupant's satisfaction**

Figure 4 represented the occupant's satisfaction in all three floors and according to that, when compared the acoustic quality, views, natural lighting, artificial lighting, thermal comfort and ventilation, majority was very satisfied with the view, which they were able to enjoy from their working place. Almost similar number of satisfied occupants can be seen on natural lighting and the ventilation, within the complex. Among all the variables, there were occupants who were dissatisfied with acoustic quality, artificial lighting and thermal comfort and similar number of dissatisfied occupants can be seen with respect to acoustic quality and the artificial lighting. Considerable number of occupants were dissatisfied with thermal comfort than acoustic quality and artificial lighting and that proved, even though the occupants were satisfied on all the variables, less number of occupants were satisfied with thermal comfort and at the same time there were more number of occupants who have neutral feeling on the thermal comfort when compared to other variables.

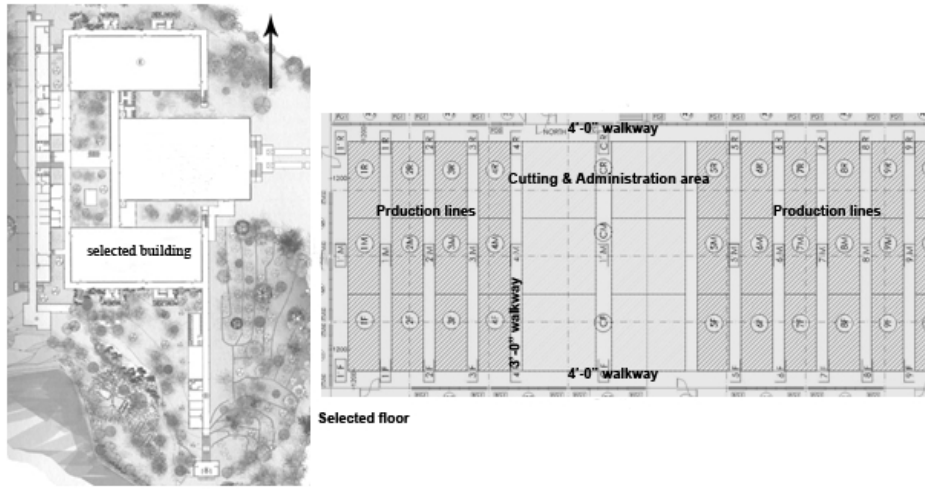
Therefore, after careful consideration, aspect of thermal comfort was further analyzed, to find out which floor has more number of occupants, who were not satisfied with the thermal comfort of their workplace. From the comparison carried out, considering all three production floors, according to Figure 5, "Nelum"; the only production floor located in an upper level was identified, that has a drastic variation with compared to other two floors.



**Figure 5 : Comparison of level of satisfaction with respect to thermal comfort in three production floors**

Likewise, the most appropriate floor to conduct the questionnaire survey was determined as the only production floor, which was located in an upper level and drawings, documents and the interview, which was held with the maintenance engineer, was helped for the selection. It was perceived that, the selected production floor has more exposure to the sun and less trees surrounding it, which has more tendency of heating up. The longer facades of the building oriented to north-south axis and the shorter facades to east – west and to get the maximum cross ventilation to the floor, the openable glazed windows were placed on all four sides of the walls. There were 10 production lines with sewing machines and center of

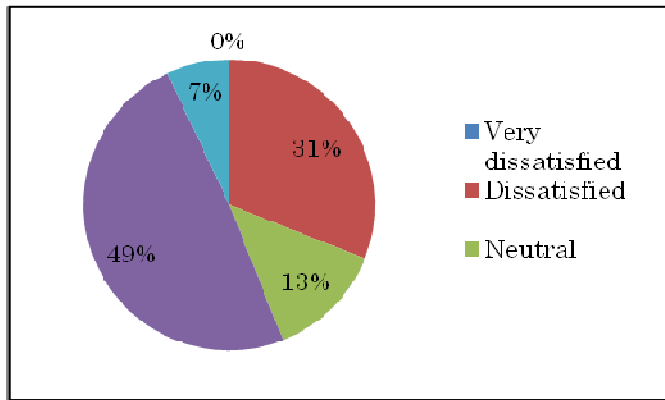
the floor housed the cutting and administration area with other relevant machinery. Periphery was demarcated by 4'-0" wide walkway and each production line was separated by 3'-0" wide walkways. The layout shows in Figure 6.



**Figure 6: Layout of the complex and the layout plan of the selected floor**

From the first section of the detailed questionnaire survey carried out in the selected production floor, there were only few male population and it was only 5.6% of the sample and 94.4% were female population.

The second section contained 4 main sub sections; Temperature, Humidity, Air velocity and overall satisfaction with respect to thermal comfort and each of these sub sections followed series of questions and during the analysis the responses of each subsection were analyzed separately concentrating on the responded population rate and the majority level of satisfaction for the each subsection. Finally, majority level of satisfaction with respect to the aspect of thermal comfort was summarized and illustrated in Figure 7.



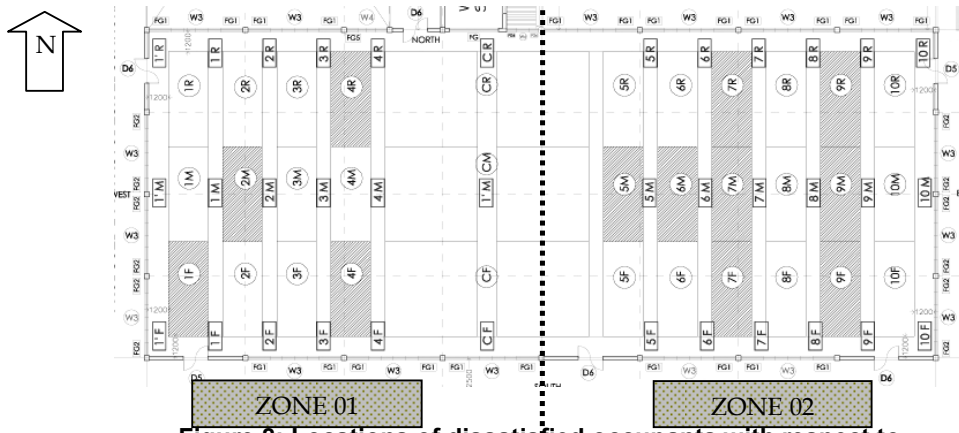
**Figure 7: Level of satisfaction of the selected sample with respect to thermal comfort**

Figure 7 shows, 13% from the sample population has neutral feeling about the workplace and 31% was not satisfied with the factors effecting to the thermal comfort within their workplace. However, 56% was satisfied with the thermal comfort of the workplace and of the satisfied population, 7% were very satisfied and there were not any, very dissatisfied occupants in the sample. Therefore, finally it can be stated that, though, the majority of 56% of the selected sample was clearly satisfied with the thermal comfort of their workplace, another 31% was not satisfied.

Open comments with respect to indoor environmental quality of the workplace were sated in the third section of the questionnaire and, it was found that from the respondents who have commented on that section, were complained about one common aspect; the uncomfortable situation they feel within the workplace as "too hot".

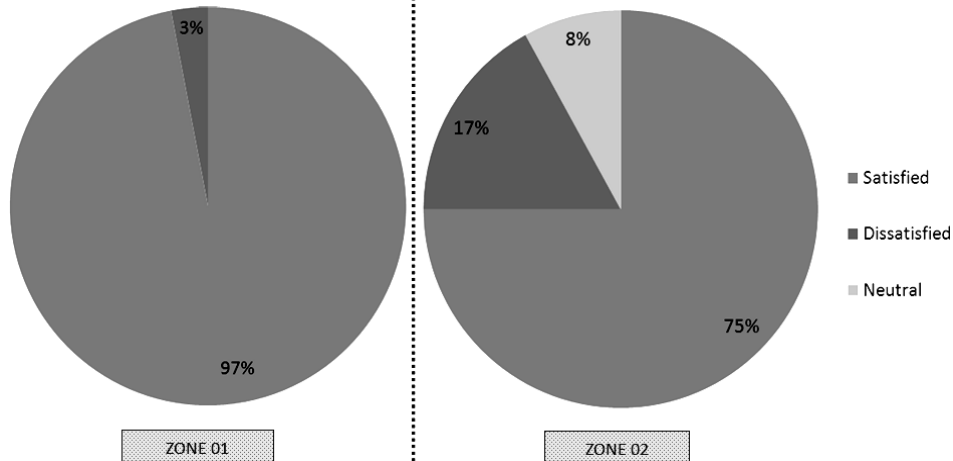
#### 4. DISCUSSION

Further analysis was carried out to find out the locations of the dissatisfied occupants and when it was marked on the floor plan shown in Figure 8, it was identified, compared to the orientation of the floor, more dissatisfied occupants were located in the area facing towards the “west”. This lead to floor divided into 2 zones as Zone 01 and Zone 02.



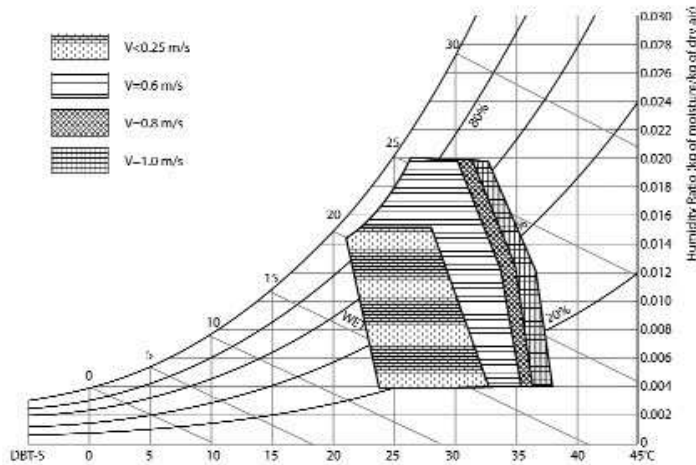
**Figure 8: Locations of dissatisfied occupants with respect to Zone 01 and Zone 02**

When compared the respondents of each zone, the findings can be illustrated in Figure 9.



**Figure 9: Comparison between Zone 01 & Zone 02**

Conversely, according to, Holcim (Lanka) Ltd (2009), production spaces and offices are ventilated and cooled by evaporative cooling units. These units draw in fresh air, filter it, and add moisture to lower the dry-bulb temperature. The air is distributed through a balanced system of ducts and fed into the spaces, which remain under positive static pressure. Indoor air is not recirculated, but extracted by suitably sized exhaust fans to ensure effective moisture and heat removal. The air-exchange rate is about 40 air changes per hour. Indoor air movement is perceptible, about 0.8 meters per second at the minimum. ANSI/ASHRAE Standard 55-2004 allows the thermal comfort zone to be extended upward by about 2.7°C when indoor air velocity is 0.7 meters per second. The psychometric chart at Figure 10 shows, the extended comfort zone at higher indoor air speeds considering ASHRAE 55-2004 and research conducted in tropical climates.



**Figure 10: Psychrometric Chart from the ASHRAE standard handbook showing extended comfort zone.**

The cooling system at the complex is designed to make use of these zones and make use of Section 5.2.3 of ANSI/ASHRAE Standard 55-2004. Year round, the indoor dry-bulb temperature is up to 3°C cooler than the outdoors, and the indoor relative humidity about ten percent higher than the outdoors. Humidistat in each cooling unit keeps the indoor relative humidity at or below 80 percent. Staff wears short-sleeve shirts, many workers go barefoot. The combination of dressing cool, activity at low metabolic rates, and air movement makes the plant a comfortable working environment.

Though, the work place was within its extended comfort zone, as LEED platinum rated green building, the questionnaire survey proved that, building was incapable to satisfy the occupants with respect to thermal comfort. When analyzed the Figure. 7, from the complete sample, 56% were satisfied and 31% were dissatisfied with the thermal comfort in the work place. According to Dear & Brager (2002), about 80% of the people would be thermally comfortable within a band of 7- 8 °C about the neutrality temperature in free running buildings and width of psychrometric chart can be considered as  $\pm 4$  °C from the neutrality temperature. In free running buildings, it is necessary to have some air movement. When the air velocities are significant as found close to fan, it can produce physiological cooling effect. The air velocities can be in the range of 0.25 m/s to 1.0 m/s. Such indoor air velocities can be easily achieved by using table fans or ceiling fans. When the physiological cooling effects are taken into account, the comfort zone can be extended to include a broader range (Jayasinghe & Jayasinghe, 2009). Therefore, it can be seen that, though 56% of majority satisfied with the thermal comfort in the work place, it has not reached the reasonable limit for the minimum percentage to decide the workplace thermally comfortable. This explained, even though the workplace technically satisfied the requirements of thermal comfort, physically the occupants were not satisfied.

Further, according to Figure 8 and 9, it was cleared that, there should be some external factors, which already exist, around the workplace, which are directly affect the thermal comfort of the occupants, which was displayed from the drastic difference between two zones with respect to number of dissatisfied occupants.

## 5. CONCLUSION

The significant performance of USGBC and the LEED certification program, encourage green buildings within the sustainable build environment, to buildings to be performed as truly as green buildings by following, high environmental standards and difficult procedures. Therefore, it is important to find out, whether LEED certified green buildings can truly satisfy the occupants. POE was conducted, focusing on aspects of thermal comfort to find out the occupant satisfaction on a LEED certified green building and it was mainly contained with a pilot survey and a detailed questionnaire survey based on the key variables of thermal comfort. Though, the building was within its extended comfort zone, from the questionnaire analysis, it was proved; that this selected workplace was not thermally comfortable for the occupants. Simultaneously, two zones were identified in the same floor and it was found that one zone has 22% dissatisfied occupants with respect to thermal comfort, than the other zone and that proved some external factors are effecting to the thermal comfort, which was not discovered in the standards or guidelines. From the research, it was evidenced that, buildings can technically achieve their goals by following established guidelines and standards, however, there can be significant and sensible design aspects beyond that guidelines and standards, which can be the most important aspects that makes the occupants satisfied.

## 6. ACKNOWLEDGEMENT

The authors wish to express gratitude, for the technical assistance given by Katnithi Manike of the University of Moratuwa and the Management, Executives and Production staff at MAS Intimates Thurulie, for giving support to conduct this research, successfully at the selected building.

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