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Comparing Occupants' Satisfaction in LEED Certified Office Buildings and Non LEED Certified Office Buildings - A Case Study of Office Buildings in Egypt and Turkey

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Abstract**—**Energy consumption and users' satisfaction were compared in three LEED certified office buildings in turkey and an office building in Egypt. The field studies were conducted in summer 2012. The measured environmental parameters in the four buildings were indoor air temperature, relative humidity, CO_2 percentage and light intensity. The traditional building is located in Smart Village in Abu Rawash, Cairo, Egypt. The building was studied for 7 days resulting in 84 responds. The three rated buildings are in Istanbul; Turkey. A Platinum LEED certified office building is owned by BASF and gained a platinum certificate for new construction and major renovation. The building was studied for 3 days resulting in 13 responds. A Gold LEED certified office building is owned by BASF and gained a gold certificate for new construction and major renovation. The building was studied for 2 days resulting in 10 responds. A silver LEED certified office building is owned by Unilever and gained a silver certificate for commercial interiors. The building was studied for 7 days resulting in 84 responds.

The results showed that all buildings had no significant difference regarding occupants' satisfaction with the amount of lighting, noise level, odor and access to the outdoor view. There was significant difference between occupants' satisfaction in LEED certified buildings and the traditional building regarding the thermal environment and the perception of the general environment (colors, carpet and decoration. The findings suggest that careful design could lead to a certified building that enhances the thermal environment and the perception of the indoor environment leading to energy consumption without scarifying occupants' satisfaction.

Keywords**—**Energy consumption, occupants' satisfaction, rating systems.

I. Introduction

ONE main objective of building rating systems is to help architects, developers and managers to create better environments in their buildings through minimizing energy consumption without sacrificing occupants' satisfaction.

LEED (Leadership in Energy & Environmental Design) and BREEAM (Building Research Establishment's Environmental Assessment Method) are the most commonly used independent systems for rating "Green Buildings" [1].

A new rating system was developed for Egypt, the Egyptian pyramid system, its primary version is found since 2010, it is a new rating system to evaluate Egyptian green buildings and it is developed based on the LEED rating system [2]. The main objective of rating systems is to conserve energy and enhance the internal environment of buildings without sacrificing occupants' satisfaction. The fact of energy conservation is proved by many studies as certified buildings use 18% to 39% less energy than their conventional counterparts [3]. The objective of this study is to evaluate occupants' satisfaction and energy consumption across four categories of buildings, one that is not certified and three others with different certificate levels. This was done through monitoring the indoor environmental quality, collecting information regarding energy and water consumptions together with evaluating the users' satisfaction in the four buildings.

II. Methodology

A. Buildings' Selection and Description:

Four buildings were selected for the study aiming at assessing and comparing energy consumption as well as occupants' satisfaction.

The study was conducted in one conventional well designed office building in Egypt, and three LEED certified office buildings in Turkey with three certificate levels; silver, gold and platinum. The managers of the only certified building by 2012 in Egypt didn't accept to share in the study due to the political circumstances in Egypt. Turkey is similar in culture to Egypt. Also, buildings were selected due to the approval of the buildings' management to share in the study. The building of Egypt was studied in the first week of May 2012 and the buildings in Turkey were studied in the mid of June in order to minimize the difference in the outdoor environmental conditions.

The building of Egypt is in Smart Village Cairo-Alexandria Desert Road in the Abu Rawash area, the building functions as administrative office building with a total area of 8439 m^2 ,the building consists of six floors(two basements and four typical floors) as shown in Fig. 1.

Each floor is occupied with different organizations with various office layouts that is planned and designed according to each company requirements. Across all floors, the layout consists of main open work space area and several closed offices for managers and meeting rooms. The services area is

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located at the entrance of each floor. The study took place in seven days during summer (May) 2012 with a total of 84 responds, the field study was a transverse Class (iii) field study, to allow a large number of subjects to contribute to the study at the same time, simple measurements of indoor physical parameters at 1m height (desk level) were taken simultaneously, each respondent gave one assessment of the indoor environment.

Fig. 1 The conventional non rated building in Smart Village

The first certified building in Turkey is Unilever Head Office - silver LEED certified building for commercial and interiors, by 26 points from total 57 points. The building is an office building located in Istanbul, Turkey with a total area of 17017 m^2, the building consists of eleven floors (three basement floors and eight typical floors) as shown in Fig. 2.

Fig. 2 Unilever Head office - silver LEED certified building, Istanbul, Turkey

The ground floor and each of the typical floors has an area of 2431 m^2 each. Floor layouts contain open work space, laboratories, meeting rooms, and café area. Reception, dining hall, and conference hall are located in the ground floor. Furthermore, basement floors are used for parking and gym area to provide employees with comfortable and enjoyable working conditions. The study took place in four days during summer (mid of June) 2012 with a total of 95 responds, the field study was a transverse Class (iii) field study, as each respondent gave one assessment of the indoor environment.

The second certified building in Turkey is BASF Gold LEED certified office building - for New Construction and Major renovation by 72 points. The building is used as an office building, located in Dilovasi area; Turkey with a total area of 1600 m^{2,} the building consists of ground, first and second floor as shown in Fig. 3.

Fig. 3 BASF Gold certified office building, Dilovasi, Turkey

The ground floor is 740 m^2 that contains the entrance, shower rooms, and lunch area. The first and second floors with an area of 440 m^2 each contain office rooms. The study was conducted in the first and second floors office rooms. The study took place in two days during summer (mid of June) 2012 with a total of 10 responds, the field study was a longitudinal Class (iii) field study, as each respondent gave more than one assessment for the indoor environment during the day.

The third certified building in Turkey is BASF Platinum LEED certified for New Construction and Major renovation, by 83 points. The building is used as an office building, located in Gebze area; Turkey with a total area of 4777 m^2, the building consists of ground, first and second floor as shown in Fig. 4.

Fig. 4 BASF Platinum certified office building, Gebze, Turkey

The ground floor contains office rooms, laboratories, and storage area. The second floor consists of storage areas. The third floor consists of two offices. The study took place in three days during summer (mid of June) 2012 with a total of 13 responds, the field study was a longitudinal Class (iii) field study, as each respondent gives more than one assessment for the indoor environment during the day.

B. Data Collection Methodology

One of the study objectives was to assess the quality of the internal work space in the studied buildings. This was done through monitoring air temperature, relative humidity, light intensity, and air quality (percentage of CO_2). This was done using data loggers to record the different parameters during working hours, normally from 9 a.m. till 4 p.m. The measuring devices were placed on the level of the working plane. For closed rooms, devices were located in the center of the room at 1m height from the floor. Devices were adjusted to take measures every 5 minutes for a minimum duration of four hours during the day of the study.

The data logger of the company Onset was used to measure air temperature, relative humidity and light intensity with a measuring range for temperature -20° to 70°C with accuracy level ± 0.35°C from 0° to 50°C, and measuring range for relative humidity 5% to 95% with accuracy level ± 2.5% from 10% to 90% and measuring range for light intensity from 0 to 320,000 lux (0 to 30,000 lumens/ft2). Another device was used to measure CO2 level in spaces with accuracy ranging from 0 to 6,000ppm. Fig. 5 shows the different devices used in the study.

Fig. 5 Measuring devices used in the study

C. Questionnaire Design and Its Distribution

Simultaneously to the measurements of the physical environment, a questionnaire was distributed to determine the level of occupants' satisfaction. The distributed questionnaire was divided into three parts; the first part was designed to assess occupants' overall perception and general satisfaction regarding the building. The second part was designed to assess occupants' satisfaction regarding the indoor environment, the questions asked about the air temperature, relative humidity, light intensity, acoustics, odor, the ability to interact with external environment, general environment (colors, carpet, decoration), and the ability to control light and temperature levels. The third part was designed to measure users' preference within the indoor environment. The questionnaire was on a five point scale and was distributed after passing a minimum of two hours from the start of the measurements of the physical environment, and it was considered to try to distribute the questionnaire between 12:30 and 2:00 o'clock, as it is the noon time and the hottest time of the outdoor climate.

III. Data Analysis

Three key data sets were compared; namely energy and water consumption, measurements of indoor physical environment affecting the indoor environment comfort level (Air temperature, Light intensity, Relative humidity, CO_2 level), and occupants' satisfaction within their working spaces.

A. Energy and Water Consumption

The actual annual energy consumption for the year 2011 of the four buildings was obtained. The total consumption of each building was divided by the total area of each building in order to find and indication about the consumed energy per square meter. The non-LEED building consumed 145 Kwh/m2/year, the Silver LEED certified building consumed 141 Kwh/m2/year, the Gold LEED certified building consumed 115 Kwh/m2/year, and the platinum LEED certified building consumed 77 Kwh/m2/year. This means that the non-LEED building represented the highest electricity consumption compared to LEED certified buildings as shown in Fig. 6.

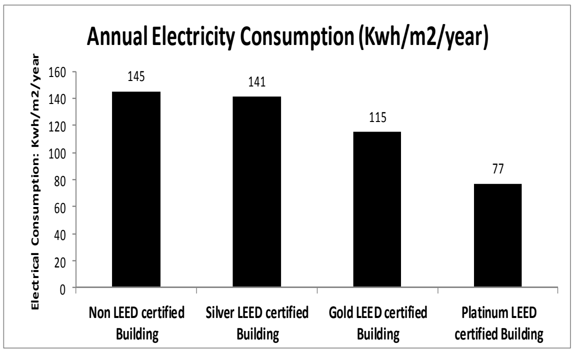

Fig. 6 Electricity consumption in the studied buildings

The annual water consumption in m3/m2/year for the four buildings was obtained according to 2011 consumption bills; the non-LEED building was with the highest water consumption compared to the other three LEED certified buildings (2.37 m^3/m^2/year). On the other hand, the platinum certified building had the lowest water consumption level (0.089 m^3/m^2/year). The gold certified building water consumption was 0.27 m^3/m^2/year, and the silver certified building water consumption was 0.54 m^3/m^2/year as shown in Fig. 7.

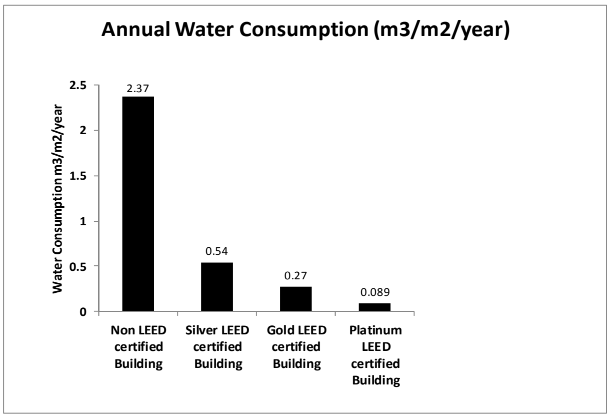

Fig. 7 Annual water consumption of studied buildings

B. Indoor Physical Environment Measurements

Four parameters were utilized to evaluate the indoor physical environment in the studied buildings: air temperature, light intensity, relative humidity, and CO_2 level. The results showed that the mean values of the four parameters were within the human comfort levels according to ASHRAE standards - 55; detailed description for each parameter is highlighted below.

The mean value for each parameter hinted here is the average of the measured parameter for each building during the days of the study.

It was found that the mean air temperature in the non-LEED building was 23°C, while in LEED buildings the mean air temperature in the silver certified building was 25.34°C; Gold certified building was 26.10°C, and 24°C in the Platinum certified building as shown in Fig. 8.

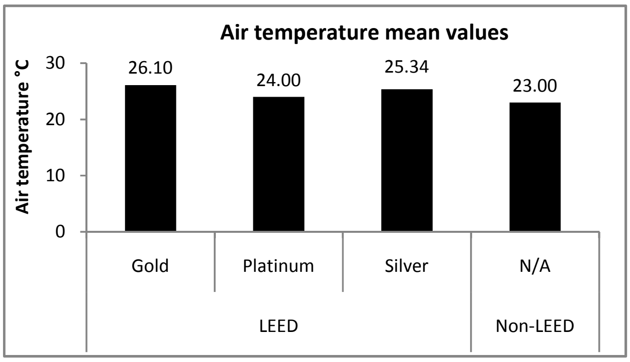

Fig. 8 Mean air temperature for each building during the days of the study

The mean relative humidity within the four studied buildings is shown in Fig. 9. It was found that the mean relative humidity during summer in the non-LEED building was 51%. In the silver certified building the mean relative humidity was 53%, in the gold certified building the mean relative humidity was 37%, and finally, the platinum certified building mean humidity was 59%.

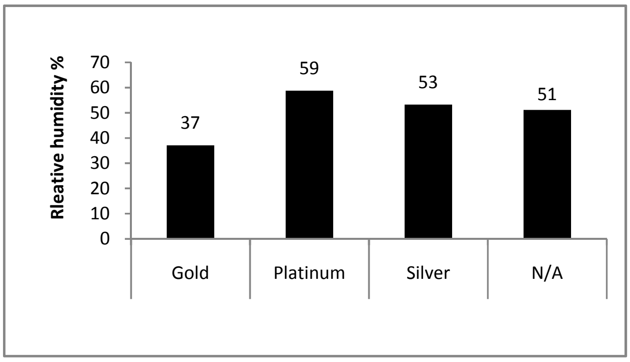

Fig. 9 Mean relative humidity for each building during the days of the study

In the non-LEED building the mean light intensity level was 418 Lux, in the Silver certified the mean light intensity level was 210 Lux, in the Gold certified building the mean light intensity was 247 Lux, and finally, in the Platinum certified building the mean light intensity level was 311 Lux as shown in Fig. 10.

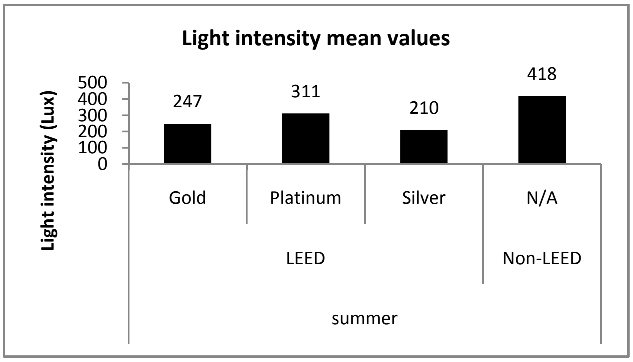

Fig. 10 Mean light intensity for each building during the days of the study

The mean CO2 level was found to be 419 ppm for the platinum, 608 ppm for the Gold, 267 ppm for the silver and 316 ppm for the non-LEED, as shown in Fig. 11 .

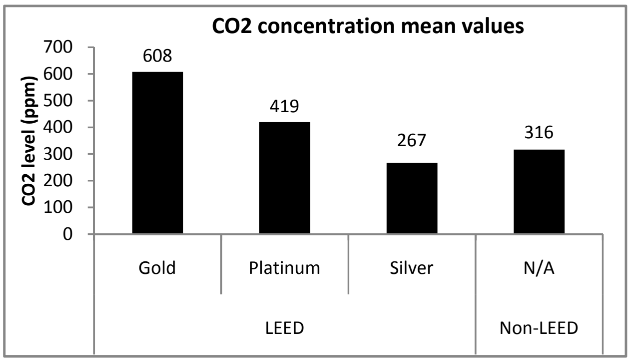

Fig. 11 Mean Carbon dioxide level for each building during the days of the study

C. Occupants' Satisfaction

This section aims at determining if there are differences between LEED and non-LEED buildings in terms of users' satisfaction, and to find whether there is a difference in users 'satisfaction between various LEED buildings with different certificate levels.

Six key parameters (light intensity, air temperature, noise level, odor, the ability to access external views, and general indoor environment (carpets, decoration, color….)) were assessed to determine the satisfaction level with the indoor environment, a survey was distributed among users to determine the level of their satisfaction rating the above parameters on a five point scale and here are the results for each parameter.

A holistic analysis is shown here; the mean satisfaction values of the used five point scales are shown in Fig. 12. It shows that users in both types of buildings are satisfied with the light, temperature, general environment, and the ability to access external views. For odor, the mean value of results was split between satisfaction and neutrality (neither satisfied nor dissatisfied). For noise level, the satisfaction mean score was fragmented showing that some users are satisfied, some are neutral (neither satisfied nor dissatisfied) and some are somewhat dissatisfied with the indoor noise level.

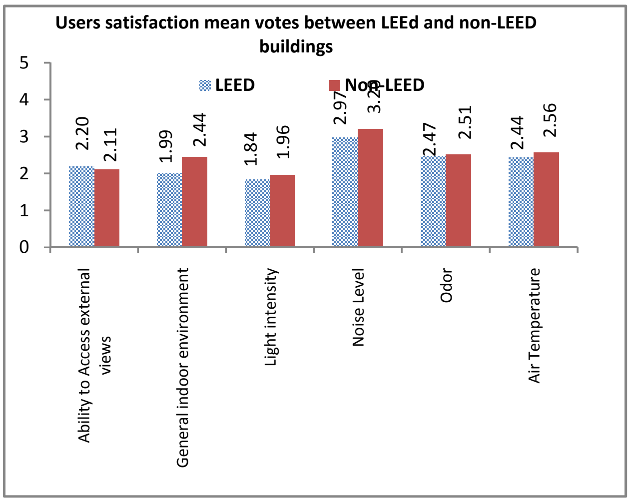

Fig. 12 The mean satisfaction responses between LEED and non-LEED buildings' users

There is no statistical difference between LEED and non-LEED buildings regarding users' satisfaction with the indoor air temperature, where the t-test for the indoor air temperature is α= 0.05, t (201) = 0.822, P= 0.412.

In Fig. 13, out of 119 responses in LEED certified buildings, 47.9% were somewhat satisfied and 23.5% were neither satisfied nor dissatisfied (μ = 2.44) regarding the indoor temperature, while out of 84 responses in non-LEED 44% of votes were somewhat satisfied and 21.4% were neither satisfied nor dissatisfied (μ = 2.56).

Regarding users' satisfaction with the indoor light intensity, the t-test identified that there is no statistical difference between LEED and non-LEED buildings users' satisfaction with the indoor light intensity, where the t-test for light is α= 0.05, t (201) = 0.960, P= 0.338. In Fig. 14, in LEED buildings 34.5% were very satisfied with light and 53.8% were somewhat satisfied (μ = 1.84). In non-LEED building 39.3% were very satisfied with light and 36.9% are somewhat satisfied (μ = 1.96).

No statistical difference between users' satisfaction in LEED and non-LEED buildings regarding the indoor noise level, where the t-test for the indoor noise level is α= 0.05, t (201) = 1.371, P= 0.172. For noise satisfaction 32.8% were somewhat satisfied, 26.1% were neither satisfied nor dissatisfied, and 22.7% are somewhat dissatisfied (μ = 2.97) in LEED buildings, while in non-LEED building 27.4% were somewhat dissatisfied, 23.8% were somewhat satisfied, and 19% neither satisfied nor dissatisfied (μ = 3.20) as shown in Fig. 15.

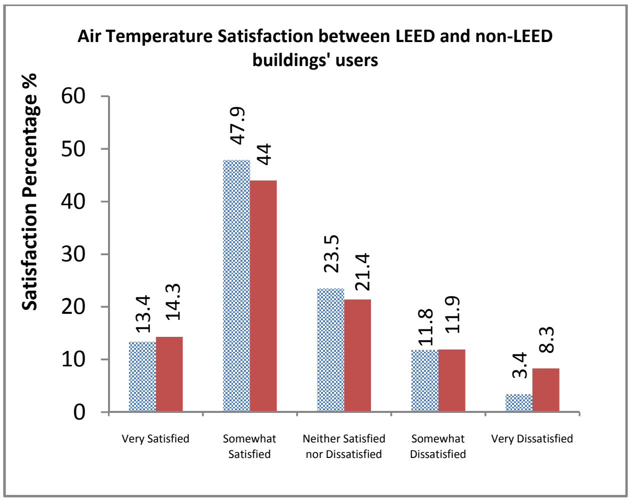

Fig. 13 Air temperature users' satisfaction percentage of votes between LEED and non-LEED buildings

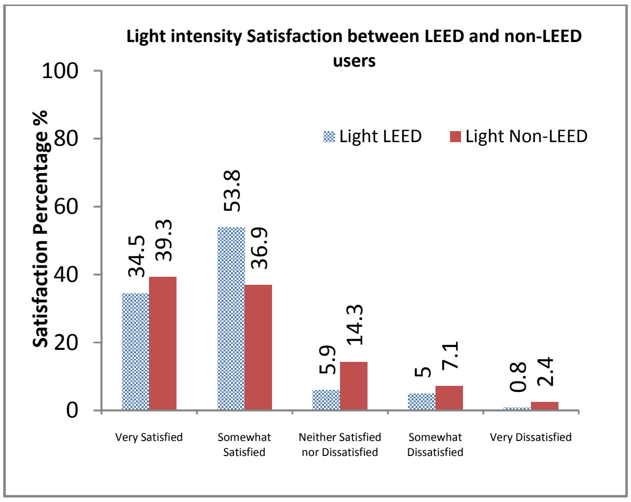

Fig. 14 Light intensity users satisfaction percentage of votes between LEED and non-LEED buildings

The t-test identified that there is no statistical difference between users' satisfaction in LEED and non-LEED buildings with the odor noise level, where the t-test for odor is α= 0.05, t (201) = 0.293, P= 0.770. In Fig. 16 the frequency of votes for odor satisfaction in LEED buildings were 47.1% were somewhat satisfied and 31.9% were neither satisfied nor dissatisfied (μ = 2.47). While 33.3% were somewhat satisfied and 31% were neither satisfied nor dissatisfied in non-LEED building (μ = 2.51).

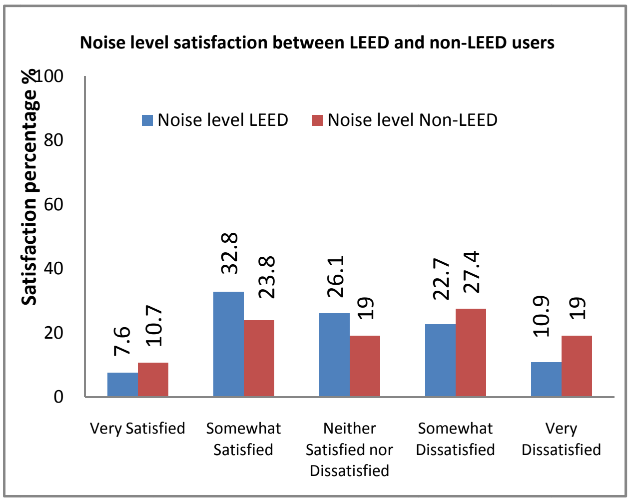

Fig. 15 Noise level users satisfaction percentage of votes between LEED and non-LEED buildings

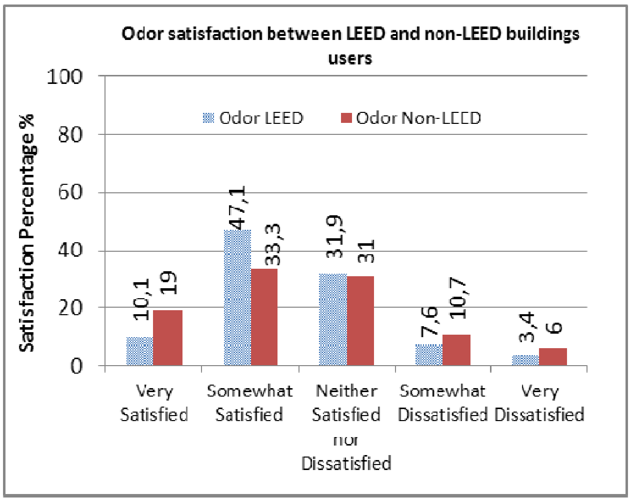

Fig. 16 Odor level users 'satisfaction percentage of votes between LEED and non-LEED buildings

The t-test identified that there is no statistical difference between users' satisfaction in LEED and non-LEED buildings with their ability to access external views, where the t-test of the ability to access external views is α= 0.05, t (201) = -0.670, P= 0.504. In Fig. 17, in LEED buildings 16.8% were very satisfied and 55.5% were somewhat satisfied, and 21% were neither satisfied nor dissatisfied with their ability to access external views (μ = 2.20), while in non-LEED percentage of votes showed that 35.7% were very satisfied and 38.1% were somewhat satisfied, and 10.7% were neither satisfied nor dissatisfied with their ability to access external views (μ = 2.11).

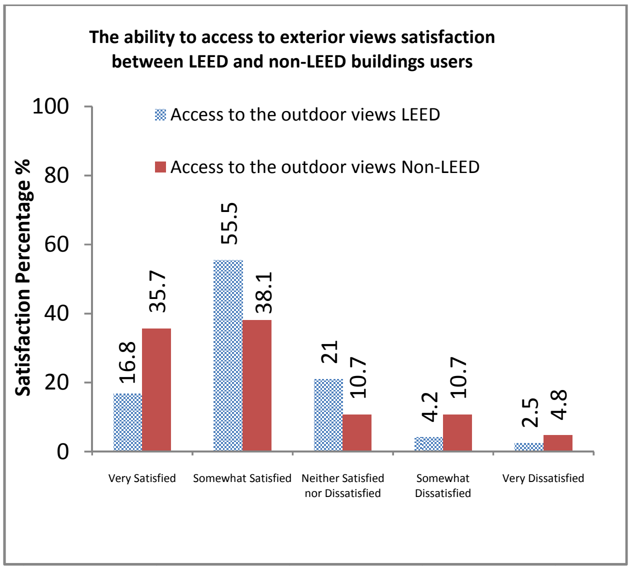

Fig. 17 The ability to access external views users' satisfaction percentage of votes between LEED and non-LEED buildings

The t-test identified a significant difference between users' satisfaction in LEED and non-LEED buildings general indoor environment satisfaction (furniture, carpets, cleanness…...) where, α= 0.05, t (201) = 3.350, P < 0.000. In Fig. 18, in LEED buildings users responses showed that 65.5% of users were somewhat satisfied and 19.3% were very satisfied with the general indoor environment (μ = 1.99). In the non-LEED building, 36.9% were somewhat satisfied and 28.8% were very satisfied with the building's general indoor environment (μ = 2.44).

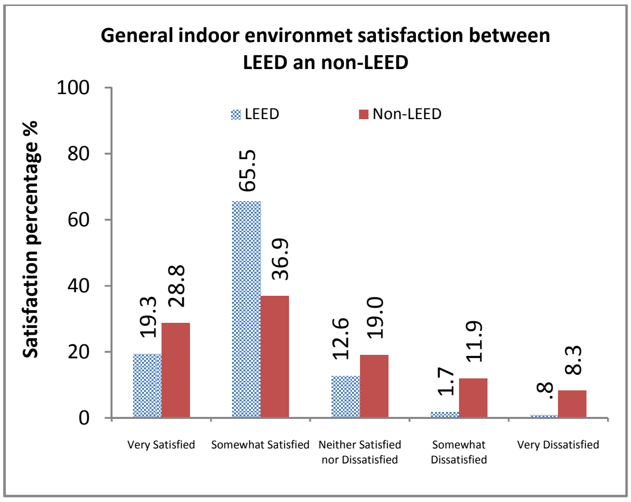

Fig. 18 General indoor environment users' satisfaction percentage of votes between LEED and non-LEED buildings

IV. Conclusion and Discussion

The higher satisfaction levels were found to be in LEED buildings. As shown in Fig. 19, the total users' satisfaction in LEED buildings was 61.3% for temperature, 57.2% for odor, 88.3% for light, 84.8% for general indoor environment, and 73.8% for the ability to access external views. While in non-LEED building users' satisfaction for temperature was 58.3%, 52.3% for odor, 76.2 for light, 65.7 % for general indoor environment, and 72.3% for the ability to access external views.

Finally, for noise level the total users 'satisfaction for both LEED and non-LEED buildings were found to be 33.5% for LEED buildings and 34.5% in non-LEED building users which refer to the dissatisfaction of users in both building types. Dissatisfaction appeared in the four studied buildings because of the open working space that support higher noise levels due to employees' use of phone and chats. This confirms previous studies where it was proved that irrelevant talks or intermittent noise causes negative effect on users' performance [4], [5].

LEED buildings with different certificate levels are more efficient in energy and water consumption rather than the studied non-LEED building. The annual consumption is 145 Kwh/m^2 in the non-LEED building which was higher than other certified buildings. The silver LEED building consumes 141 Kwh/m^2 annually and the platinum consumes 77 Kwh/m^2 annually although they contain a larger area, while the Gold building consumes 0.11 Kwh/m^2 annually. LEED platinum and gold certified buildings saves more than 40 % of the annual energy consumption compared to the non-LEED building. Despite the fact that silver certified building nearly consumes the same energy as the non-LEED building.

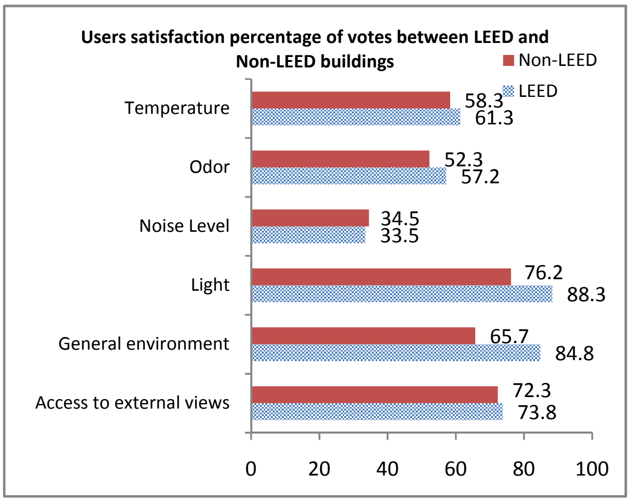

Fig. 19 Users Satisfaction percentage of votes between LEED and Non-LEED buildings

The highest consumption of water was found in the non-LEED building, compared to the platinum LEED certified building which consumes the least amount of water.

This confirms that using efficient water fixture, and efficient irrigation systems in buildings decreases amount of potable water used. Therefore, LEED buildings compared to non-LEED building saved up to 50% of water consumed.

Energy reduction occupies the highest level of attention in the green buildings movement and the highest rates in LEED rating system. LEED buildings consume 25-30% less energy than conventional buildings [6]. In this study non-LEED certified building consumed double the amount of energy consumed in the platinum certified building (highest certificate used).

There were no significant differences between users satisfaction of LEED and non-LEED buildings in terms of light (P= 0.338), temperature (P= 0.412), odor (P= 0.770), Noise (P= 0.172), and the ability to access external views (P= 0.504), While for general indoor environment there was a significant difference (P= 0.000).

Users' total satisfaction was higher among LEED buildings versus the non-LEED building. Light satisfaction level took the highest votes in LEED building scoring 88.3% while in non-LEED building 76.2% of users were satisfied with light. The high satisfaction level is due to providing a combination of natural and artificial light in both types of buildings.

Satisfaction with general indoor environment and users' ability to access to external views came in second and third place. 84.8% of LEED buildings and 65.7% of non-LEED building users were satisfied with their general indoor environment (colors, carpets, furniture…..). 73.8% of LEED buildings users and 72.3% of non-buildings users were satisfied with the ability to access external views.

Satisfaction with odor and temperature follows where 61.3% of LEED buildings' users and 58.3% of non-LEED users were satisfied with the indoor temperature levels. This is due to the lack of temperature control systems and the absence of operable windows in non-LEED building. For odor, 57.2% for LEED buildings and 52.3% of non-LEED building users were satisfied.

Finally, satisfaction with noise level was found to be the lowest rank where in LEED buildings only 33.5% were satisfied with noise level in their work space and 34.5% of users in non-LEED building were satisfied. This is due to open space office layout that leads to interruption caused by the use of phone.

After studying the three levels of LEED certificates it is worth highlighting that the nature of rating buildings according to LEED considers applying strategies, designs, material that contributes to energy reduction and water consumption putting into consideration the possibility that the higher the certificate is that would lead to higher efficiency in energy and water use. As per the study findings the Platinum building consumes the minimal consumption in both energy and water followed by the Gold then the Silver.

LEED certificate with its different levels does not guarantee additional users 'satisfaction compared to non-LEED building. No significant differences between users' satisfaction in LEED and non-LEED buildings regarding light, temperature, noise, odor levels and their ability to access external views, while significant difference was found between their users regarding the general indoor environment (carpet, color, furniture….). Common factors drive satisfaction in LEED and non-LEED building which are light level, general indoor environment, and the ability that users could achieve outdoor views.

On the other hand, the lack of natural ventilation and temperature control systems are the main reasons for dissatisfaction with the odor and temperature levels. Also, open office layout is the reason for dissatisfaction with noise level in the two buildings types.

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