INDOOR ENVIRONMENTAL QUALITY IN THE JORDANIAN CONTEXT: INFLUENCE ON OCCUPANTS' SATISFACTION

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ABSTRACT

The applicability of building rating systems has gained attention for achieving indoor environmental quality. Considering the wider internationalized recognition of LEED (Leadership in Energy and Environmental Design) and other rating systems, the case of Jordan provides a sense of particularity in consideration to its rather recent history in acknowledging these progressive standards. Utilizing a mixed approach based on paired comparisons between local LEED and non-LEED certified buildings, this research paper explores the level of satisfaction pertaining to Indoor Environmental Quality of building occupants. While it touches on the generality of such satisfaction, it proceeds to unpack and investigate how it resonates with the sustainability of the building measured through various means. The research outcomes reflected an overall appeal of LEED certified buildings and a decent level of comfort of their dwellers. Yet, it conveyed a vague, rather sporadic relation when comparing the subjective perception to the objective measures due to multiple potential reasons. The paper concludes by stressing the need for further appropriation of international environmental codes to better suit the local context. It lays a reliable foundation for further research, utilizing more case studies and exploring the applicability of rating systems in Jordan.

KEYWORDS

Building rating systems; green buildings; sustainability; local context; built environment

INTRODUCTION

The concern over sustainability has been well positioned over the last few decades due to a growing concern over finite energy resources and environmental deterioration. Buildings, whether during construction or occupation, are among the highest consumers of energy and the top contributors to the adverse impacts on the environment (Berardi 2017; IPCC 2014; Jones et al. 2016; Monahan and Powell 2011), accounting for 36% of global energy use and nearly 40% of related carbon dioxide (CO_2) emissions in 2017 (IEA and UNEP 2018). Building rating systems have accordingly been recognized as being quite influential in achieving the

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sustainability mandate (Gonzalez et al. 2011; Robichaud and Anantatmula 2011). These rating systems focus on selected physical aspects while maintaining a comfortable livable environment due to the role of buildings in occupants' health and wellbeing. Considering the prominent building rating systems, among which is the LEED standard that originated in the US and gained worldwide recognition, Indoor Environmental Quality (IEQ) was highlighted to cater for the comfort, health and well-being of occupants (De Giuli et al. 2012). Within the workplace in particular, IEQ has had a significant effect on workers' productivity (Bluyssen 2014; Institute of Medicine 2011). However, there is little evidence that the indoor environment designed according to these standards acts as expected based on their LEED certification scores (Altomonte et al. 2016; Mendler et al. 2005; Young et al. 2010). This has been shown through studies that demonstrated the differences apparent when it came to the reality of the building occupants' responses (see Altomonte and Schiavon 2013; Hedge et al. 2014; Lee and Kim 2008 as examples of such studies). In other words, by comparing design to reality the relation of IEQ is not as straightforward as indicated in LEED scores, but is more complex and controversial when it comes to such building occupants (Altomonte and Schiavon 2013; Frontczak and Wargocki 2011; Geng et al. 2017; Schiavon and Altomonte 2014). Accordingly, there is a pressing need to uncover these differences, and fill these identified gaps, in order to enhance the level of adoption of such standards within these livable spaces. This research paper aims to study the potential of green buildings in Jordan, focusing on the applicability of LEED standards when utilized with the indoor environment of workplaces. It utilizes a number of case studies (LEED and non-LEED certified buildings) through paired comparisons to address a number of key aspects that would support a stronger local endorsement of environmental rating systems. This research explores, firstly, the correspondence of building occupants' satisfaction to the buildings' compliance with LEED sustainable strategies and how this reflects a higher level of satisfaction upon LEED building certification or when comparing LEED and non-LEED certified buildings. Secondly, the research unpacks how occupant satisfaction is aligned with the detailed scorecards of the building and, thirdly, the correspondence of such satisfaction with the objective indoor environmental measurements taken from within the building. Not only are these areas important for understanding the level of acceptance to the newly introduced green building standards in Jordan, but they also highlight more detailed domains of alignment to further enhance their applicability.

LITERATURE REVIEW

Building sustainability and occupant satisfaction

Multiple studies have stressed the importance of building design and occupant satisfaction as people spend a significant amount of their time inside buildings (Abbaszadeh et al. 2006; Khoshbakht et al. 2018). Research has shown that problems with the building IEQ parameters, be they regarding the air quality, thermal, visual or acoustics of a building, have a direct effect on occupants' comfort, health and wellbeing (De Giuli et al. 2012). Within the workplace in particular, satisfaction of building occupants with the quality of their indoor environment has a direct relation to their productivity (Bluyssen 2014; Institute of Medicine 2011). This also has a significant influence on building energy requirements, as a result of occupant reactions (e.g., on thermostats, blinds and sensors) to adapt to environmental conditions (Haldi and Robinson 2011; Sharif 2016).

This mutually influential relationship between buildings and their occupants has raised many concerns regarding the potential assessment of IEQ. Many studies have been conducted to define the major factors of IEQ that affect occupants' satisfaction and productivity (Astolfi and Pellerey 2008; Humphreys and Nicol 2007; Leder et al. 2016). Indoor air quality, thermal comfort, interior lighting and acoustic performance have been determined as the most essential aspects of IEQ, emphasized in building rating systems as a means for improving workplace efficiency and experience (USGBC 2017).

IEQ was addressed in the LEED rating system as one of its five environmental categories (Portman et al. 2006). The importance of this category lies in its direct effect on occupants compared to other categories (energy, material, water, waste, etc.) In fact, the increase in overall employee performance is believed to be more substantial than the cost savings in utilities and maintenance (Lee and Guerin 2009).

The IEQ category of the LEED rating system addresses design and construction guidelines (USGBC 2017), where LEED compliance is predicted to result in a measurably improved IEQ in buildings, which guarantees the satisfaction and productivity of their occupants (Lee et al. 2019). However, there is still little evidence that an indoor environment designed according to these standards is satisfactory and productive to occupants in reality (Young et al. 2010). As a result, built environment design professionals continuously emphasize the importance of occupants' assessment in LEED certified buildings and sustainable buildings at large (Mendler et al. 2005).

Various studies have investigated the effect of LEED building certification on occupant IEQ satisfaction, while others have compared such satisfaction in LEED certified and conventional, non-LEED certified buildings (Altomonte and Schiavon 2013; Hedge et al. 2014; Lee and Kim 2008). Some of these studies compared LEED and non-LEED certified buildings by going into detailed categories. Table 1 shows varying results among these studies revealing the controversy between LEED building standards and the level of influence they attain over occupant satisfaction.

TABLE 1. Studies on IEQ-related satisfaction in LEED and non-LEED certified buildings.

Aspect	Sample Studies
Indoor Air Quality	Higher Satisfaction: Abbaszadeh et al. 2006; Altomonte et al. 2016; Frontczak et al. 2012; Huizenga et al. 2005; Issa et al. 2011; Kim et al. 2015; Lee and Guerin 2009; Lee and Kim 2008
Thermal Comfort	Higher Satisfaction: Abbaszadeh et al. 2006; Baird et al. 2012; Frontczak et al. 2012; Newsham et al. 2013 No Significant Difference: Altomonte and Schiavon 2013
Internal Lighting	Higher Satisfaction: Baird et al. 2012; Frontczak et al. 2012; Issa et al. 2011; Kim et al. 2015 Lower Satisfaction: Altomonte and Schiavon 2013; Brown et al. 2010; Lee and Guerin 2009; Lee and Kim 2008 No Significant Difference: Abbaszadeh et al. 2006; Altomonte and Schiavon 2013; Huizenga et al. 2005
Acoustic Performance	Higher Satisfaction: Frontczak et al. 2012; Newsham et al. 2013 Lower Satisfaction: Brown et al. 2010; Issa et al. 2011; Lee and Guerin 2009; Lee and Kim 2008 No Significant Difference: Abbaszadeh et al. 2006; Altomonte and Schiavon 2013; Baird et al. 2012; Huizenga et al. 2005

Despite the general assumption that a LEED certified building indicates an improved IEQ (USGBC 2017), empirical evidence has often been inconsistent. In other words, the relation between IEQ, as identified in LEED scorecards/measurements and as assessed through occupant satisfaction, is too complicated to give direct or similar results due to the many limitations that might be faced. This is sometimes due to differences in the metrics utilized and the methods deployed in data collection and analysis (Thatcher and Milner 2016). Altomonte and Schiavon (2013) reported that some studies failed to consider certain differences between the buildings under study (including building size, floor area and the number of floors) and were also short of direct occupant responses (as a result of their reliance on secondary resources). Moreover, studies suggested that specific standard measurements were determined by their singular performances and did not address the interrelation of measures when mixed with other environmental items. Thus, adopting certain standards may result in differences from the desired outcome of the occupants, who experience the environment as a whole (Kim et al. 2008). Studies also suggested that comfort and satisfaction could be influenced by other non-environmental variables, such as the personal characteristics of occupants, workplace features and work-related conditions (Altomonte and Schiavon 2013; Frontczak and Wargocki 2011; Geng et al. 2017; Schiavon and Altomonte 2014).

Green building standards in Jordan

Jordan is an example of a rather recent introduction to green building standards, having had its first LEED accredited building certificate issued in 2009. A number of local governmental and non-governmental institutions and building codes were developed and endorsed to address the sustainability agenda at large (JGBC 2017). Jordan's Green Building Guide (JGBG) was drafted in 2009 under the guidance of the Ministry of Public Works and Housing, which relied mainly on international rating tools such as LEED and BREEAM as a starting point (EcoMENA 2017). JGBG was designed for new buildings being developed, covering different building types. It included IEQ among its main categories alongside Management, Sustainable Site, Water Efficiency, Energy Efficiency and Resources and Materials (Shareef and Altan 2017). Despite its completion in 2013, JGBG was only approved in 2015 (JGBC 2017).

The introduction of the LEED rating system, and other related sustainability codes, was attributed to Jordan's unusual reliance on imported energy resources, mainly fuel, which exceeds 90% of the total and comprises 20% of the country's GDP. This is further exacerbated by persistent development stimulating more importation of such finite energy sources. With its slow-paced direction towards green building standards coupled with a modest level of public awareness, the targets set for green buildings are debated as hard to achieve (Rosenlund et al. 2010). This renders Jordan an urgent case for studying the applicability and acceptance of green buildings.

This paper builds upon previous research by comparing IEQ standings between LEED and non-LEED certified buildings in Jordan, utilizing three paired comparisons of buildings under study. It explores the diverse interrelationships between the designed IEQ and occupant responses of LEED certified buildings through a comparison with non-LEED certified buildings, an evaluation that is currently lacking in Jordan (Al-Atrash et al. 2018).

MATERIALS AND METHODS

To achieve the research purpose, it is based on a case study comparative methodology (Goodrick 2014) that focuses on three pairs of LEED and non-LEED certified buildings in Jordan in terms of their IEQ parameters. The pairs are first taken in their singularity to explore the level of occupant satisfaction before and after LEED certification and then in total to compare occupant satisfaction with the building sustainability scorecard as well as the collected indoor environmental measurements. In light of the research aims and similar previous studies, a mixed methodology has been adopted incorporating objective (scorecards, live recorded environmental measurements and monitoring) and subjective data sources (occupants' self-reported questionnaires). The incorporation of objective and subjective data comes in line with the focused approach of the study addressing a specific context. Considering buildings as complex systems entailing multiple physical and human elements with various associations and interactions, viewing each and every element from a pure statistical stance would not achieve formidable findings on its own (Leaman and Bordass 1999), where both aspects need to jointly fall under consideration.

The combination between objective and subjective factors in the study of building sustainability is seen as quite beneficial and important, where the objective factors alone are seen as deprived from the valid opinions of the ones actually occupying and using the building. The lack of alignment between physical measures and subjective feedback indicates underlying factors that are influencing the collected data (Sanders and Collins 1995). Pure subjective factors, on the other hand, carry the limitation of being generally deductive and in need for validation (Sadick 2018) as well as the difficulty in specifying a proper survey period and the proper interpretation of survey results (Laskari et al. 2017). IEQ is claimed to be subjective in nature, where the addition of objective measurements can shed light into the design, construction and operational issues affecting the building (Webster et al. 2013). When embarking on studies of similar scope, consideration should be provided to ongoing occupant feedback (the subjective part) as well as building physical measurements (the objective part) in order to ensure that buildings continue to be operated in line with their design (Altomonte et al. 2019).

Multiple researches utilized this approach including the holistic approach combining objective and subjective data utilised in the building occupancy survey system in Australia (Candido et al. 2016). Other similar studies include the works of Cakmak et al. (2014) and De Giuli et al. (2014). A study by Heinzerling et al. (2013) identified the use of IEQ subjective and objective measurements in many scoring systems targeting building performance.

The selected LEED certified buildings shared an intermediate certification rating level of Silver or Gold of LEED. For each of the chosen certified cases, an equivalent conventional case was selected. These non-LEED certified cases also shared similar characteristics in terms of building type, location (and, accordingly, climatic conditions), population, number of office occupants and occupation patterns (Table 2).

Data typology and collection

Data collection in this research was conducted during the period between August and October 2017, covering summer and autumn, through live recorded indoor environmental measurements, and also the building occupants' self-reported questionnaires reflecting their level of satisfaction pertaining to the detailed IEQ parameters (Table 3). Indoor measurements were taken during standard working times covering the morning and afternoon periods (8 am to 5 pm) utilizing monitoring tools supported by built-in data loggers (see Table 4 for the description of the utilized devices). The total number of readings for monitored parameters was 1,620 reading per parameter (60 readings per hour, covering 9 work hours per day) for three selected cases of both LEED and non-LEED certified buildings. The readings were compared to the

TABLE 2. General comparative description of LEED and non-LEED certified case studies (with the LEED certified building coming first in each pair).

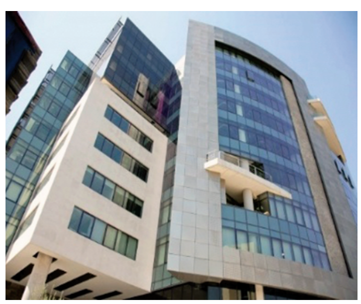
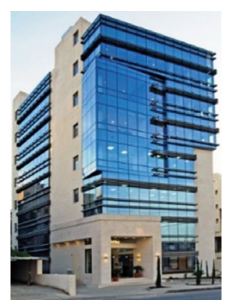
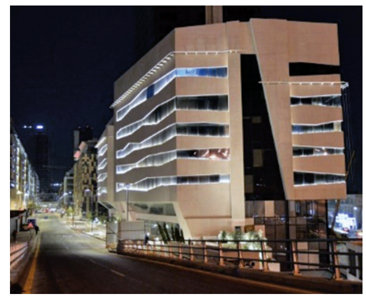
First part	Netherlands Embassy	Canada Embassy
		
Year Certified/ Year Built	2010	2011
Type	Embassy	Embassy
Location	Abdoun, Amman	5th Circle, Amman
Designer	Rudy Uytenhaak	Jafer Tukan
Building construction type	Major renovation	New Construction
Building population[a]	62	57
Number of office occupants[b]	40	45
Occupation pattern	8 hours	8 hours
Certification level	Silver	Not Certified
LEED achieved scores in IEQ category	6/15	Not Certified
Second pair	**Middle East Insurance**	**Delta Insurance**
		
Year Certified/ Year Built	2013	2013
Type	Insurance company	Insurance company
Location	3rd Circle, Amman	3rd Circle, Amman
Designer	Faris Bagaeen	Ruqn Al Handasa
Building construction type	New Construction	New Construction
Building population[a]	100	85
Number of office occupants	63	55

TABLE 2. (Continued)

Second pair	Middle East Insurance	Delta Insurance
Occupation pattern	8 hours	8 hours
Certification level	Gold	Not Certified
LEED achieved scores in IEQ category	8/23	Not Certified
Third pair	**Edgo Atrium**	**Eagle Hills**
		
Year Certified/ Year Built	2017	2013
Type	Office building	Office building
Location	Rafiq Al-Hariri Avenue, Amman	3rd Circle, Amman
Designer	Maisam Architects & Engineers	Ruqn Al Handasa
Building construction type	New Construction	New Construction
Building population[a]	75	85
Number of office occupants	51	55
Occupation pattern	8 hours	8 hours
Certification level	Gold	Not Certified
LEED achieved scores in IEQ category	5/20	Not Certified

[a]These figures are approximate numbers based on human resources department of each building.
[b]These figures are an approximate annual average based on job nature that requires periodic traveling.

standards used by the US Green Building Council (USGBC) in LEED certification which are; Environmental Protection Agency (EPA) standards and The American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE) 62.1-2019 for IAQ, ASHRAE 55-2017 for ITC, ASHRAE 90.1-2019 for IL and The American National Standards Institute standards published by the American Standards Association (ANSI/ASA) S12.2-2008 based on noise curve criteria for IAP.

Data collection also included a sample of around 30 questionnaires for each case, with a total of 182 questionnaires covering the buildings under study, shared almost equally between LEED and non-LEED certified buildings. The participants were randomly selected according

TABLE 3. Categorical information collected through the self-reported questionnaire.

Category	Questions
Background Information	Age; gender; employment duration; weekly working hours; type of work; office type; proximity to windows; faced direction
Overall Satisfaction	Satisfaction with overall environment;
IAQ	Air quality; type of ventilation;
ITC	Thermal quality; control over indoor temperature
IL	Amount of light; control over office lighting; daylighting
IAP	Acoustic performance; sound privacy

TABLE 4. Devices utilized for obtaining indoor environmental measurements.

Category	Device	Quantity	Parameter	Accuracy
IAQ	Air visual Node	1	Air Quality Index (AQI)	—
			CO_2 (ppm)	30ppm +3% of measured value
			PM10* (ug/m^3)	4ug/m^3 (+/–) 0.8 ug/m^3
ITC	Air visual Node	1	Air temperature (Celsius) Relative Humidity (RH%)	(+/–) 0.05 Celsius (+/–) 2%
IL	Light Meter	1	Interior luminance level (Lux)	+ or – 3%
IAP	Sound Meter	1	Noise Level (dB)	—

* Particulate Matter 10

to data provided by human resource departments in the selected case studies to represent a distributed sample in terms of age, gender, type of workspace, distance from external windows and faced direction (Table 5). The sample size was calculated based on providing a 90% confidence level and a 10% margin of error, which are typical of the parameters used for similar research in this field using the following formula and resulting in an average sample size of 30 per case study:

$$\text{Sample size} = \frac{\dfrac{z^2 \times p(1-p)}{e^2}}{1+\left(\dfrac{z^2 \times p(1-p)}{e^2 N}\right)} \quad (1)$$

N = population size • e = Margin of error (percentage in decimal form) • z = z-score, the z-score is the number of standard deviations a given proportion is away from the mean. For 90% confidence level percentage z-score = 1.65.

TABLE 5. Attributes of questionnaire respondents.

Parameter	Description				
Age	≤30 37.9%	31–50 51.7%	>50 10.4%		
Gender	Male 46.2%	Female 53.8%			
Employment Duration	≤3 months 3.3%	4–6 months 4.9%	7–12 months 9.9%	>1 year 81.9%	
Weekly Working Hours	≤10 hours 1.6%	11–30 hours 7.1%	>30 hours 91.2%		
Work Type	Admin 36.8%	Technical 24.2%	Supervisor 30.2%	Other 8.8%	
Personal Workspace	Private Office 18.6%	Shared Office 31.1%	Cubicle 50.3%		
Distance from a Window	Within 5 m 24.8%	Beyond 5 m 38.7%	Unknown 36.5%		
Faced Direction	East 11.6%	West 10.8%	North 20.2%	South 15.2%	Unknown 57.8%

Participants were classified into three categories; department staff, department heads and top management, with percentages of 60, 30, and 10 respectively. As Table 5 shows, the questionnaires were designed to cover personal and demographic information (age and gender), working conditions (employment duration, work duration and typology), physical conditions (office type, proximity to windows and faced direction) and workplace IEQ parameters (IAQ, ITC, IL and IAP).

A Likert scale of seven evaluation rating levels was utilized, ranging from (-3) to (+3) with (0) representing occupants who regarded their workplace neutrally. This research defined triangulation as the proper tool to validate its results (Adami and Kiger 2005), whether applied on the data or the utilized methods, in order to obtain a sense of consistency across all results that confirm or deny the expected findings.

Data validation and analysis

The collected data was processed and analyzed using the Statistical Package of Social Sciences software (SPSS) 21.0. The calculations included the measurements of descriptive statistics (such as the frequency and percentage for categorical variables), and continuous variables (such as the mean and standard deviation (SD)). To determine the statistical hypothesis testing methods, the distribution characteristics of the scale scores were investigated in terms of normality. For this purpose, Kolmogorov–Smirnov test of normality, Shapiro–Wilk test of normality, Q-Q plots, skewness and kurtosis values were all analyzed. Additionally, Levene's test of homogeneity of variances was applied where required. Using all the gathered data, parametric hypothesis tests were performed throughout the whole data analysis phase; since it is the most commonly used method for interface regarding the mean of quantitative response variables, it assumes that the tested variables have a normal distribution (Moore and McCabe 2002).

To understand the possible associations between different independent samples, as with the occupant questionnaires on satisfaction with IEQ parameters and overall satisfaction, the t-test was used to stand on the significance of the two sets of data. Additionally, and in light of the small sample size and its diversity, the One-Way Analysis of Variance (ANOVA) test was performed for each demographic characteristic that was composed of more than two groups, in order to understand the significance of the score differences between the categories. This was due to the dependent variable having more than two independent categories. Two Multiple Linear regression analyses were applied in order to understand the correlation between satisfaction with IEQ parameters, and overall satisfaction in the included LEED and non-LEED certified buildings. The accepted level of significance adopted throughout the study was $\alpha = 0.05$.

With the above said, and when comparing occupant satisfaction results between LEED and non-LEED certified buildings, the effect size was calculated using Cohen d (Cohen 1988) to stand on the substantiality of the difference in means obtained, as the t-test would only show their significance without providing the level of importance of such differences. For that purpose, the relation was considered negligible for an effect size below 0.2, small for effect size between 0.2 and 0.5, medium for effect size between 0.5 and 0.8, and large for effect size above 0.8.

The analysis of collected data commenced by studying the possible association between satisfaction with IEQ parameters, and overall satisfaction reflected in the occupant questionnaires. Applying focus to LEED and non-LEED certified buildings, two stages of analysis followed. The first stage considered the selected LEED certified buildings via a comparison of their scorecards and occupant questionnaires to reflect how the scores achieved by these buildings resonated with reported satisfaction levels after their certification. The second stage included paired comparisons of LEED and non-LEED certified buildings based on the collected occupant satisfaction questionnaires and the indoor environmental measurements.

Research limitations

It is worth mentioning that, in light of the recency of the green building concepts in Jordan, the number of LEED certified buildings is relatively limited. Indeed, most similar studies conducted used small sample sizes of less than 10 green buildings (Radwan et al. 2013), such as the works of Paul and Taylor (2008) and Konis (2013). Despite the limitation implied by the small research sample, it can be addressed through the assurance of the statistical significance of the collected data as well as the careful consideration prior to any generalizations in light of the study findings. Furthermore, as the study maintains an exploratory stance, a small sample size is considered adequate to fulfill its purpose (Onwuegbuzie and Collins 2007).

Considering the small sample size as stated above, the research faced a limitation in regard to the generalization of its findings. Here, we would have to refer to the purpose and exploratory nature of the subject matter. Pure quantitative research tends to reach statistical generalizations based on representative statistical samples. However, and through its mixed approach, this research aims to reach analytic generalizations based on case-to-case consideration (Firestone

1993; Kennedy 1979). The sample size utilized, despite its limitation, aligns with the study as it aims to obtain further insights over a particular phenomenon (Onwuegbuzie and Collins 2007).

RESULTS AND ANALYSIS

The analysis of data resulted in a number of findings that highlighted the level of correlation between building occupant satisfaction and the application of sustainability measures within the building.

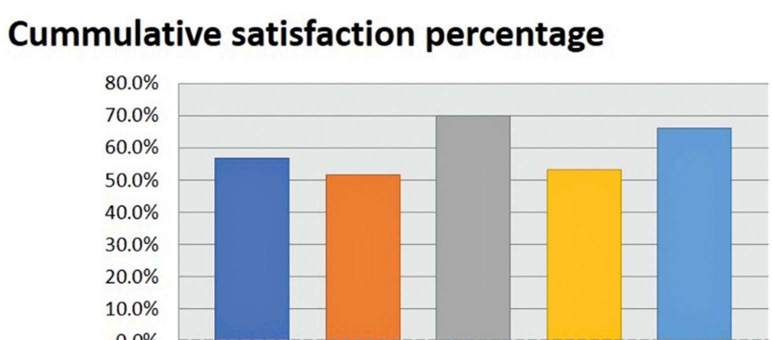
Occupant satisfaction and IEQ parameters

For understanding the association between occupant satisfaction and the LEED certification of the building, satisfaction levels with IEQ in both LEED and non-LEED certified buildings were investigated regarding the influence of the checked satisfaction of the parameters (IAQ, ITC, IL and IAP) on each other and on overall satisfaction. This demonstrated the level to which these parameters were interrelated and how they influenced occupant responses in order to best stand on the impact of LEED certification on occupant satisfaction. Figure 1 shows the frequencies of satisfaction with each of the IEQ parameters in the workplace, based on the feedback received from the occupants' questionnaires. The cumulative results show a higher satisfaction with IL, followed by IAQ, IAP and finally with ITC.

Next, satisfaction with IEQ parameters' possible association with overall satisfaction was tested using the t-test to check if any of the parameters had a significant effect on overall satisfaction. The calculated levels of significance for satisfaction with IAQ, ITC, IL and IAP with overall satisfaction were within the accepted significance level ($\alpha = 0.05$). Thus, there is a significant relationship between satisfaction with IEQ parameters (with significance values ranging from 0.000 to 0.006) and overall satisfaction.

Multilinear regressions were conducted to identify the correlation between satisfaction with different IEQ parameters, and overall satisfaction in both LEED and non-LEED certified

FIGURE 1. Cumulative satisfaction with IEQ based on occupant questionnaires.



	Cummulative satisfaction percentage
Satisfaction with air quality	56.6%
Satisfaction with Thermal Conditions	51.6%
Satisfaction with Interior Lighting	69.8%
Satisfaction with Acoustical Performance	53.3%
Overall satisfaction	65.9%

TABLE 6. Cross-correlation between satisfaction with IEQ parameters and overall satisfaction.

	Overall Satisfaction	Satisfaction with IAQ	Satisfaction with ITC	Satisfaction with IL	Satisfaction with IAP
Overall Satisfaction		.646	.590	.565	.350
Satisfaction with IAQ	.646		.703	.493	.237
Satisfaction with ITC	.590	.703		.423	.172
Satisfaction with IL	.565	.493	.423		.406
Satisfaction with IAP	.350	.237	.172	.406	

buildings. Table 6 demonstrates the variable correlation ranging from 0.172 to 0.703. It is important to realize that overall satisfaction is correlated with satisfaction with most IEQ parameters except for IAP. The majority of cross correlations are greater or close to 0.5, which reflects a relatively strong correlation between IAQ, ITC and IL. The dependence of these parameters should be kept in mind when they are considered individually, as is the case of most sustainability standards and codes.

The values of these correlations are hardly predictable or explainable, but they have significance in realizing the instances where the correlation is in its utmost strength (the case of IAQ correlation with ITC) or utmost weakness (the case of IAP with all the remaining parameters).

Occupant satisfaction and the building scorecard

The case study approach comprised a two-way comparison concerning LEED certified buildings. The first tackled IEQ using objective criteria (scorecards) and compared them to the subjective criteria (occupants' self-reported questionnaires) to reveal how the scores achieved by the buildings resonated with reported satisfaction after their certification. The second comparison was for the purpose of re-ordering the LEED certified buildings from the initial order of the scorecards, to the order that is achieved when occupant questionnaires were considered.

Based on their available IEQ scores, the selected LEED-certified cases followed a certain order with the highest rank belonging to the Embassy of the Netherlands, followed by the Middle East Insurance Company and lastly the Edgo Atrium. The means of collected data from the occupant questionnaires were calculated with regard to overall satisfaction as well as to satisfaction with different IEQ parameters (shown in Table 7). Based on the calculated means of overall satisfaction results, the arrangement of the selected LEED certified buildings differed from the one based on their scorecard scores during building certification. The Edgo Atrium had the highest mean, followed by the Middle East Insurance Company and finally the Embassy of the Netherlands. The arrangement of the buildings in relation to their detailed satisfaction results had somehow demonstrated further variances; satisfaction with IAQ showed the same order as overall satisfaction, whereas ITC, IL and IAP showed a different order, with

TABLE 7. The achieved IEQ score maintained in the selected LEED certified buildings scorecard compared with the mean of overall satisfaction and each parameter's satisfaction results.

Case Study	Embassy of the Netherlands	ME Insurance Company	Edgo Atrium
IEQ Score (based on the scorecard)	6/15	8/15	5/12
Mean of Overall Satisfaction	5.033/7	5.53/7	6.07/7
Mean of Satisfaction with Indoor Air Quality	5.13/7	5.3/7	5.3/7
Mean of Satisfaction with Thermal Comfort	4.93/7	5.3/7	5.1/7
Mean of Satisfaction with Interior Lighting	5.63/7	6.093/7	5.87/7
Mean of Satisfaction with Acoustic Performance	4.57/7	5.093/7	4.97/7

the Middle East Insurance Company having the highest mean, followed by the Edgo Atrium and the Embassy of the Netherlands.

The outcomes of this part of the comparison indicated two key findings. Firstly, by comparing each building scorecard with its occupants' satisfaction results, the overall trend demonstrated the same if not improved levels of satisfaction after certification. In other words, there is an overall positive impact in adhering to the strategies used for achieving LEED in building occupants' perception and satisfaction.

Secondly, the re-ordering of the buildings based on their scorecards as well as occupant satisfaction demonstrated discrepancy. The detailed scores obtained on the scorecards were not necessarily correlated in the same manner to occupants' satisfaction results, whether taken as overall satisfaction or in detail regarding the particular IEQ parameters. The reason for this bears a number of possibilities; it could be due to regular maintenance and quality control for the certified buildings that might not follow in the same pattern after certification, or it could be due to unexpected aspects that were not considered in the scores, or even in the occupant questionnaires.

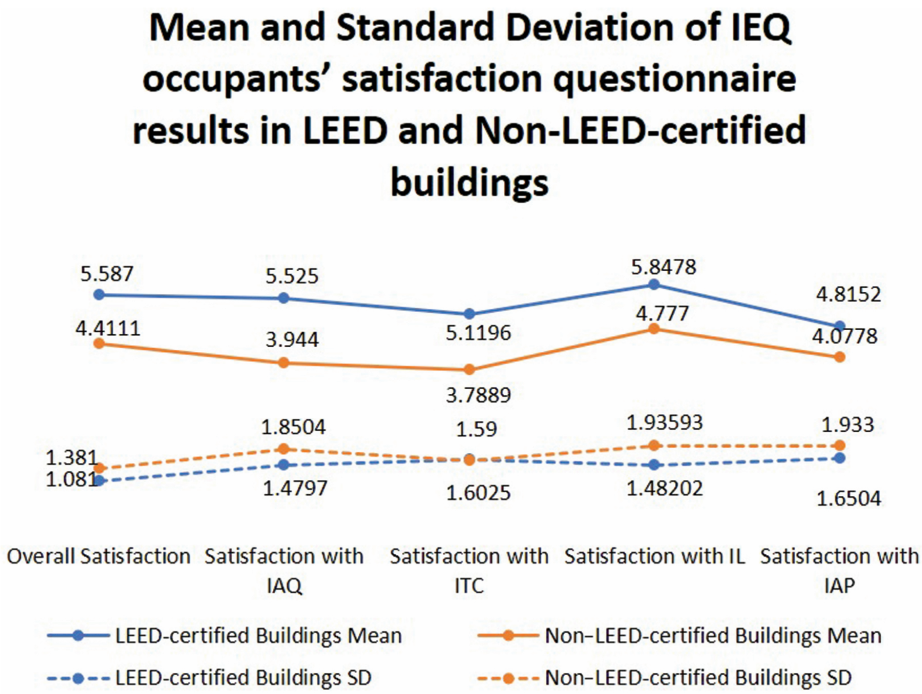
Occupant satisfaction and building environmental measurements

The paired comparisons of LEED and non-LEED certified buildings at this stage utilized data obtained from objective sources (live-recorded environmental measurements and monitoring, compared to the internationally adopted LEED standards), as well as subjective sources (occupants self-reported questionnaires). It was aimed at comparing satisfaction levels between LEED and non-LEED certified buildings as well as exploring the correlation between the recorded environmental measurements and occupant questionnaire results.

LEED and non-LEED certified building occupant satisfaction

Based on the occupant questionnaire results, the means were compared in both types of building (Figure 2). The results pertaining to LEED certified buildings revealed that occupants were generally "satisfied" with a mean value of 5.587. Going into further detail, they were mostly satisfied in terms of IL, followed by IAQ and ITC with mean values of 5.8478, 5.525 and 5.1196, respectively. Occupants were less satisfied with IAP and sound privacy with mean values

FIGURE 2. Mean and Standard Deviation of IEQ occupant questionnaire results in LEED and Non-LEED certified buildings.



of 4.8152 and 4.0778. In contrast, occupant satisfaction means of non-LEED certified buildings fell within the range of being "neither satisfied nor dissatisfied" to "somewhat satisfied" with a mean value of 4.4111. Occupants felt "somewhat satisfied" with IL, "neither satisfied nor dissatisfied" with IAP and IAQ, and "somewhat dissatisfied" with sound privacy with mean values of 4.777, 4.0778, 3.944 and 3.3778 respectively.

To investigate the substantiality of the comparative satisfaction results between LEED and non-LEED certified buildings, the difference in means was calculated for overall satisfaction and for satisfaction with different IEQ parameters. This was done in order to estimate the impact of this difference in satisfaction on the overall result. For the purpose of measuring the significance of such correlation, the Effect Size of the difference in means was calculated using Cohen's d based on the following equation:

$$d = t\sqrt{\frac{(N1+N2)}{N1N2}} \tag{2}$$

Where: (d: Effect Size, t: t value in the t-test, $N1$: Sample of group 1, $N2$: Sample of group 2)

Whereas:

Effect size: < 0.2 negligible, = 0.2 small, = 0.5 medium, = or > 0.8 large

Table 8 shows the relative difference between means (ΔM = M LEED – M non-LEED) and the calculated effect size for overall satisfaction, and satisfaction with different IEQ parameters. The difference in means between LEED and non-LEED certified buildings shows that

TABLE 8. Mean, standard deviation, mean difference and effect size of the overall satisfaction and the satisfaction with different IEQ parameters for both LEED and non-LEED certified buildings.

Category	LEED (mean ± SD)	Non-LEED (mean ± SD)	Mean Difference ΔM	Calculated Effect Size
Overall Satisfaction	5.58 ± 1.08	4.46 ± 1.30	1.12[a]	0.9 Large
Satisfaction with IAQ	5.25 ± 1.47	3.94 ± 1.85	1.31[a]	0.7 Medium
Satisfaction with ITC	5.11 ± 1.60	3.78 ± 1.58	1.33[a]	0.8 Large
Satisfaction with IL	5.84 ± 1.48	4.77 ± 1.93	1.07[a]	0.6 Medium
Satisfaction with IAP	4.81 ± 1.65	4.07 ± 1.93	0.74[a]	0.3 Small

[a]Statistically significant mean difference between LEED and Non-LEED, $p < 0.001$

the former exceeds the latter in terms of overall satisfaction, with a mean difference of 1.12. This is regarded as a step according to the satisfaction Likert scale. LEED certified buildings also exceed non-LEED certified buildings in terms of ITC, followed by IAQ, IL and IAP with mean differences of 1.33, 1.31, 1.07 and 0.74, respectively. The effect size reflects a considerable value for most of the parameters where it is large for overall satisfaction and ITC, medium for IAQ and IL, and small for IAP.

Applying an overview of the findings stated above, a key point should be raised regarding the variance in occupant satisfaction between LEED and non-LEED certified buildings within the context of Jordan. While the mean variances demonstrated a higher satisfaction amongst the occupants of LEED certified buildings compared to non-LEED certified ones, the categorical classification of such variance ("satisfied" in LEED buildings compared to "neither satisfied nor dissatisfied" in non-LEED buildings) shrinks the perceived gap. This could be the result of a need for better awareness within the local context to the multiple parameters pertaining to green buildings, mandating further attention to the issue, in order to pave the way for a higher level of adoption required for supporting such futuristic initiatives in Jordan.

LEED and non-LEED certified buildings indoor environmental measurements

The means of measurement in both LEED and non-LEED certified buildings were calculated. The purpose was to compare them with the results of the occupant questionnaires in order to understand the possible association between them. Such association was tested using the t-test to check if any of the measured parameters had a significant effect on overall satisfaction. Despite the difference in means of satisfaction in the case of AQI and CO_2 between LEED and non-LEED certified buildings, as Table 9 demonstrates, they both still fall within the range identified by standard codes. LEED certified buildings are also better than non-LEED certified buildings in terms of PM10, although the latter is still close to the standard requirement. These measured parameters, reflecting the IAQ in the buildings, were in line with the occupant questionnaire results, which showed that occupants were "somewhat satisfied" with a mean score of 5.25 in the case of LEED certified buildings, and "neither satisfied nor dissatisfied" with a mean score of 3.94 in non-LEED certified buildings.

TABLE 9. Means of monitored parameter measurements and their correlation with overall satisfaction.

Indoor Measured Parameters	Mean in LEED	Mean in non-LEED	Std. Codes for Offices	Reference	t-test (Sig[a])
AQI	60.8	85	1–100	EPA	<0.001
PM_{10}	23.5 ug/m^3	51.6 ug/m^3	50 ug/m^3 in 24 hours.	EPA	<0.001
CO_2	746.5 ppm	920.3 ppm	700 to 1000 ppm in 24 hours	ASHRAE 62.1-2019	.135
Temperature	22.3 Celsius	23.2 Celsius	23 to 26 Celsius	ASHRAE 55-2017	<0.001
Relative Humidity	37.8%	45.9%	30% to 65%		<0.001
Illumination Level	248.7 lx	1075.8 lx	300 to 500 Lux	ASHRAE 90.1-2019	<0.001
Noise Level	56.8 dB	46.5 dB	45 to 50 dB	ANSI/ASA S12.2-2008	<0.001

[a]Equal values were assumed.

Furthermore, there is no significant difference in temperature between both building pairs as they fall within the range set by standard codes. This is similar to the case of relative humidity while showing a higher mean variance. These measured parameters, reflecting the ITC qualities in the buildings, do not show strong alignment with the occupants' questionnaire responses. The slight difference in measurements does not justify the difference in occupant questionnaire results that show that they are "somewhat satisfied" in LEED certified buildings, with a mean score of 5.11, compared to "neither satisfied nor dissatisfied" with a mean score of 3.78 in non-LEED certified buildings, which highlights a need for further research on this particular aspect.

Concerning illumination levels, both LEED and non-LEED certified buildings fall outside the range of standard codes, although LEED buildings still provide values that are closer to the range. It can be concluded then that the illumination level, as a measured parameter reflecting IL in these buildings, is in line with occupant questionnaire results, which demonstrate that occupants were almost "satisfied" with a mean score of 5.84 in LEED certified buildings, and "somewhat satisfied" with a mean score of 4.77 in non-LEED certified buildings.

Finally, while LEED certified buildings fall short of satisfying the criteria of standard codes for offices in terms of noise level, non-LEED certified buildings seem to satisfy the criteria. This result contradicts the occupants' questionnaire outcomes, which show that occupants were almost "somewhat satisfied" with a mean score of 4.81 in the case of LEED certified buildings and "neither satisfied nor dissatisfied" with a mean score of 4.07 in non-LEED certified buildings.

Table 9 shows the correlation between the measured parameters and overall satisfaction of the occupants, according to the conducted t-test. The only measured parameter that shows no significance is the CO_2 level, in spite of its effect on the IAQ.

TABLE 10. Comparison between indoor environmental measurements and occupant questionnaire results.

Method Tool	Parameter*	LEED Vs. non-LEED
Occupant Satisfaction Questionnaire	Overall	LEED > NON
	IAQ	LEED > NON
	ITC	LEED > NON
	IL	LEED > NON
	IAP	LEED > NON
Indoor Environmental Measurements	IAQ	LEED > NON
	ITC	LEED = NON
	IL	LEED > NON
	IAP	LEED < NON

* IAQ: Indoor Air Quality / ITC: Internal Thermal Comfort / IL: Indoor Lighting / IAP: Indoor Acoustic Performance

Table 10 shows a summary comparing the indoor environmental measurements with the occupant questionnaire results. Concerning overall satisfaction, the questionnaire results demonstrate that LEED certified building occupants have always expressed higher satisfaction compared to the occupants of non-LEED certified buildings. This can be emphasized through occupant responses reporting higher rates in terms of overall satisfaction with a value of 5.58 in LEED certified buildings compared to 4.46 in non-LEED certified buildings. This is supported by higher satisfaction with the IEQ parameters (IAQ, ITC, IL and IAP), which are correlated with overall satisfaction.

When comparing the indoor environmental measurements with occupant questionnaire results, a number of discrepancies were identified. IAQ and IL measurements showed a higher level of satisfaction in LEED certified buildings compared to non-LEED certified buildings, whereas both measurements were within the standard range in the case of the former, and both are out of range in the case of the latter.

In the case of ITC, both LEED and non-LEED certified buildings show close measurements demonstrating a similar thermal status while, in the case of IAP, the indoor environmental measurements of the non-LEED certified buildings are more favorable than those of the LEED certified buildings which demonstrates opposite results to the occupant satisfaction questionnaire.

DISCUSSION AND CONCLUSIONS

The analysis and findings have resulted in a number of key concluding points that summarize the research outcome and establish a starting point for further research initiatives in this field. In terms of the impact of a building's LEED certification on occupant satisfaction, the study has shown quite a positive trend towards a general acceptance of LEED strategies locally, as part of the general concern regarding green buildings. Whether in assessing the levels of indoor environment satisfaction expressed by the occupants of LEED certified buildings post-certification, or upon comparing LEED to non-LEED certified buildings, a higher satisfaction was associated with the implementation of LEED strategies overall, as well as the different parameters of IAQ, ITC, IL and IAP. This indicates a notion of building occupants partially gaining comfort and satisfaction with their internal environment simply by being in a sustainable building (Altomonte et al. 2016; Khashe et al. 2015; Schiavon and Altomonte 2014; Tsushima et al. 2015). This has been exacerbated by the discrepancy found in the level of correlation between occupant satisfaction and indoor environmental measurements, in comparison to the above, emphasizing the influence of the abstract notion of sustainability, rather than the actual differences it introduces into the internal environmental conditions.

Despite the general satisfaction associated with the implementation of LEED strategies, going into detail does not necessarily reflect the same level of correspondence. This is revealed by the different levels of correlation between overall satisfaction and satisfaction with different IEQ parameters (IAQ, ITC, IL and IAP), which highlights a need for further appropriation of LEED with other sustainability codes to ensure a higher level of applicability within the local context of Jordan. Whether through the complexity in associating occupant satisfaction with the building scorecards or indoor environmental measurements, a straightforward relation cannot be clearly established to reflect how occupant satisfaction is impacted as the building becomes more or less sustainable. Indeed, sustainability codes usually tend to treat IEQ aspects separately, which makes attaining a building that balances these aspects quite challenging (Ma and Cheng 2016) especially when the building occupants are concerned. This emphasizes the importance of associating occupant satisfaction and concurrence on the aspects of sustainability within the building, if not in the original certification of a building, then in the revisiting of the continuous achieved sustainability of the building, representing another potential for future research. Going through the details explored in this research, and while it has demonstrated a weaker correlation with IAP compared with other parameters, further research entailing larger and more diversified samples might lead to further correlations. The balanced integration of such aspects becomes quite important to achieve a higher level of satisfaction (Kim and De Dear 2013; Schiavon and Altomonte 2014).

The incorporation of a small research sample can be considered a main research limitation, which was addressed by following appropriate research procedures and sound statistical analysis. Despite the relevance of the resulting findings of the research, caution should be taken prior to generalization. Alternatively, this exploratory study should be considered as a stimulus for further research that expands upon the methods utilized by widening the range of case studies, as more buildings become LEED certified in Jordan. It should also explore other related aspects that could affect occupant satisfaction in green buildings, such as the controllability and adjustability of the parameters explained earlier (Arens et al. 1998; Brager et al. 2004; Zhang et al. 2010, 2015) considering that these aspects could, in turn, affect the applicability of the codes (Sharif 2016). Going in-depth in the Jordanian context, further studies could reveal additional challenges that have not yet been explored through this research when the applicability of codes and satisfaction of occupants are taken into account. With further exploration of such aspects, recommendations could be made regarding the potential appropriation of LEED standards, and other green building codes, to better address these challenges.

The combination of objective (scores and measurements) and subjective (occupants' questionnaires) inputs in unpacking IEQ within the workplace has highlighted the importance of both in formulating a comprehensive outlook towards the applicability of green buildings. As the correlation between both inputs demonstrated numerous complexities according to the outcome of the research, it is regarded of relevance for all such assessment sources to go hand-in-hand to ensure better integration of the green buildings in Jordan. This attains further importance particularly when considering the numerous challenges green buildings face in Jordan, where various complexities remain unrevealed.

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