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## Are Building Occupants Satisfied with Indoor Environmental Quality of Higher Education Facilities?

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### Abstract

Balancing energy performance and Indoor Environmental Quality (IEQ) performance has become a conventional tradeoff in sustainable building design. In recognition of the impact IEQ performance has on the occupants of educational facilities, universities are increasingly interested in tracking the performance of their buildings. This paper highlights and quantifies several key factors that affect the occupant satisfaction of higher education facilities by comparing building performance of two campuses located in two different countries and environments. A total of 320 occupants participated in IEQ occupant satisfaction surveys, split evenly between the two campuses, to investigate their satisfaction with the space layout, space furniture, thermal comfort, indoor air quality, lighting level, acoustic quality, water efficiency, cleanliness and maintenance of the facilities they occupy. The difference in IEQ performance across the two campuses was around 17% which lays the foundation for a future study to explore the reasons behind this noticeable variation.

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## 1. Introduction

Sustaining adequate Indoor Environmental Quality (IEQ) decreases the frequency and severity of illness and therefore the absenteeism and lost time of building users [1]. In recognition of IEQ's impact on the users of educational facilities, schools and universities are increasingly interested in measuring and understanding the performance of their buildings. The architecture, engineering and construction industries have developed several policies and practices to improve the health and maintain the comfort of faculty, staff, students and visitors of educational facilities. Concurrently, a recent surge in the green building movement led numerous universities to commit to employing sustainable building practices for their facilities. Accordingly, several building rating systems emerged to standardize some of these practices, such as Leadership in Energy and Environmental Design (LEED) and Building Research Establishment Environmental Assessment Method (BREEAM).

The aim of this study is to investigate the actual occupant satisfaction performance of educational facilities. First, the paper compares the level of satisfaction with IEQ of two higher educational campuses located in two different environments and countries: Arizona State University (ASU) in Tempe, Arizona, USA and the American University of Beirut (AUB) in Beirut, Lebanon. Second, the paper examines the factors that could affect the IEQ performance of educational structures including LEED design improvements and building age. The paper ends with a discussion of the recommendations to be implemented in designing, constructing and maintaining an educational facility.

## 2. Literature and Background

The literature shows an increasing state of awareness concerning IEQ and its related effects on the satisfaction, health and performance of occupants. Indoor environment performance is considered a major factor of "sustainable" buildings and has been increasingly studied in the past decade. In fact, minimizing the effects of indoor pollutants is a priority in building design, especially since Americans spend on average 90% of their time indoors where the Environmental Protection Agency (EPA) reports that levels of pollutants may run two to five times – and occasionally more than 100 times – higher than outdoor levels [2]. Consequently, the U.S. Green Building Council (USGBC) rated thermal comfort, lighting and acoustics as major aspects of indoor environmental quality [3]. Although it is rarely achieved, the USGBC recommends also a minimum level of 80% of satisfaction regarding the thermal comfort of high performance facilities [2].

Several studies investigated the factors that affect educational facilities occupants' satisfaction and consequently their performance and grades. A preliminary study conducted by Heschong [4] showcased the effect of daylighting in classes by improving the performance of students on math tests by 20% and reading tests by 26%. Moreover, Heschong [5] established that good views could enhance student learning whereas glare, direct sun penetration, poor ventilation and poor indoor air quality could worsen it. Another study by Hathaway et al. [6] found that studying in classrooms with natural daylight reduced the absenteeism 3.5 days per year compared to little daylighting classrooms. Issa et al. [1] showed that student, teacher and staff absenteeism in green Canadian schools improved by 2–7.5%, whereas student performance improved by 8–19% when compared with conventional schools. Despite of the limited accomplished work on the indoor environments quality of educational buildings, researchers have not exposed the main parameters that might be affecting the users' satisfaction in education facilities.

The quality of the overall building is important to workers as their psychological well-being and morale at work are fulfilled [7]. Lee [8] concluded that an improvement in indoor air quality (IAQ) would increase worker satisfaction with the overall building quality. IAQ and thermal comfort are directly associated with worker productivity and health issues in the workplace. Since the cost of employees in doing business is substantially higher than the cost of energy, workplace designers need to provide workers an environment as comfortable and productive as possible through improved IAQ and thermal comfort. In addition, Miller et al. [9] surveyed 2,000 workers and showed that improving the IEQ could increase the productivity by 4.8% and reduce the sick leave days by 3 days per year. Besides showing that user access to natural daylight and views, comfortable temperatures and appropriate

acoustics can directly affect the sense of satisfaction, health and productivity, Fisk [10] found that greener indoor environments could reduce allergies and asthmas by 8 to 25%, and reduce sick building syndrome symptoms by 9 to 20%, leading to savings in lost time and productivity of US \$10 to 35 billion. Another study [11] noticed that improved IEQ contributed to reductions in perceived absenteeism and work hours affected by asthma, respiratory allergies, depression, and stress and to self-reported improvements in productivity. These improvements in perceived productivity were fairly substantial and could result in an additional 38.98 work hours per year for each occupant.

The IEQ parameters that mostly affect occupant satisfaction have been studied thoroughly. Frontczak and Wargocki [12] found that thermal comfort is the most important factor among others IEQ parameter. Lee and Guerin [13] showed that office furnishing quality has a significant impact on occupants' satisfaction and performance while indoor air quality affected only the occupants' performance. Kim and De Dear [14] identified the nonlinear relationship between IEQ factors and occupant overall satisfaction and categorized the factors into Basic Factors and Proportional Factors according to their influence on occupant satisfaction.

The U.S. Green Building Council (USGBC)'s LEED rating system organizes these different IEQ metrics as part of a structured category as shown in Figure 1 [adapted from 15]. The primary goal of LEED is to promote green building practices to provide environmentally responsible, profitable and healthy environments for building occupants [16]. The creation of LEED was a national response to the increasing social awareness and concerns about the negative environmental impacts that could be generated by buildings including increased energy consumption, depletion of natural resources and waste production, and the increasing reported incidences of the adverse health impacts caused by problems of indoor environmental quality (IEQ) such as sick building syndrome (SBS), multiple chemical sensitivity (MCS), and building related illness (BRI) [13]. IEQ is one of the five main LEED categories whose design criteria are sought most often in LEED certification and whose points were most frequently earned in many early LEED-certified buildings [17]. The LEED IEQ category intends to provide indoor environmental design criteria to create healthy, comfortable and productive indoor environments for building occupants [18].

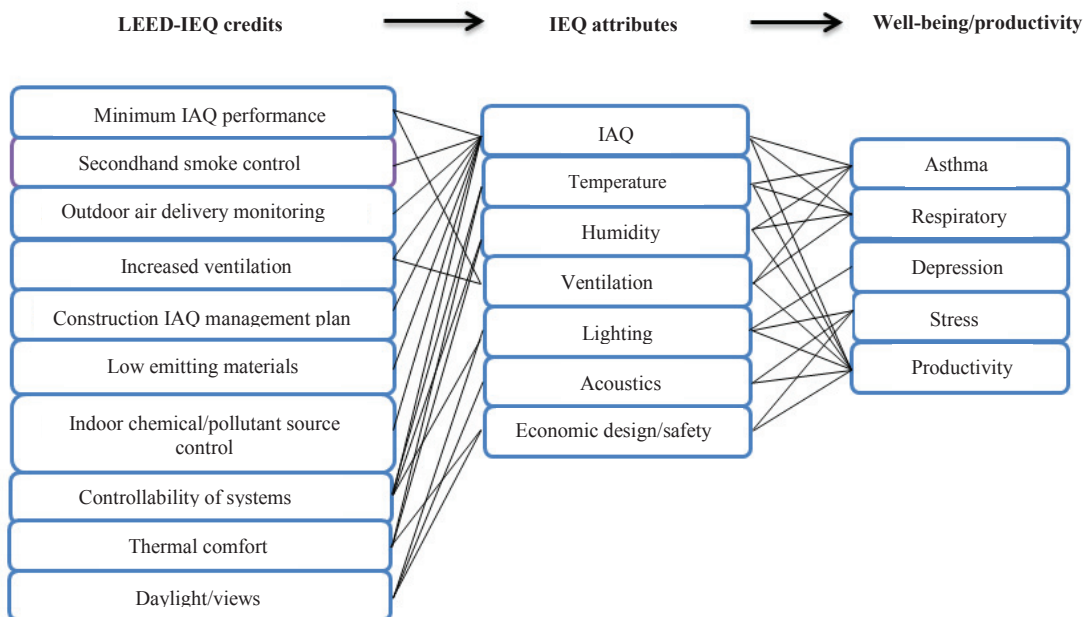


Figure 1: LEED - IEQ occupant well-being and productivity structure [adapted from 15]

### 3. Objective and Methodology

The main purpose of indoor environmental quality standards is to best serve the occupants' interest throughout the design, construction and operation phases of built facilities. The objective of this paper is to measure the occupant satisfaction with key IEQ metrics during the operation phase of educational facilities. The methodology used to collect data and compute levels of satisfaction is detailed next and entails four steps: (1) selecting buildings at the ASU Tempe campus and the AUB Beirut campus; (2) selecting a Post Occupancy Evaluation (POE) survey to evaluate the occupant's levels of satisfaction; (3) collecting the satisfaction levels data from both campuses; (4) analyzing the levels of satisfaction in both campuses and discussing potential parameters that might be affecting the users' satisfaction with IEQ performance in higher education facilities.

#### 3.1. Building selection

For a building to be selected, it had to be occupied for at least one year prior to the start of the data collection, i.e. June 2013. A total of seven ASU facilities were chosen for this study upon the suggestion of the ASU Facilities Development and Management (FDM) in Tempe, in Arizona, USA. Similarly, eight AUB facilities were selected according to their life of service on the Beirut campus in Lebanon. Table 1 summarizes the names, occupancy dates, gross area (m<sup>2</sup>), net area (m<sup>2</sup>), classroom area percentages, offices area percentages, research area percentages, library area percentages and classroom laboratories percentage of the buildings.

Table 1: Characteristics of ASU and AUB selected buildings

	Building name	Occupancy Date	Gross Area (m <sup>2</sup> )	Net Area (m <sup>2</sup> )	classroom %	Office %	Research %	Library %	Classroom Laboratory %
ASU	Wrigley Hall	2004	4807	2790	30%	70%	0%	0%	0%
	ISTB2	2005	6596	3437	0%	30%	60%	0%	10%
	Fulton Center	2005	15232	6420	0%	100%	0%	0%	0%
	ISTB1	2006	17930	8083	0%	29%	71%	0%	0%
	Hassayampa Village	2006	55294	N/A	N/A	N/A	N/A	N/A	N/A
	Barett Village	2009	54404	N/A	N/A	N/A	N/A	N/A	N/A
	ISTB4	2012	30379	14864	0%	24%	16%	57%	3%
AUB	Bliss Hall	1900	2646	1838	37%	41%	0%	0%	22%
	Fisk Hall	1901	3507	1816	33%	64%	0%	0%	4%
	Dal Al Handasah Architecture Building	1930	4063	2398	81%	15%	0%	0%	4%
	Bechtel Engineering	1952	6347	5085	61%	23%	0%	7%	10%
	Nicely Hall	1960	6740	4857	89%	11%	0%	0%	0%
	Raymond Ghosn	2000	1338	838	0%	30%	0%	0%	70%
	CCC SRB	2006	5416	2626	0%	13%	0%	0%	87%
Olayan School of Business	2009	19734	4667	50%	40%	0%	0%	10%	

N/A: Data is not available

#### 3.2. Survey Selection

In order to measure users' satisfaction with respect to the indoor environment performance of each building, a survey was developed based on the Occupant IEQ survey of the Center for the Built Environment (CBE) at the University of California at Berkeley. After analysing the questions from the CBE's original survey, an adaptation of Cotera's Occupant Indoor Environment Quality Satisfaction Survey [19] was created to best fit the difference in environments and occupants characteristics in both campuses. The CBE's survey is recognized as a reliable post-occupancy evaluation tool for measuring occupants' opinions and satisfaction with the IEQ performance of buildings [20]. This tool offers a qualitative methodology to estimate how a building is performing through eight equally important sections. These are: workspace layout, workspace furniture, thermal comfort, indoor air quality, lighting levels, acoustic quality, water efficiency and cleanliness and maintenance in addition to the occupant background information and the overall satisfaction with space [21]. Building users across the two

considered campuses were asked to rate their satisfaction levels in each section on a 5-point Likert scale (1 being very dissatisfied, 5 being very satisfied). All respondents were eighteen years old or more, and were classified according to their ultimate use and the duration of occupying the building. As such, users were categorized into three main types: (a) students who used the building continuously for more than three months; (b) faculty/staff who worked in the designated building for more than three months; and (c) visitors who spent less than three months using this building. Average satisfaction ratings for each of the eight survey sections were computed and compared to the CBE's database, which contains results from over 59,000 completed surveys.

### 3.3. Data Collection

Participants were invited at random in each campus to participate by completing a paper-based survey, which takes from 10 to 15 minutes. The responses were kept anonymous to guarantee a strict confidentiality and privacy of the provided information. In each of the 15 considered buildings, 20 persons were asked to complete the survey which resulted in a total of 320 responses (The ASU Hassayampa Village was split into two buildings or sub-villages).

### 3.4. Data Analysis and Discussion

For each campus, the collected data was entered and analysed for all eight survey sections. First, the average satisfaction index was computed for each survey participant. . Second, the average level of satisfaction for each building and consequently the average overall satisfaction level in each of the two campuses were calculated. An unpaired t-test was then used to check the statistical significance of the results across the two campuses.

## 4. Results and Discussion

This section presents the results of the survey and ends with a discussion of the potential parameters that could explain the difference in performance across the two campuses. Of the respondents at AUB 16.9% were faculty/staff, 80.6% were students and only 2.5% were visitors. This percent split is comparable to the total number of users of the selected buildings. In contrast, of the respondents at ASU 41.9% were faculty/staff, 49.3% were students and only 8.8% were visitors (figure 2).

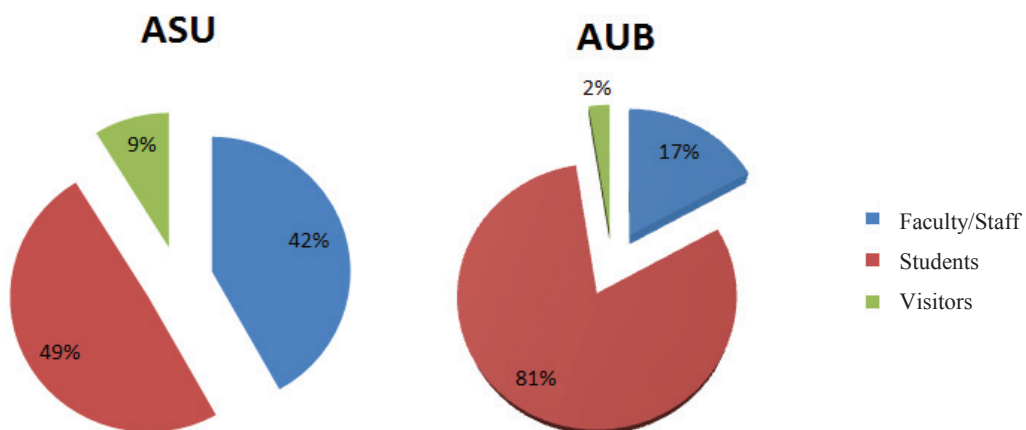


Figure 2: Participants characteristics

In order to check the statistical significance of the results, an unpaired t-test with unequal variances and a 0.05 significance level was used. For that purpose, the average points of 160 participants from AUB was compared to the average points of 160 participants from ASU. This contributes to the hypothesis that occupants' satisfaction of AUB users (x) is equal to that of ASU users (y). This assumption will be confirmed, at a 95% confidence level, for the null hypothesis ( $H_0$ ) or its rejection ( $H_1$ ):

$H_0$ :  $x = y$  if p-value is greater than 0.05; then, occupants' satisfaction with IEQ is similar for both campuses.

$H_1$ :  $x \neq y$  if p-value is less than 0.05; then, occupants' satisfaction with IEQ is different across the two campuses.

These results show that p-value is very small (less than 0.05) which correspond to the null hypothesis rejection; therefore, the collected data is statistically significant at a 95% confidence level.

The average levels of satisfaction were calculated for both campuses by assuming equal weights for all eight sections and all the considered buildings. As shown in Table 2, the average satisfaction levels were 78% for ASU buildings and 61% for AUB buildings. Figure 3 provides a graphical illustration of the difference in performance throughout the eight survey questions across the two campuses.

Table 2: ASU and AUB survey results

	Space Layout	Space Furniture	Thermal comfort	Indoor Air quality	Lighting level	Acoustic Quality	Water Efficiency	Cleanliness & Maintenance	Overall Satisfaction	Average
ASU	80%	80%	71%	79%	77%	71%	74%	83%	83%	78%
AUB	61%	61%	58%	61%	62%	60%	58%	66%	62%	61%

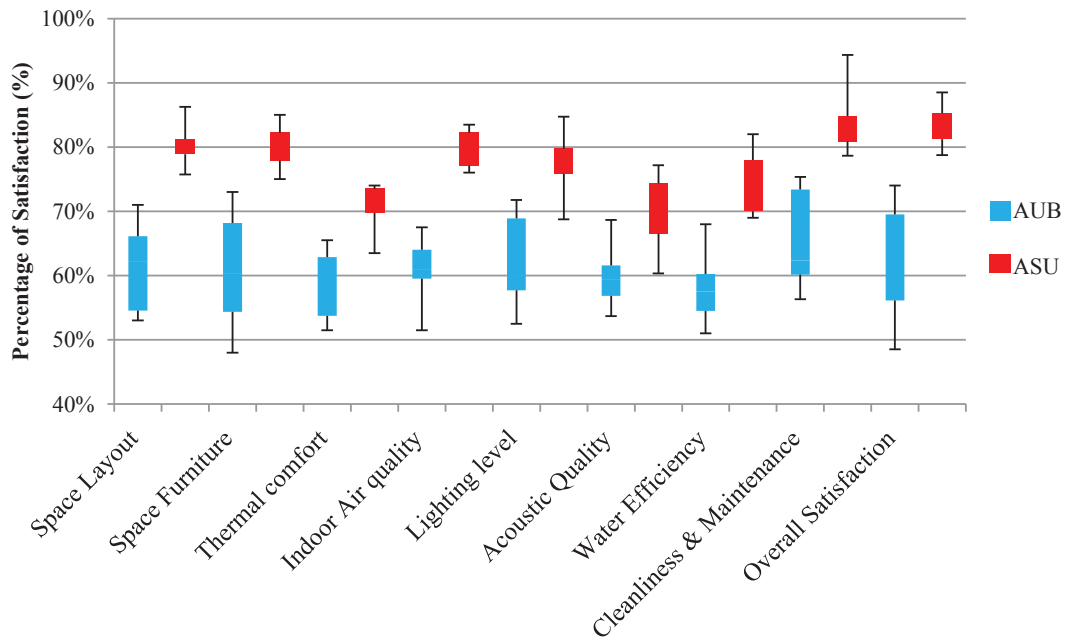


Figure 3: AUB vs. ASU Percentages of Satisfaction

Figure 4 illustrates the CBE results (59,359 participants) compared to the selected buildings from ASU and AUB. Although both campuses failed to achieve the recommended levels of 80% for thermal comfort according to ASHRAE Standard 50 and USGBC, they performed better than the CBE benchmark. This is particularly true for ASU buildings. AUB building, on the other hand, had higher scores than the CBE benchmark in the areas of thermal comfort and acoustic quality, and similar performance in lighting level, indoor air quality, and overall satisfaction.

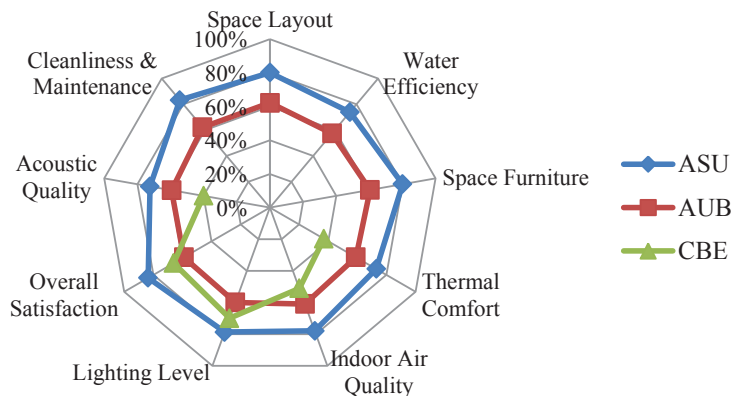


Figure 4: Overall Satisfaction Levels of ASU, AUB and CBE

Several factors could play a role in determining occupant satisfaction with the IEQ of higher education facilities. This section suggests two main reasons that could explain the difference in IEQ performance across ASU and AUB buildings: LEED regulations and building age.

ASU is committed to leadership in sustainability education, research, operations, and outreach. As such, the university has been implementing sustainable practices in the planning, design, construction, operation and maintenance of all university facilities [22]. Therefore, all surveyed ASU buildings were LEED-certified (Table 3). In contrast, AUB buildings are all conventional and were not designed to meet eco-friendly requirements which could explain the difference in IEQ performance across the two campuses. These results are in-line with the literature and confirm the positive relation between improving IEQ design through LEED and occupants' satisfaction. Yet, the surveyed ASU buildings failed to achieve an adequate thermal environment. Only 71% of participants were satisfied with their workplace which is lower than the USGBC's recommended value of 80%. A close examination reveals no clear correlation between the building's earned points on the LEED scale and the level of users' satisfaction. For example, Fulton Center had the highest percentage of satisfaction with IEQ performance (82%) although it achieved the least number of points on the LEED scale. USGBC's LEED system is often criticized for the absence of future assessment of certified buildings. With the exception of projects registered under LEED version 3.0, once a building is certified, it is certified for life. Though many steps are carefully taken to ensure that these buildings meet the required standards during the design and construction processes, none are taken to verify that the buildings are still maintaining their efficient performance levels after certification [19]. That's why several recent studies, e.g. Menassa et al. [23], raise many questions about the actual energy consumption of LEED versus Non-LEED buildings.

Table 3: LEED Characteristics of ASU buildings

Building name	LEED Rating	LEED version	Award Date	Total points (out of 69)	Sustainable Sites (out of 14)	Water efficiency (out of 5)	Energy & Atmosphere (out of 17)	Materials & Resources (out of 13)	Indoor Environmental Quality (out of 15)	Innovation and Design (out of 5)	Occupant Satisfaction %
Hassayampa Village	Silver	LEED for New Construction	10/18/2009	33	9	3	3	5	8	5	77
ISTB 1	Gold	LEED for New Construction	3/29/2007	39	9	3	7	5	10	5	78
ISTB 2	Silver	LEED for New Construction	7/21/2006	33	10	3	5	5	8	2	75
ISTB 4	Gold	LEED for New Construction	9/7/2012	48	11	3	15	5	9	5	76
Barrett Honors College	Gold	LEED for New Construction	4/29/2010	39	10	3	7	5	9	5	78
Wrigley Hall	Silver	LEED for Existing Building	7/23/2009	37	10	3	3	7	9	5	80
Fulton Center	Certified	LEED for New Construction	8/28/2007	26	8	3	3	4	5	3	82

Building age is another important factor that could have an effect on IEQ performance and therefore could explain the difference in results across the two campuses. The selected buildings at ASU were recently constructed, i.e. over the past decade. In contrast, the selected AUB buildings had a wider age range which allows for plotting building age versus IEQ performance (Figure 5). There seems to be a negative correlation between building age and level of satisfaction of building users, which suggests the need for continuous renovation and rehabilitation of indoor environments. More studies are needed to confirm this trend.

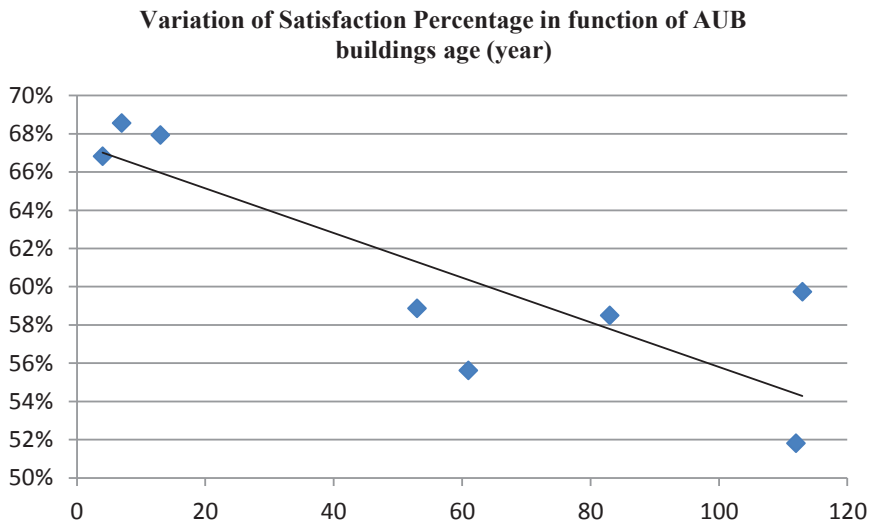


Figure 5: The variation of Satisfaction % in function of AUB buildings age



## 5. Conclusion

This paper compares the levels of satisfaction in IEQ for two sets of higher education facilities located in Arizona, US and Beirut, Lebanon respectively. Factors explaining the difference in performance across the two campuses might include commitment to sustainable and environmentally aware design, and building age. For the past 10 years, ASU has been designing and constructing buildings that are in-line with LEED requirements. AUB has recently made a similar commitment. Several ongoing projects are being designed and executed at AUB with the goal of obtaining LEED certification. Additionally, building age seems to have a correlation with level of satisfaction of users with IEQ. The results of the conducted surveys highlight the need to continuously monitor and improve indoor environmental conditions. This need is applicable not only to ASU and AUB buildings but also to any educational facility around the world. Improvements in IEQ performance could be costly; nonetheless, they can help reduce absenteeism and increase the productivity of students, staff, and faculty at higher educational facilities.

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## References

- [1] Issa M, Rankin J, Atallah M, Chritian A. Absenteeism, Performance and Occupant Satisfaction with the Indoor Environment of Green Toronto Schools. *Indoor Built Environment* 2011;20;5:511–523.
- [2] U.S. Green Building Council. *New Construction Reference Guide Version 2.2* (2nd edition); 2006.
- [3] U.S. Green Building Council. *Green Building Design and Construction* (1st edition, 240); 2009.
- [4] Heschong L. *Daylighting in schools: an investigation into the relationship between daylighting and human performance*. California Energy Commission; 1999.
- [5] Heschong L. *Windows and offices: a study of office worker performance and the indoor environment*. California Energy Commission; 2003.
- [6] Hathaway W, Hargreaves J, Thompson G, Novitsky D. *A study into the effects of light on children of elementary school age – a case of daylight robbery*. Planning and Information Services Division, Alberta; 1992.
- [7] Webster T, Bauman F, Dickerhoff D, Lee YS. *Case study of Environmental Protection Agency (EPA) region 8 headquarters building in Denver, Colorado*; 2008.
- [8] Lee Y.S. Comparisons of Indoor Air Quality and Thermal Comfort Quality between Certification Levels of LEED-Certified Buildings in USA. *Indoor and Built Environment* 2011 20: 564; 2011.
- [9] Miller N, Pogue D, Gough Q, Davis S. Green buildings and productivity: *J Sustainable Real Estate* 2009;1(1):1–31.
- [10] Fisk W. *Health and productivity gains from better indoor environments and their implications for the US Department of Energy*. E-Vision Conference, Washington, DC; 2000.
- [11] Singh A, Syal M, Korkmaz S, Grady S. Costs and Benefits of IEQ Improvements in LEED Office Buildings. *J. Infrastructure System* 2011;17(2): 86–94.
- [12] Frontczak M, Wargocki P. Literature survey on how different factors influence human comfort in indoor environments. *Building Environment* 2011; 46(4):922e37.
- [13] Lee Y, Guerin D. Indoor Environmental Quality Related to Occupant Satisfaction and Performance in LEED-certified Buildings. *Indoor and Built Environment* 2009;18: 293.
- [14] Kim J, De Dear R. Nonlinear relationships between individual IEQ factors and overall workspace satisfaction, *Australia Building and Environment* 2012; 49:33e40.
- [15] Singh A, Syal M, Grady CG, Korkmaz S. Effects of green buildings on employees health and productivity. *Amer J Pub Health* 2010;100(9): 1665–1668.
- [16] U.S. Green Building Council. *About USGBC*. U.S. Green Building Council.; 2008.
- [17] *Building Design & Construction: White Paper on Sustainability: A Report to the Green Building Movement, Building Design & Construction*, Washington DC, USA, 2003.
- [18] CGOEM. *Using LEED-NC in Colorado: Tips, Resources and Examples*, Colorado Governor's Office of Energy Management & Conservation, Colorado, USA.; 2006.
- [19] Cotera P.J. *A Post-Occupancy Evaluation: To What Degree do LEED Certified Buildings Maintain Their Sustainable Integrities Over Time?* University of Florida; 2011.

- [20] Lee, Y. S., & Kim, S. K. Indoor Environmental Quality in LEED-certified buildings in the U.S. *Journal of Asian Architecture and Building Engineering*, 7(2), 293-300; 2008
- [21] Center for the Built Environment, University of California Berkeley . Occupant IEQ Survey Demo; 2010.
- [22] ASU Sustainable Design Policy. Arizona State University; 2009.
- [23] Menassa C, Mangasarian S, El Asmar M, Kirar C. Energy Consumption Evaluation of U.S. Navy LEED-Certified Buildings. *J. Perform. Constr. Facil.* 2012.26:46-53.