A comparison of indoor air quality and employee absenteeism in ‘local’ and ‘imported’ green building standards

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Abstract. Buildings are responsible for a quarter of global carbon emissions. In the developing world, the desire to reduce energy consumption initially resulted in the adoption of ‘imported’ standards such as LEED and BREEAM and, over time, the development of several ‘localised’ standards that either supplant or compete with the imported standards. However, such standards have often been implicated in the unintended consequence of reduced indoor air quality resulting from lowered ventilation rates, in turn affecting employee productivity and absenteeism. Here, we systematically review and compare the performance of office buildings built to the localised Jordanian Green Building Guide (JGBG) and the well-known international LEED standard. We measure building performance in terms of the indoor air quality (via CO₂ concentration) and occupant absenteeism during winter 2019. Results show that the JGBG building had a significantly lower mean indoor CO₂ concentration than the LEED building during working hours (p < 0.00). In addition, the occupants in the JGBG building reported 20% more working hours (p < 0.03) and approximately 9 hours less of absolute absenteeism. These initial results suggest that further development of localised codes is likely to bring greater benefit to the performance of building and occupants compared to imported standards.

1. Comparison between Jordanian Green Building Guide and LEED

In 1998, the U.S. Green Building Council (USGBC) produced the Leadership in Energy and Environmental Design (LEED) Green Building Rating System. LEED encompasses more than 90,000 registered buildings in the US and 165 countries, it covers 2.2 million m² of projects area every day [1]. Recently, several countries, particularly in the developing world, have started to develop their own rating systems that address specific regional needs (e.g. climate, socio-economic, and cultural) [2]. The Pearl Rating System (PRS) in the United Arab Emirates, Qatar Sustainability Assessment System (QSAS) in Qatar, and ARZ Building Rating System in Lebanon are good examples of green assessment tools in the Middle East, which consider local needs. Jordan as part of the Middle Eastern countries has experienced several phases of green building developments, which are presented chronologically in Figure 1, with LEED being the most common. According to the Jordanian Green Building Council (2019), Jordan has 21 registered buildings and seven certified buildings by LEED in the commercial sector [3]. In 2013, the Jordanian Green Building Guide (JGBG) was produced to replace the international rating system gradually. JGBG is a voluntary rating system available for everyone to use and is connected to an incentive scheme put forth by the Jordanian government [2]. Despite common targets and approaches to the issue of sustainability assessment with LEED, JGBG’s structure, indicators, and metrics were developed independently. JGBG has four categories that are classified according to the building type: single residential, multi-residential, commercial/offices, and educational. Each category includes two subcategories, either conditioned or free running, and each has its own assigned points [4]. The number of points collected for each style of building indicates the degree of building’s sustainability, which is divided into four classifications: A, B, C, and D. Table 1 compares
the main attributes of LEED and JGBG. Closer inspection of the table shows that JGBG consists of six main parameters; five of them are in common with LEED but with different weight for each parameter depending on the local priorities. LEED’s ‘innovation’ and ‘recycling and pollution’ categories are absent in JGBG while it adds the ‘building management’ as a sixth parameter that is concerned with the overall performance of building post-handover. The relative weights for energy and water efficiency in JGBG (36% and 15%) and LEED (32% and 9%) demonstrate the localisation of the standard as each reflects the scarcity of energy and water resources faced by Jordan [1,5]. However, the actual performance of green buildings in Jordan certified either by LEED or JGBG have never been evaluated systematically, hence this paper compares the performance between LEED and JGBG buildings in terms of indoor air quality and occupants’ absenteeism rate as representative metrics to investigate if the local rating system has a positive impact on the performance of building and their occupants.

| 1998 | The Royal Scientific Society (RSS) issues insulation codes. |
| 2008 | The first Energy Efficiency Code developed. |
| 2009 | The Jordanian Green Building Council established. |
| 2013 | The Jordanian Green Building Guide (JGBG) produced |
| 2016 | The first building certified according to the JGBG is built. |

**Figure 1.** The green building developments in Jordan.

**Table 1.** The main attributes of LEED and JGBG.

| Tool | Rating level | Total points and % of total |
|------|--------------|----------------------------|
| LEED | Certified ≥40 | 165 countries 1998 2013 |
|      | Silver ≥50   | 10 (9.1 %) 38 (15.2%) |
|      | Gold ≥60     | 35 (31.8 %) 89 (35.6%) |
|      | Platinum ≥80 | 14 (12.7 %) 36 (14.4%) |
|      | Material     | 15 (13.6%) 24 (9.6%) |
|      | IEQ           | 6 (5.5 %) - |
|      | Innovation   | 4 (3.6 %) - |
|      | Recycled and pollution | - |
| JGBG | A (≥80 points) | Building management |
|      | B (70–79 points) | - |
|      | C (60–69 points) | - |
|      | D (50–59 points) | - |
|      | 1 country 2013 | 28 (11.2 %) |
|      | 2013 2013 | 28 (11.2 %) |
|      | Total points | 110 250 |

2. Indoor air quality and absenteeism rate in green office buildings

The indoor air quality of office buildings is considered one of the most important factors affecting employee health. This is also known to affect the absenteeism rate due to an increase in sick leave. Carbon dioxide (CO₂) is a primary indicator of indoor air quality and the healthy workplace should have low CO₂ concentration above ambient levels, delivered through a high level of ventilation. However, the necessity to decrease energy consumption in green buildings has traditionally resulted in low rates of ventilation to avoid ventilation heat loss or gains. This tends to increase indoor CO₂ concentration that can affect occupant performance [6]. In addition, high levels of indoor CO₂ concentration can be a reason for sick building syndrome symptom [7]. CO₂ concentration more than 2,000 ppm causes deepened breathing; 4,000 ppm increases respiratory diseases; 10,000 ppm is associated with loss of consciousness and visual disorder; and 25,000 ppm can be a reason for death [8,9]. Consequently, research has attempted to associate the CO₂ concentration in workplace with employee work
performance [10]. For example, in a study comparing the absenteeism rates of occupants working in free-running and mechanically conditioned buildings in France, found that employees in the naturally-ventilated building had a lower rate of absenteeism compared to the employees in the mechanically-conditioned buildings [11]. These results support the idea that the indoor air quality of the workplace can affect employee health related indicators such as absenteeism.

3. Methods

3.1. Indoor Carbon dioxide (CO2) measurement

Indoor CO2 concentration was measured in the JGBG and LEED buildings (Figure 2, 3) in the winter of 2019 for five weeks (7th Jan – 14th Feb 2019) using Raspberry-Pi sensors (Figure 4). The Raspberry-Pi sensors were used as they have undergone rigorous testing and calibration, making them suitable for continuous measurements with good accuracy (±30 ppm) [12,13]. The sensors were tested before starting the study. The data were logged at 5-minute intervals. The sensors were installed in the two buildings and located in the shared multi-occupant workspaces that have the most occupation density. They were placed in the middle of the monitored area at seated head height (0.9 m to 1.10 m). The employees were asked not to cover or touch the sensors during the monitoring period. Both buildings were in Amman, reducing logistical burden, and providing climatic homogeneity. The physical characteristics of the selected spaces in the two buildings were matched as closely possible:

- The volumes of the monitored rooms were approximately 216 m³ (L= 12 m, w = 6 m, H = 3 m) and 210 m³ (L= 10 m, w = 7 m, H = 3 m) in the JGBG and LEED buildings respectively.
- The occupancy area was 4 m² per occupant.
- The rooms have walls with low VOC paint, normal fixed double glazed facades.
- The floors were covered with carpet; no moistures problems were reported in the buildings.
- There were no plants inside the monitored rooms.
- Active ventilation is used in both buildings designed to achieve 8.5 litres/second/person according to JGBG and LEED specifications.

3.2. Absenteeism rate measures

Participants were surveyed to measure the absenteeism rate in workplaces for 4 weeks using the well-tested and reliable Health and Performance Questionnaire (HPQ), developed by the World Health Organization (WHO) [14,15]. As most of the participants speak Arabic as a first language, the questionnaire was translated to Arabic, tested using a pool of technically literate bilingual speakers at the University of Bath through re-translation to English. The survey was combined with a consent form, and distributed in the monitored spaces. The sample consisted of 100 employees, 50 participants from each building. Before starting the study, the upper management of the buildings were contacted directly to obtain their consent, and ethical approval was obtained from the University of Bath. As both buildings in this study were used as workspaces, their occupants were involved in typical office tasks (i.e. computer typing, reading, writing, and occasional walking for document delivery or communication).
4. Results

Figure 5 shows the measured indoor CO2 concentrations during 5 weeks in the monitored spaces. Data were cleaned and analysed using the statistical programming language R. Mean CO2 concentration in the LEED building was higher (661 ppm) compared to the JGBG building (470 ppm) during the working hours. A standard t-test at 99% confidence level suggests this is a significant difference (p < 0.000). Interestingly, there is a considerable temporal variation of CO2 concentration between the two buildings. Figure 6 presents the CO2 concentration over a typical 24-hour period in both buildings. The indoor CO2 concentration in the JGBG building is almost constant during the working hours (0700 to 1700 hours, mean = 456 ppm) meeting the JGBG specification of indoor CO2 concentration in offices. It increases after working hours (1700 to 300 hours) peaking at 664 ppm. Conversely, the mean CO2 concentration in the LEED building during working hours is higher (693 ppm), declining dramatically during the lunch break between (1300 to 1400 hours), and subsequently falling to 404 ppm after working hours.

The above differences can be attributed to the different ventilation approaches that have been followed in the two buildings. The JGBG building is provided with a ventilation rate 30% above that corresponding to the minimum rate required by LEED, due to an IEQ requirement in JGBG. Mechanical Ventilation Heat Recovery System (MVHR) is used in the JGBG building, which provides a balance between saving energy and providing high indoor air quality. The efficiency of the MVHR can be controlled according to the occupancy level. Therefore, the efficiency is raised to the maximum during the working hours to ensure a continuous ventilation rate, while it is reduced after working hours, when the building is almost empty. In contrast, the LEED building is provided with a constant level of airflow around the day, and hence CO2 concentration increases during the daytime because of human activity.

Absenteeism is scored in terms of “hours lost per month”, which is to say that a high score indicates a higher amount of absenteeism. The JGBG has a higher mean (206 h) of total working hours during 4-week compared to the LEED building (189 h) and compared to the expected working hours by the employer (180 h/ per 4-week). This is a statistically significant difference (p < 0.03) at 95% confidence level. The JGBG building reported lower mean (0.60) of missing days due to the sick leave in 4-week compared to the LEED building (mean = 2.6), and there was a significant difference between the two means (p < 0.00) at 99% confidence level. In addition, absolute absenteeism, calculated using the absenteeism score set by Health and Performance Questionnaire [16], was substantially lower in the JGBG building (by 9 hours) during the 4-weeks, compared to the LEED building. Of course, it is worth noting that we do not investigate causality for these results beyond those arising from the design,
specification and operation of the building and there could be other factors at play that create these differences. This will require further investigation.

5. Conclusion
Indoor CO2 concentration has often been used as an indicator of adequate indoor air quality, which affects occupants’ health and performance. This paper aims to compare the performance of buildings built to the localized Jordanian Green Building Guide and the international LEED standard in terms of indoor air quality and occupant absenteeism rate. The results of this investigation show that there is a highly significant difference between the two means of the indoor CO2 concentration between the two buildings during working hours. The mean in the LEED building was higher compared to the JGBG building. However, the two buildings were within the recommended limits of CO2 concentrations inside offices for an 8-hr workday under both LEED and JGBG specifications (1,100 ppm). Further, respondents who reported higher levels of absenteeism rate were working in the building that reported significantly higher levels of CO2 concentrations during working hours. These results suggest that the development of local green assessment tool could bring better benefits to both building performance and occupants’ performance, although this requires further investigation in more buildings over longer periods.

Acknowledgement
The authors would like to thank Baha Mualla for helping in collecting the data, and to thank the management of the office buildings for giving their consent to conduct this study. This work was supported by Al-Ahliyya Amman University in Jordan.

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