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# Indoor environmental quality in Korean green building certification criteria—certified office buildings—occupant satisfaction and performance

BINYAM GR SEDISO and MYUNG SIK LEE\*

*Division of Architectural Engineering, Dongguk University, Seoul 04620, South Korea*

The aim of this study is to evaluate the indoor environmental quality of workplaces in Korean green building certification criteria-certified office buildings in Korea. A post-occupancy evaluation of two green and two conventional office buildings was conducted. Occupants ( $N = 222$ ) completed a paper-based questionnaire related to perceived environmental satisfaction and performance. The study compared nine indoor environmental quality criteria in relation to occupant satisfaction and performance between Korean green building certification criteria-certified and non-Korean green building certification criteria-certified office buildings. The data were analyzed by descriptive statistics. The study found that in both cases (Cases 1 and 2) Korean green building certification criteria-certified buildings had better satisfaction scores in office furniture, cleanliness and maintenance, lighting, and thermal comfort quality than did non-Korean green building certification criteria-certified buildings. The study also found that in both cases (Cases 1 and 2) Korean green building certification criteria-certified buildings had better performance scores in lighting and thermal comfort quality than did non-Korean green building certification criteria-certified buildings. Office layout, office furniture, cleanliness and maintenance, lighting, thermal comfort, indoor air and indoor public space qualities have a higher influence on overall satisfaction and performance than other indoor environmental quality criteria. This study shows the value of some indoor environmental quality criteria that show a strong positive association with overall satisfaction and performance enhancement, but are not yet included in the official Korean green building certification criteria list of indoor environmental quality categories.

## Introduction

Healthy, comfortable employees are often more satisfied and productive. Unfortunately, this simple truth is often lost, for it is easier to focus first on the energy cost of a project than it is to determine the value of increased user productivity and health (Whole Building Design Guide 2015). Occupants' satisfaction in office buildings is associated with the quality of the indoor environment and building features such as size, aesthetic appearance, furniture, and cleanliness (Frontczak et al. 2012). Korean green building certification criteria (KGBCC) has set as its goal improving the quality of occupants' lives through a sustainably built environment (Korea Green Building Council [KGBC] 2015). Occupants' lives are directly affected by the environments in which they spend their days, and indoor environmental quality (IEQ) is the main issue which directly affects the quality of the occupants' lives. Therefore, the success of a sustainable building relies on its IEQ (Lee and Kim 2008). However, the majority of studies on the subject of sustainable design and construction, including those on KGBCC-certified buildings, have focused on energy and cost-related items. There

is a lack of comprehensive study examining whether or not the IEQ of a sustainable building contributes positively to occupants' lives (Lee and Kim 2008). Especially because little is known about whether or not the IEQ of KGBCC-certified office buildings truly improves occupants' satisfaction and performance over that of occupants of conventional buildings. Therefore, it is important to assess whether KGBCC-certified office buildings are truly successful, sustainable buildings—by examining the quality of the indoor environment. Finding the effects of the IEQ of workplaces of KGBCC-certified office buildings would be especially pertinent since many building owners and organizations are willing to pursue a KGBCC certification.

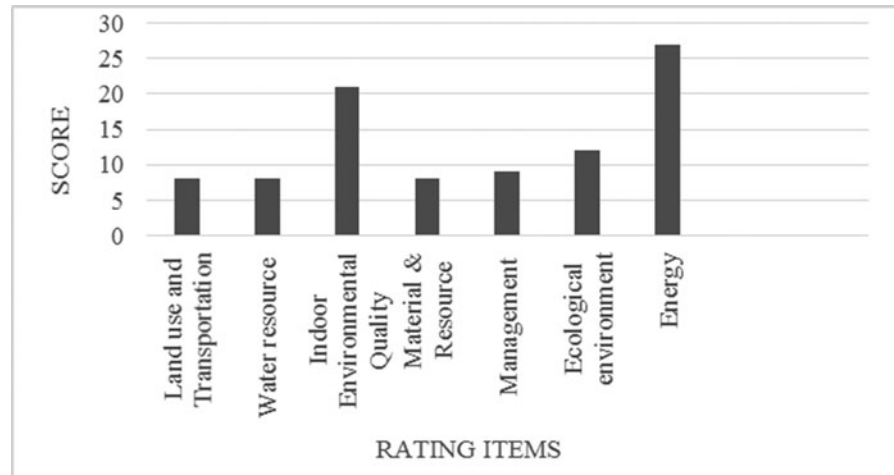
## Purpose and scope of study

The primary purpose of this study is to evaluate the effectiveness of IEQ in KGBCC-certified office buildings by comparing the IEQ to perceived occupant satisfaction and performance, between buildings that are KGBCC-certified and buildings that are not. Based on the evaluation, this study aims to give suggestions for improving the IEQ standards and to present implications for the future design of KGBCC-certified office buildings. The IEQ criteria were evaluated with regard to occupant satisfaction and performance. The study is significant in that it identifies strengths and weaknesses of the current

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**Binyam Gr Sediso** is a PhD Candidate. **Myung Sik Lee, PhD**, is a Professor.

\*Corresponding author e-mail: mslee@dongguk.edu



**Fig. 1.** KGBCC rating items in an office building.

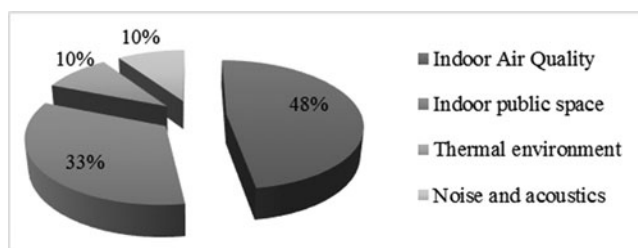
sustainable building practice compliance with KGBCC standards and suggests implications for the future practice.

### KGBCC and IEQ

KGBCC for office building has 7 divisions, 21 categories, and 33 subcategory indexes (KGBC 2015). The quality of the indoor environment is considered as a key criterion in all building schemes (KGBC 2015). In the office building category it was given a higher certification credit than any other KGBCC issue except energy management. Figure 1 shows Korean Green Building Certification Criteria for office buildings. For an office building, the IEQ issue has four categories and eight subcategories. It has one mandatory criterion: the use of low-emitting materials. The “indoor air quality” and “creation of comfortable indoor public space” categories were given the higher certification scores (KGBC 2015). Figure 2 shows IEQ categories and the percentages of scores given to each item.

### IEQ and satisfaction and performance

There is abundant evidence that better indoor environments in office buildings are correlated with more satisfied occupants with higher levels of well-being, and thus to better outcomes



**Fig. 2.** IEQ categories of KGBCC in office buildings.

for organizations (Newsham et al. 2008, 2009; Thayer et al. 2010). First and foremost, a building must meet user needs if it is to be successful, and so a measurement of occupant satisfaction is a vital part of assessing building performance to reveal particularly valuable features (Building Use Studies 2014) and to highlight the top issues affecting the occupants (Zalejska-Jonsson and Willhelmsson 2013). However, there has been little formal investigation of whether green buildings specifically offer measurably better physical environments, and in turn, if occupant environmental satisfaction, job satisfaction, and health are benefitted (Newsham et al. 2013).

A number of studies have attempted to understand the quantitative relationship between occupant overall satisfaction and building performance and individual IEQ factors, such as thermal comfort, acoustic quality, air quality, and visual comfort, primarily to find out which factor has the most significant effect on occupant satisfaction (Kim and de Dear 2012). Some scholars argue that an increase in occupants' overall satisfaction does not correspond uniformly to improvements of individual IEQ factors (Bluyssen et al. 2011; Humphreys 2005). Humphreys (2005) and Wong et al. (2008) focused only on the impact of IEQ on building occupants' satisfaction. They found that thermal, visual, acoustical, and air quality factors contributed to building occupants' satisfaction. Other studies show there are other factors unrelated to the indoor environmental parameters that can influence satisfaction within a building, such as occupants' control over the indoor environment (Frontczak and Wargocki 2011; Schiavon and Altomonte 2014). The studies by Bluyssen et al. (2011), Choi et al. (2009), and Veitch et al. (2007) show that the building occupants' satisfaction was also affected by satisfaction with the view, control over the indoor environment, the amount of privacy, layout, size, cleanliness, aesthetics, and furnishings. This study will investigate which subjectively evaluated IEQ parameters and building features are most associated with occupants' satisfaction, as its aim is to evaluate the extent of the effectiveness of IEQ on KGBCC-certified office buildings.

## Method

### *Data collection and instrument*

The study used primary data based on an occupant IEQ survey format from the Center for the Built Environment (CBE 2015). According to the CBE, the questionnaire was developed with a focus group that included industry partners and was tested and refined by the Survey Research Center and U.C. Berkeley by using a cognitive interviewing method to ensure the instrument's effectiveness (Eisenhower 2000). The survey has compiled occupants' responses on IEQ criteria regarding their environmental satisfaction and performance enhancement in their workspaces. It is a paper-based survey using a self-assessment questionnaire. The questionnaire included a core survey section regarding occupant satisfaction and performance in relation to nine IEQ criteria, as well as characteristics of their demographics and personal workspaces. The study compared nine IEQ criteria (seven from the CBE survey format and two additional IEQ criteria from KGBCC) in relation to occupant satisfaction and performance, between two buildings that are KGBCC-certified and two that are not. The nine IEQ criteria included the qualities of office layout, office furnishings, thermal comfort, indoor air quality, lighting, acoustics, public space, accessibility, cleanliness, and maintenance. The category pertaining to occupant satisfaction has more than one question and it asks how satisfied workers were with each IEQ criterion. Respondents rate the nine aspects on a scale of 1–7 choices from “very satisfied” (+3) to “very dissatisfied” (–3). All IEQ criteria regarding the occupant's performance asked, for each IEQ criterion, whether the circumstances of that criterion enhanced or interfered with their ability to get the job done. In addition to the responses to these core questions, information on the characteristics of respondents' demographics and their workspaces was collected. This was to compare the commonalities and differences of occupants between two building groups and to help explain the findings of the study.

For the purpose of this study the buildings are categorized into two classes: Case 1 and Case 2. Case 1 consists of one small-sized KGBCC-certified office building and a small-sized non-KGBCC-certified office building. Case 2 consists of one medium-size KGBCC-certified office building and a medium-size non-KGBCC-certified office building. In Case 1, the total population of both buildings is low, so that the questionnaires were distributed to all of the 55 employees of both buildings: 35 for the KGBCC-certified and 20 for the non-KGBCC-certified. Of the 35, 33 (94.3%) were retrieved for data analysis from the KGBCC-certified Kolon building, and out of 20, 17 (85%) were retrieved for data analysis from the non-KGBCC-certified Animal and Plant Quarantine Center (A&P) building. However, in Case 2 the total population is higher in number 266: 130 for the KGBCC-certified and 136 for non-KGBCC-certified. So a random sampling method was used. A total of 200 questionnaires were administered, 100 for each building. Out of the 100 questionnaires administered randomly to employees in each building 82 (82%) were retrieved for data analysis from the KGBCC-certified Kyobo building, 90 (90%) were retrieved for data analysis from the non-KGBCC-certified National Pension Service (NPS) building.

## Analysis

Likert-type rating scales were used to measure respondents' views on their satisfaction and performance in relation to the IEQ criteria. Likert-type categories were coded and summed up to an interval-level measure for analysis. The data were analyzed by descriptive statistics. Descriptive statistics explained the occupants' responses to the nine IEQ criteria using means, standard deviations, and parametric tests (*t*-test, analysis of variance [ANOVA], and Pearson). For the demographic and workspace characteristics questions, frequency distributions were analyzed and translated into percentages.



Cronbach's alpha was used to measure the reliability of the data. A mean score was calculated for each criterion to compare the central tendencies between the two building groups. An independent sample *t*-test was conducted to examine whether there was a significant difference in satisfaction and performance between KGBCC-certified and non-KGBCC-certified office buildings. Only the results of statistically significant tests are presented in the tables. The tests are considered statistically significant if  $p \leq 0.05$ . Means for green and conventional buildings are reported in the figure to illustrate the general conditions in the studied buildings. A one-way ANOVA test was conducted to examine whether there was a statistically significant difference among demographic and workspace characteristics with the satisfaction and performance enhancing levels of IEQ criteria. Correlation analysis was conducted to examine the associations of individual IEQ criteria with the overall satisfaction and performance of occupants in KGBCC-certified office buildings.

### *Summary of the research cases*



For this study, two KGBCC-certified office buildings, one of small size and the other of medium size, each with a different certification score, “Best” and “Good,” and two non-KGBCC-certified office buildings, again one small and one of medium size, were selected and surveyed. Building pairs were sought, one KGBCC-certified (green) and one conventional, that were as similar as possible (e.g., of the same size and age, in the same climate zone, and with occupants doing similar work). This provides confidence that any differences in the measured outcomes are due to “greenness” rather than other factors (Newsham et al. 2013). Perfect matching is never possible in any practical sample of real buildings. And due to the historically recent development of the sustainable buildings movement, green buildings do tend to be newer than non-green buildings (Newsham et al. 2013).

For Case 1, the KGBCC-certified Kolon building and the non-KGBCC-certified A&P buildings were chosen. Both are research offices located next to each other with each having four stories (three stories above ground, one story underground). In Case 2, KGBCC-certified Kyobo and non-KGBCC-certified NPS buildings were chosen. Both are insurance office buildings located within 2 km of each other. Table 1 shows circumstances of the KGBCC-certified Kyobo life insurance and the non-KGBCC-certified NPS buildings and Table 2 shows the same type of information for the Kolon and the non-KGBCC-certified A&P buildings.

**Table 1.** Kyobo Life Insurance and National Pension Service building.

	Kyobo Life Insurance	National Pension Service
<b>Building location</b>	475-6 Geumam 1(il)-dong Deokjin-gu, Jeonju-si, Jeollabuk-do, South Korea	13, Ongoeul-ro, Wansan-gu, Jeonju-si, Jeollabuk-do, South Korea
<b>Building type</b>	Office	Office
<b>Certification grade</b>	Green 2	None
<b>Building area</b>	755.94 m <sup>2</sup>	998 m <sup>2</sup>
<b>Gross floor area</b>	9773.32 m <sup>2</sup>	10568 m <sup>2</sup>
<b>Number of stories</b>	(9 stories above ground, 3 stories underground)	8 (6 stories above ground, 2 story underground)
<b>Date built</b>	1985, Remodeled in 2014 to comply with KGBCC requirement	1990
		

**Table 2.** Kolon and Animal and Plant Quarantine Agency building.

	Kolon	Animal and Plant Quarantine Agency
<b>Building location</b>	46, 16 Beon-gil, Jeondae-ro, Pogok-eup, Cheoin-gu, Yongin city, Gyeonggi-do, South Korea	44, 16 Beon-gil, Jeondae-ro, Pogok-eup, Cheoin-gu, Yongin city, Gyeonggi-do, South Korea
<b>Building type</b>	Office (research)	Office
<b>Certification grade</b>	Best	None
<b>Building area</b>	604.52 m <sup>2</sup>	852.9 m <sup>2</sup>
<b>Gross floor area</b>	2,061.28 m <sup>2</sup>	3088.6 m <sup>2</sup>
<b>Number of stories</b>	4 (3 stories above ground, 1 story underground)	4 (3 stories above ground, 1 story underground)
<b>Date built</b>	2004	2010
		

## Specific green features

### *KGBCC-certified Kolon building*

The site is near to public transportation, and bicycle racks and shower rooms were provided. The building's total heating, cooling design loads are supplied by a geothermal system and it has a daylighting control system, a light shelf and a solar sun lighting system to enhance the natural light. Environmentally certified products were used for paint and insulation. Interior surfaces are of Ecolabeled paint and gypsum board. A manual and guide on building operation and management is provided. The rooftop and street are landscaped, aquatic and terrestrial habitats were created and plants grow on the walls. A thermostatic control system and integrated photovoltaic systems were installed. Temperature, ventilation, and lighting were controlled by each occupant in offices of the typical floor. The building is entirely non-smoking with a rest place for occupants.

### *KGBCC-certified Kyobo building*

The building site is near to public transportation, a thermostatic control system is installed. The building is entirely non-smoking with a rest place provided for occupants. The desire for good indoor air quality has influenced many material decisions and so the building uses low-emitting materials. Materials and resources were conserved by the reuse of existing building structures. Eco-certified products were used for effective recycling. For reducing energy use, cost, and providing acceptable IEQ, a natural ventilation plan is used. Potable water use is minimized through the use of low-flow toilets and sinks.

### *Non-KGBCC-certified buildings*

Non-KGBCC-certified NPS and A&P buildings were typically not designed from the point-of-view of energy, water, material, and indoor environmental efficiency. They didn't incorporate efficient strategies to reduce the impact of key resources like energy, water, materials, and land upon the environment like

the KGBCC-certified ones. The building sites are near to public transportation.

## Findings

### *Characteristics of occupant demographics and workspaces*

#### *Case 1: KGBCC-certified Kolon and non-KGBCC-certified A&P buildings*

Responses on the demographic information of respondents showed similarity. The majority of respondents of both were between 31–40 years old; there were more males than females; they had worked for more than 1 year in their current workspace for more than 30 hours per week. Respondents from the KGBCC-certified building had stayed for more than 5 years in the building and worked as technical staff (33.3%), whereas for non-KGBCC-certified building the majority had stayed between 1–3 years and had a professional job (50%).

The characteristics of occupants' personal workspaces between the two buildings also showed similarities: the majority occupy cubicles with low partitions, had a workstation located within 4.6 m from a window and an exterior wall. The differences between the respondents of the two buildings were with regard to the location of the workspaces and the direction of the closest window to the workspaces: Most respondents from the KGBCC-certified building had the workspace and closest window direction on the south (45.5%) and (54.5%) respectively, whereas in the non-KGBCC-certified building they had the workspace at the core (44.4%) and closest window direction on the west (33.3%). Table 3 shows the characteristics of occupants' demographics between the two building groups. Figure 3 shows the workspace partition layout of the Kolon building.

#### *Case 2: KGBCC-certified Kyobo and non-KGBCC-certified NPS buildings*

The responses on the demographic information of respondents showed similarity. The majority of respondents of both buildings were above 40 years of age; there were more fe-



**Fig. 3.** Workspace partition layout of Kolon building.

**Table 3.** Characteristics of demographic and workspaces analysis results.

Demographic characteristics					
Personal characteristics	Answer	Case 1		Case 2	
		KGBCC-Certified (%)	Non-certified (%)	KGBCC-Certified (%)	Non-certified (%)
Gender	Male	78.8	94.4	20.7	36.7
	Female	21.2	5.6	79.3	63.3
Age	<30 years	9.1	38.9	3.7	25.6
	31–40 years	60.6	50.0	43.9	33.3
	>40 years	30.3	11.1	52.4	41.1
Job category	Admin. support	27.3	5.6	22.0	20.0
	Professional	21.2	50.0	36.6	37.8
	Technical	33.3	—	3.7	—
	Managerial	—	—	8.5	5.6
	Other	15.2	44.4	29.3	36.7
Duration of working in the building	<1 year	6.1	16.7	18.3	33.3
	1–3 years	27.3	77.8	20.7	40.0
	4–5 years	6.1	5.6	26.8	2.2
	>5 years	60.6	—	34.1	24.4
Duration of working at present workspace	4–6 months	3.0	11.1	13.4	18.9
	7–12 months	3.0	33.3	51.2	21.1
	>1 year	93.9	55.6	35.4	50.0
Time spent at workspace per week	<10 hours	30.4	16.7	29.3	32.2
	11–30 hours	6.1	27.8	32.9	22.2
	>30 hours	63.6	55.6	37.8	45.6
Workspace characteristics					
Personal workspace	Cubicles with high partition	24.2	27.8	8.5	4.4
	Cubicles with low partition	72.7	72.2	72.0	48.9
	Enclosed, Private	—	—	3.7	—
	Open office without partition	—	—	13.4	46.7
	Other	3.0	—	2.4	—
Location of workspace	South	45.5	16.7	23.2	24.4
	North	3.0	5.6	11.0	3.3
	East	15.2	5.6	34.1	20.0
	West	6.1	11.1	4.9	30.0
	Core	18.2	44.4	11.0	14.4
	Don't know	12.1	16.7	15.9	7.8
Closest window direction to workspace	North	6.1	16.7	20.7	20.0
	South	54.5	22.2	24.4	27.8
	East	6.1	5.6	39.0	15.6
	West	12.1	33.3	3.7	30.0
	Don't know	21.2	22.2	11.0	6.6
Workstation's distance within 4.6 m from a window	Yes	93.9	66.7	79.3	54.4
	No	6.1	33.3	20.7	45.6
Workstation's distance within 4.6 m from an exterior wall	Yes	81.8	66.7	67.1	46.7
	No	18.2	33.3	32.9	53.3



**Fig. 4.** Workspace partition layout of Kyobo building.

males than males; they had a professional job and spent more than 30 hours at their workspace per week. There were differences in the demographic information, for the duration of working in the building and the duration of working at the present workspace. Respondents from the KGBCC-certified building had stayed for more than 5 years (34.1%) and had worked between 7–12 months (51.2%) at their current workspace, whereas for the non-KGBCC-certified building they had stayed between 1–3 years (40%) and had worked for more than 1 year (50.0%) in their current workspace.

The characteristics of occupants' personal workspaces also showed similarity between the two buildings: The majority occupy cubicles with low partitions and had a workstation located within 4.6 m from a window. The differences between the respondents of the two buildings were with regard to the location of the workspaces, the direction of the closest window to the workspaces and the workstation closeness to an external wall. The KGBCC-certified building had a workspace location and closest window direction on the east, 34.1% and 39%, respectively, and had workstation located within 4.6 m from an external wall; the non-KGBCC-certified building had the workspace and closest window direction on the west, 30% and 30%, respectively. Table 3 shows the characteristics of occupants' demographics between two building groups. Figure 4 shows the workspace partition layout of the Kyobo building.

### Analysis results

#### Case study 1: Kolon and A&P building

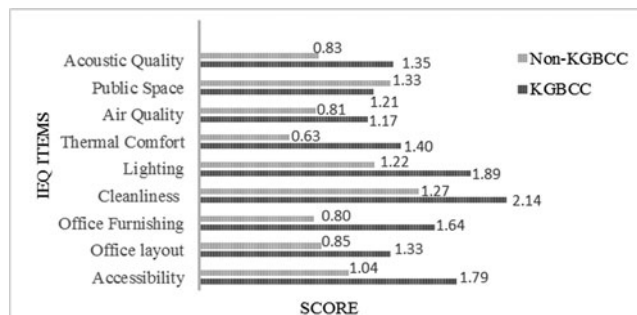
From Cronbach's alpha test, an alpha score of 0.88 is obtained for the Kolon and 0.92 for A&P building, suggesting that the items have relatively high internal consistency.

### Satisfaction

The test revealed statistically significant differences between the satisfaction levels of the two buildings with regard to

accessibility of space, office furniture, cleanliness and maintenance, lighting quality, thermal comfort, and overall average satisfaction level with IEQ criteria. With regard to those factors, the KGBCC-certified Kolon building's occupants reported significantly higher satisfaction levels than those of the non-KGBCC-certified A&P building. Figure 5 presents average satisfaction mean scores of IEQ criteria between the two building groups. There was no statistically significant difference between the satisfaction levels of the two buildings with regard to office layout, indoor public space, indoor air quality or acoustic quality. Table 4 shows the results of the statistically significant tests.

In the KGBCC-certified Kolon building, the ANOVA test revealed a statistically significant difference among age groups and gender with the satisfaction level of thermal comfort. There was no statistically significant difference among workspace characteristics. In the non-KGBCC-certified A&P building there was a statistically significant difference among the durations of working at the present workspace with the satisfaction level of acoustic quality. The test also revealed a statistically significant difference among personal workspace with the accessibility of space. In both buildings, the test revealed a statistically no significant difference among demo-



**Fig. 5.** IEQ, average satisfaction score comparison (Kolon and A and P building).



**Table 4.** The statistically significant test results of satisfaction—Kolon and A&P building.

IEQ criteria	Building	Sig.	df	Mean	SD	Sig. (2-tailed)
Accessibility	Kolon	0.49	49	1.79	0.86	0.001
	A&P			0.83	1.04	
Office furniture	Kolon	0.08	49	1.64	0.87	0.001
	A&P			0.89	0.56	
Cleanliness and maintenance	Kolon	0.45	49	2.14	0.81	0.009
	A&P			1.53	0.67	
Lighting	Kolon	0.95	49	1.89	0.74	0.007
	A&P			1.22	0.91	
Thermal	Kolon	0.84	49	1.40	0.76	0.001
	A&P			0.63	0.74	
Overall average	Kolon	0.33	49	1.55	0.64	0.005
	A&P			1.01	0.58	

graphic and workspace characteristics with the average satisfaction of IEQ criteria.

### Performance

The test revealed a statistically significant difference between the performance enhancement levels of the two buildings in cleanliness and maintenance, lighting quality, thermal comfort, and the overall average performance enhancement level of IEQ criteria. The KGBCC-certified Kolon building reported significantly higher levels of overall performance enhancement than did the non-KGBCC-certified A&P building. Regarding accessibility of space, office layout, office furniture quality, indoor public space, indoor air quality, and acoustic quality there was statistically no significant difference between the performance enhancement levels of the two buildings. Table 5 shows the results of statistically significant tests.

In the KGBCC-certified Kolon building the ANOVA test revealed a statistically significant difference between the genders with the performance enhancement level of acoustic quality. In the non-KGBCC-certified A&P building the test revealed no statistically significant difference among demographic and workspace characteristics in relation to performance enhancing levels of IEQ criteria. In both buildings, the test revealed a statistically no significant difference among demographic and workspace characteristics with the average performance enhancement level of IEQ criteria. Figure 6 presents average performance mean scores of IEQ criteria between the two buildings.

The KGBCC-certified Kolon building reported significantly better levels of satisfaction with regard to accessibility of space, office furniture, cleanliness and maintenance, lighting quality, and thermal comfort and reported higher average mean scores on most indoor environmental criteria. However, an average mean score for satisfaction is +2 and the KGBCC certified Kolon building achieves this score only in cleanliness and maintenance. On both occupant satisfaction and performance enhancement, the KGBCC-certified Kolon building had shown significantly higher satisfaction and performance enhancement than the non-KGBCC-certified building in cleanliness and maintenance, lighting quality, and thermal comfort quality. It is inferred from these results that the KGBCC-certified Kolon building provides better cleanliness and maintenance, lighting, and thermal quality than the non-KGBCC-certified A&P building.

### Case study 2: Kyobo and NPS buildings

From Cronbach's alpha test an alpha score of 0.97 was obtained for the Kyobo and 0.93 for the NPS building, suggesting that the items have relatively high internal consistency.

### Satisfaction

The test revealed a statistically significant difference between the satisfaction levels of the two buildings with regard to all criteria, except the accessibility of space criterion. There is also a statistically significant difference between the overall average

**Table 5.** The statistically significant test results of performance—Kolon and A&P building.

IEQ criteria	Building	Sig.	df	Mean	SD	Sig. (2-tailed)
Cleanliness and maintenance	Kolon	0.46	49	1.73	1.13	0.05
	A&P			1.11	0.90	
Lighting	Kolon	0.58	49	1.55	1.23	0.048
	A&P			0.89	0.83	
Thermal	Kolon	0.39	49	1.33	1.34	0.035
	A&P			0.50	1.25	
Overall average	Kolon	0.95	49	1.37	0.72	0.019
	A&P			0.89	0.58	

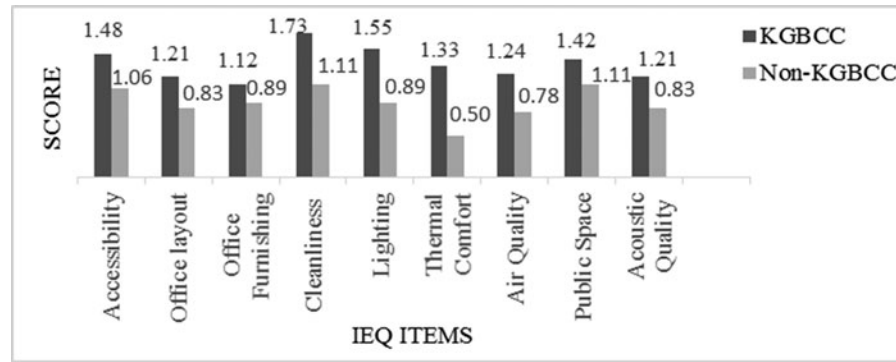


Fig. 6. IEQ, average performance score comparison (Kolon and A and P building).

satisfaction levels of the IEQ criteria. The KGBCC-certified Kyobo building reported significantly higher satisfaction levels than the non-KGBCC-certified NPS building. Table 6 shows the results of the statistically significant tests.

In the KGBCC-certified Kyobo building the ANOVA test revealed a statistically significant difference among durations of working in the building with the satisfaction levels of accessibility of space, office layout, lighting quality, and overall average satisfaction of IEQ criteria. There were also statistically significant differences among: The durations of working in their current workspace with the satisfaction levels of office layout, cleanliness, and maintenance; age groups with the satisfaction level of thermal comfort; and personal workspaces with the accessibility of space and lighting quality.

In the non-KGBCC-certified NPS building the test revealed a statistically significant difference among: Durations of working in the building with the satisfaction level of thermal comfort and indoor air quality; time spent in the workspace per week with the satisfaction levels of accessibility of space, cleanliness and maintenance, lighting quality, and acoustic quality;

age groups with the satisfaction level of cleanliness and maintenance and indoor air quality; gender with the satisfaction level of office furniture quality; and personal workspaces with lighting quality and indoor air quality. Figure 7 presents average satisfaction mean scores of IEQ criteria between the two building groups.

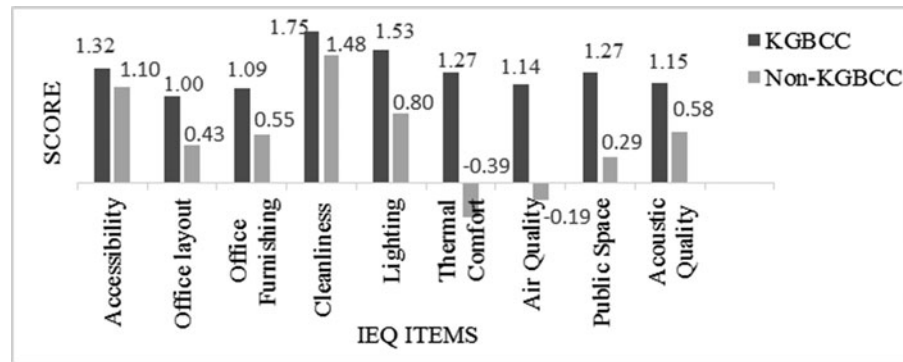
### Performance

The *t*-test revealed a statistically significant difference between the performance enhancement levels of the two buildings for all criteria, except in cleanliness and maintenance. There is also a statistically significant difference between the overall average performance enhancement levels of IEQ criteria. The KGBCC-certified Kyobo building reported significantly higher levels of performance enhancement than did the non-KGBCC-certified NPS building. Table 7 shows the results of statistically significant tests.

On both occupant satisfaction and performance, the KGBCC-certified Kyobo building showed a higher mean score

Table 6. The statistically significant test results of satisfaction—Kyobo and NPS building.

IEQ criteria	Building	Sig.	df	Mean	SD	Sig. (2-tailed)
Office layout	Kyobo	0.97	170	1.00	0.99	0.001
	NPS			0.43	1.02	
Office furniture	Kyobo	0.23	170	1.09	0.89	0.001
	NPS			0.56	1.00	
Cleanliness and maintenance	Kyobo	0.62	170	1.75	0.84	0.049
	NPS			1.48	0.95	
Lighting	Kyobo	0.27	170	1.53	0.90	0.001
	NPS			0.80	0.91	
Thermal	Kyobo	0.01	153	1.27	0.85	0.001
	NPS			-0.40	1.34	
Indoor air	Kyobo	0.01	156	1.14	0.99	0.001
	NPS			-0.20	1.50	
Indoor public space	Kyobo	0.06	170	1.27	1.24	0.001
	NPS			0.29	1.45	
Acoustics	Kyobo	0.82	170	1.15	1.09	0.001
	NPS			0.58	1.11	
Overall average	Kyobo	0.53	170	1.28	0.81	0.001
	NPS			0.52	0.81	



**Fig. 7.** IEQ, average satisfaction score comparison (Kyobo and NPS buildings).

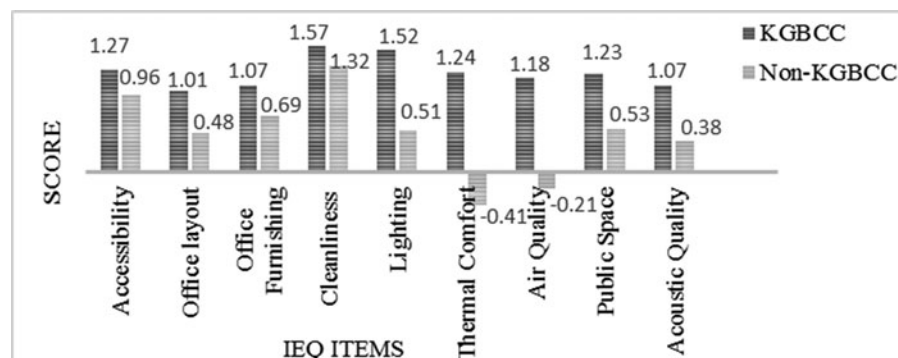
**Table 7.** The statistically significant test results of performance—Kyobo and NPS building.

IEQ criteria	Building	Sig.	df	Mean	SD	Sig. (2-tailed)
Accessibility	Kyobo	0.71	170	1.27	1.00	0.04
	NPS			0.96	1.00	
Office layout	Kyobo	0.28	170	1.01	1.09	0.003
	NPS			0.48	1.22	
Office furniture	Kyobo	0.98	170	1.07	1.07	0.019
	NPS			0.69	1.05	
Lighting	Kyobo	0.69	170	1.52	0.98	0.001
	NPS			0.50	1.02	
Thermal	Kyobo	0.01	161	1.24	1.04	0.001
	NPS			-0.41	1.45	
Indoor air	Kyobo	0.03	166	1.18	1.16	0.001
	NPS			-0.21	1.49	
Indoor public space	Kyobo	0.49	170	1.23	1.17	0.001
	NPS			0.53	1.17	
Acoustics	Kyobo	0.77	170	1.07	1.16	0.001
	NPS			0.38	1.18	
Overall average	Kyobo	0.07	170	1.24	0.87	0.001
	NPS			0.47	0.79	

in office layout, office furniture, lighting quality, thermal comfort quality, indoor air quality, indoor public space quality, and acoustic quality than did the non-KGBCC-certified NPS building. However, on both satisfaction and performance, the mean scores were low, which shows that the respondents were not much satisfied with most of the IEQ criteria. An average

mean score for satisfaction is +2 and the KGBCC-certified Kyobo building couldn't achieve this score in any of the nine IEQ criteria. Figure 8 presents average performance mean scores of IEQ criteria between the two building groups.

In KGBCC-certified Kyobo building the ANOVA test revealed a statistically significant difference among: Durations



**Fig. 8.** IEQ, average performance score comparison (Kyobo and NPS buildings).

**Table 8.** Correlation analysis of IEQ criteria on satisfaction and performance.

## Correlations—IEQ criteria with average satisfaction

Building		Accessibility	Office layout	Office fur.	Cleanliness	Lighting	Thermal	Air quality	Public space	Acoustics
Kolon	Pearson corr.	0.57**	<b>0.68**</b>	<b>0.75**</b>	<b>0.67**</b>	<b>0.72**</b>	<b>0.76**</b>	<b>0.65**</b>	<b>0.69**</b>	0.46**
	Sig.(2-tailed)	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.008
Kyobo	Pearson corr.	<b>0.77**</b>	<b>0.86**</b>	<b>0.84**</b>	<b>0.81**</b>	<b>0.88**</b>	<b>0.86**</b>	<b>0.84**</b>	<b>0.77**</b>	<b>0.86**</b>
	Sig.(2-tailed)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

## Correlations—IEQ criteria with average performance

Kolon	Pearson corr.	0.39*	<b>0.75**</b>	<b>0.67**</b>	<b>0.67**</b>	<b>0.66**</b>	<b>0.68**</b>	<b>0.67**</b>	0.40*	0.58**
	Sig.(2-tailed)	0.024	0.000	0.000	0.000	0.000	0.000	0.000	0.021	0.000
Kyobo	Pearson corr.	<b>0.88**</b>	<b>0.82**</b>	<b>0.67**</b>	<b>0.78**</b>	<b>0.82**</b>	<b>0.81**</b>	<b>0.86**</b>	<b>0.78**</b>	<b>0.84**</b>
	Sig.(2-tailed)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Note: \*Correlation is significant at the 0.05 level (2-tailed).

\*\*Correlation is significant at the 0.01 level (2-tailed).

$R > 0.6$ : considered as strong association.

of working in the building with the accessibility of space, office layout, public space quality and overall average performance of IEQ criteria; and job category with office furniture, cleanliness and maintenance, and thermal comfort. The test revealed no statistically significant difference among workspace characteristics with performance enhancing levels with IEQ criteria.

In the non-KGBCC-certified NPS building, the test revealed a statistically significant difference among: durations of working in the building with the performance enhancement level of thermal comfort, indoor air quality, and overall average performance of IEQ criteria; and time spent at workspace per week with the performance enhancement level of accessibility of space, lighting quality and overall average performance of IEQ criteria. The test also revealed a statistically significant difference among personal workspaces with office layout and indoor air quality.

A Pearson's correlation was conducted to examine whether the nine IEQ criteria have an association with the overall average satisfaction and performance levels of occupants of the two KGBCC-certified office buildings. The test result revealed a strong positive association between office layout, office furniture, cleanliness and maintenance, lighting quality, thermal comfort quality, indoor air quality, and indoor public space quality with overall satisfaction and a strong positive association between office layout, office furniture, cleanliness and maintenance, lighting, thermal comfort, and indoor air qualities with overall performance enhancement. The correlation analysis results are as shown in Table 8.

## Discussion

The study results showed that most demographic and personal workspace characteristics of respondents were similar between KGBCC-certified buildings and non-KGBCC-certified buildings. In Case 1, the differences between demographic and personal workspace characteristics of the two studied buildings were on the duration of working in the building, the job categories, locations of workspaces and closest window directions to the workspaces. However, a further analysis has revealed that none of the above differences in the demographic and personal workspace characteristics had an effect on respondents' satisfaction and performance enhancement. In Case 2, the difference between demographic and personal workspace characteristics of the two studied buildings were on the durations of working in the building and on their current workspaces, the locations of workspaces and closest window directions to the workspaces. The study analysis had revealed that the difference in duration of working in the building had an effect on the average satisfaction of IEQ criteria in the KGBCC-certified building and average performance enhancement in the non-KGBCC certified one. However, none of the other differences on demographic and personal workspace characteristics had an effect on respondents' satisfaction and performance. From this, it can be concluded that the mean differences in occupant satisfaction and performance in these two building groups may thus be attributed to the differences in the physical environment.

Comparing the nine IEQ criteria between the two building groups, KGBCC-certified buildings had shown better

satisfaction score in both cases (Cases 1 and 2) in office furniture quality, cleanliness and maintenance quality, lighting quality, and thermal comfort quality than non-KGBCC-certified buildings. KGBCC-certified buildings had shown better performance scores in both cases (Cases 1 and 2) in lighting quality, and thermal comfort quality than non-KGBCC-certified buildings. From both cases, KGBCC-certified buildings had shown a higher level of overall satisfaction and performance enhancement score than the non-KGBCC-certified building.

The study also analyzed the association of IEQ criteria with overall average satisfaction and performance. The study found a strong positive association between office layout, office furniture, cleanliness and maintenance, lighting, thermal comfort, indoor air, and indoor public space quality with overall average satisfaction and a strong positive association between office layout, office furniture, cleanliness and maintenance, lighting, thermal comfort, and indoor air qualities with overall performance enhancement.

The study shows office layout, office furniture, cleanliness and maintenance, lighting, thermal comfort, indoor air, and indoor public space quality have a higher influence on overall satisfaction and performance with the IEQ compared with the impact of other indoor environmental conditions.

## Conclusions

The study analyzed two KGBCC-certified office buildings with best and good certification grades. Both buildings had higher overall satisfaction and performance enhancement scores than non-KGBCC-certified ones. Indoor air quality, indoor public space, thermal comfort, and noise and acoustics are the four IEQ criteria of the KGBCC certification. However, in Case 1 there was no significant difference in the quality of indoor air, indoor public space, and noise and acoustics with regard to satisfaction and performance enhancement between the KGBCC-certified and non-KGBCC-certified buildings. In Case 2, all of the KGBCC IEQ criteria had shown significant differences in both satisfaction and performance between the KGBCC-certified and non-KGBCC-certified buildings. This analysis has demonstrated that better indoor environments play a role in elevating job satisfaction and other aspects of organizational productivity in office buildings. The results from this limited data set justify future studies to test using a larger model of these relationships. A study involving many more buildings, and with more detailed information, would be needed to examine this properly.

The implications of this study are that to achieve a better overall satisfaction and performance:

- First, KGBCC certification needs to do more on its four IEQ criteria, especially on those IEQ criteria that show no significant difference with non-KGBCC certified buildings.
- Second, more criteria than the current IEQ criteria should be considered in office building schemes and an equal emphasis should be given to various IEQ criteria in the design process, especially those IEQ criteria that show a strong positive association with overall satisfaction and perfor-

mance enhancement that are presently not included in the KGBCC IEQ category, such as office furniture quality, cleanliness and maintenance, and lighting quality as shown in this study.

This study tried to show the issues needed to be considered in the KGBCC-certification from occupants' perspective. It has limitations such as small sample size and subjectivity of evaluation.

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