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IEQ



GREEN BUILDING



CONVENTIONAL BUILDING

THE HONG KONG POLYTECHNIC UNIVERSITY

BENG(HONS) IN BUILDING SERVICES ENGINEERING

2017-2018 Semester 2

BSE4723 Research Project

CWK.02 Research Paper



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Title

CWK.02 The Effect of the IEQ Report (Acknowledgement) on Occupant Satisfaction and Engagement in the Green and Conventional Offices

Abstract

There were many published papers claimed that green buildings not only have a better performance on building energy saving and energy efficient than the conventional buildings, but also have a higher occupant satisfaction rate on the indoor environmental quality (IEQ). Very little had investigated the reasons behind (a higher occupant satisfaction rate was achieved in the green buildings). Moreover, it is generally believed that occupants are the main uncertainty factor affecting the building performance, and therefore, the balance between energy saving, resources efficiency and comfortable, healthy environment should be sought appropriately. In order to investigate how the acknowledgment to building environment quality apply on the occupant engagement and comfort and the difference between green building and conventional building, a study is conducted in both green building and conventional building in Kowloon Bay and Chai Wan respectively. Both objective and subjective methods will be used, including questionnaire and observation. The IEQ will be observed by the sensors installed in different places in the offices while occupant engagement and acknowledgement will be determined via questionnaire. In this study, a huge difference of occupant satisfaction rate between the green building and conventional building cannot be perceived successfully. However, there was sufficient evidence to support that if the occupants have a better acknowledgement on IEQ and building energy and providing real-time feedback to them, their satisfaction rate will be affected and hence, more active to engage in the building controls.

1. Introduction

Buildings in Hong Kong have huge impact on energy and emissions. Hong Kong, a small developed city accounts for 0.0002% of Earth's surface area, has a huge population on very scarce land with the population density of 6780 people per square kilometres [1]. With more than 75 per cent of the land comprises no-built-up areas, most of the buildings are densely packed and high rise buildings. This causes large amount of carbon dioxide emission in Hong Kong which contributes 0.13% of world's carbon dioxide emission, in which 60% of carbon dioxide emission is related to buildings [2] while carbon dioxide emission from buildings only costs 10 per cent of total emission in the world [3]. In Hong Kong, commercial buildings use the most energy and therefore, this study will mainly focus on offices.

With this concern, exploiting green buildings sped up in the world, which are designed, constructed and operated to save building energy by using different strategies. In Hong Kong, the Hong Kong Green Building Council Limited (HKGBC) published the guidelines, BEAM Plus, to promote the development of sustainable buildings in Hong Kong which aims to diminish the impacts to the environment of both new and existing buildings while also improving IEQ and user satisfaction [4]. However, the existing buildings which had been built for more than 30 years will dominate the stock in Hong Kong in the future, from 20,000 to 30,000 in ten years [5]. These existing buildings were not designed and built to meet the requirements of BEAM Plus and the structure of these buildings does not allow them to transform into a green building. Base on these background, seeking a balance between building energy saving and IEQ is important and the important factors influencing these two perspectives are occupant engagement and acknowledgement [6].

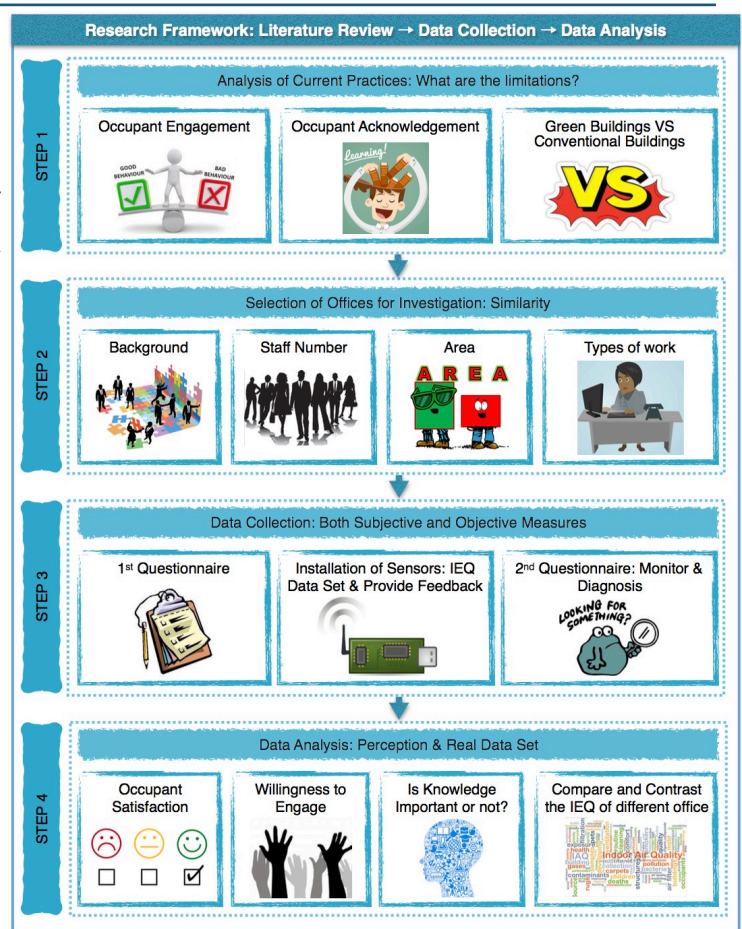


Figure 1. Research Framework

1.1 Occupant Acknowledgement

As mentioned above, occupant engagement is important to both the building energy saving and IEQ, however, keeping them engaged is a challenge, especially in the offices. Ehrhardt-Martinez [7] revealed that since the occupants in the offices were not responsible for paying the electricity bills, they did not have the awareness on controlling indoor environment. Unlike at home, occupants were taught and reminded to turn off the lights and equipment while leaving, they might not understand how to operate or remember to turn off the corresponding equipment in the offices, which led to poor occupant engagement. The lack of knowledge may become a barrier to the engagement related to building energy saving and IEQ.

Day and Gunderson [8] found that occupants who understood how to operate the controls related to comfort had a higher satisfaction with the environment than those who did not know how to use the controls. They also obtained that the productivity of occupants was elevated when they thought their environment was comfortable. They divided their study into three phrases: expert interviews, survey and follow-up occupant interviews to investigate the relationship between the satisfaction over the environment and relevant knowledge. The knowledge of building systems which could enhance the environmental satisfaction was introduced to the occupants. The results showed that occupant acknowledgement was important to both energy saving and IEQ.

Except for educating the occupants, providing feedbacks to them is also an alternative method to reinforce their knowledge, and hence, save the energy and improve the IEQ. Peterson et al. [9] pointed out that by providing real-time resource feedback and

education on electricity uses to the occupants, 55% electricity use could be reduced. They provided real-time web-based feedbacks to the occupants on energy use in the college dormitories by using automated data monitoring system. They also arranged some competitions on energy saving in the dormitories and provided information about environmental impact of electricity use to the occupants by posting posters. They concluded that with the combination of education, feedback system and motivation, the purpose of reducing energy used could be achieved.

Hence, if occupants understand and learn how to engage in controlling the corresponding system related to indoor environmental quality, they may be conducive to building energy saving and their satisfaction at workplace environment can be enhanced also.

1.2 Occupant Engagement on Indoor Environmental Quality (IEQ)

Occupant engagement refers to the interaction between building systems and occupants so that the occupants can obtain thermal, visual and acoustic comfort inside the buildings by control the indoor environment. According to Bluysen [10], there are four prerequisites for the occupants being able to engage in adjusting the building systems and components, which are the improvement in air quality, acoustical conditions, visual or lighting quality and thermal comfort inside the living environment. Therefore, occupants can influence the indoor environment through their engagement in the buildings, which is essential since better IEQ can improve their productivity and health.

Kumaruzzaman et al. [11] expressed that the IEQ could be significantly improved if occupants engaged in the controls related to IAQ since the improvement was based on the occupants' needs. They conducted a survey in six historical buildings in terms of degree of importance and occupant satisfaction in Malaysia. They found that if the occupants were not able to control or change the specific environment, the level of satisfaction of the corresponding category would be the lowest and vice versa.

This implied that if the occupants knew and were able to control the elements related to IEQ, they would engage in the environmental improvement works and hence, the IEQ could be improved.

1.3 Occupant Engagement on Building Energy

The development of high performance buildings is growing rapidly nowadays, in addition to increase the energy efficiency, the other aim of these buildings is to elevate the productivity and health of the occupants. Owen and Drifill [12] promoted that the achievement of the goals of these buildings depended on how do the occupants engage in the buildings. Although the buildings might include many energy efficient designs for saving energy, they required the operation of the occupants, which means that occupant engagement determines how energy is spent in the buildings.

Hong and Lin [13] stated that the impact of occupant engagement on building energy was significant. They conducted a study in private offices and divided the occupants work styles into three different categories according to the energy used: the austerity work style, the standard work style and the wasteful work style, which means energy saving behaviour, average usage of energy behaviour and lack of motivation to reduce the usage of energy respectively. By using EnergyPlus, building simulations were hired to evaluate how did these three different working styles influence to the energy usage. They found that a simple work style consumed up to 50% less energy while wasteful work style consumed up to 90% more energy compared with the standard work style, which indicated that energy saving in the buildings was closely linked to the engagement of the occupants.

Apart from concerning the occupant engagement during office hours, the building energy consumption during non-office hours and unoccupied hours should also be paid attention to. Masoso and Grobler [14] discovered that the total energy consumption during non-office hours is 56% more than that during office-hours. They conducted a study on investigating the total energy consumption of six commercial buildings in South Africa (with hot and dry climate) by using energy auditing equipment. At the end of the day, the air-conditioning systems, electrical equipment and lighting systems were not turned off by the occupants when they left. The result showed that even though being energy efficient is becoming a more popular issue among the world nowadays, poor occupant engagement leads to the wastage of energy is still common.

This can be concluded that occupant engagement is an important aspect in building energy performance and seeking a balance between energy efficiency and occupant comfort is very important. Therefore, it is one of the categories to be studied in this paper.

1.4 Green building VS Conventional building

On the other hand, new constructed buildings in Hong Kong are required to fulfil the BEAM Plus requirements, which means that they have to be green and this is also a global trend. Romm and Browning [15] mentioned that sustainable design strategies would improve the IEQ and therefore, more favourable to human health and productivity than just following the basic design standards. Many experts also claimed that there are numerous benefits on IEQ, occupants health and comfort in green buildings compared with the conventional buildings.

Abbaszadeh et al. [16] discovered that occupants in green buildings had a higher satisfaction with IEQ than those in the conventional buildings, especially in the categories of IAQ and thermal comfort. They utilised the data collected from the questionnaires carried out by the Centre for the Built Environment (CBE) in California to analyse the difference between green buildings and conventional buildings on occupant satisfaction with IEQ. They determined that there were various controls and design strategies that could affect IEQ in green building, such as minimising the air pollutants and improving air ventilation. Thus, occupants could control the IEQ themselves according to their needs which could raise their satisfaction with IEQ.

Singh et al. [17] declared that green buildings could not only improved occupants' health and well-being, but also their productivity. They conducted an experiment to investigate if the IEQ was more acceptable in green buildings by moving the occupants from conventional buildings to green buildings. Questionnaires were also carried out twice: pre-move and post-move. Most of the occupants expressed that they were less likely to suffer asthma, allergies, stress and depression due to the improvement of IEQ, the positive effect was remarkable.

Since there are many studies mentioned that green buildings are more desirable than the conventional buildings, this study would like to test this hypothesis.

Table 1 shown in APPENDIX 1 sums up the findings and methods of the studies related to the above categories.

2. Objectives

Based on the above literature reviews, some limitations of those studies can be summarised. Firstly, most of the methodologies of the above studies were either survey or sensors, there have been very few studies conducted in both ways. Secondly, there is little research on the influence of occupant satisfaction by providing them real-time feedback about IEQ, past studies mainly focused on

delivering feedbacks about energy saving. Last but not least, **little research** so far has dealt with the **occupant acknowledgement and willingness** towards IEQ and building energy. Therefore, the difference about occupant engagement and acknowledgement on IEQ and building energy between green building and conventional building would be investigated by using two methods: survey and sensors which can provide real-time feedback in this study. The objectives of this study are summed up below:

1. To examine the difference of **understanding and satisfaction of occupants** in terms of **building controls and comfort respectively** between the green office and conventional office.
2. To investigate the **willingness of occupants on learning and engaging** with the building controls related to IEQ and energy saving. If **feedback** of their actions is **provided immediately**, will they **monitor and diagnosis their actions**?
3. To evaluate the relationship between (1) acknowledgement and IEQ; (2) occupant engagement and occupant satisfaction in both green building and conventional building.

3. Methods and Materials

3.1 Offices Recruitment

There are two office buildings recruited to participate in this study: one green building and one conventional building. For the office in green building, it is located at Kowloon Bay which achieved BEAM Plus Existing Buildings Final Platinum while the conventional one is located at Chai Wan. These two offices are **belonged to the same company** and the **types of work** of the occupants are **similar** which provide a common baseline for the investigation and comparison. In order to have a more precise data collection, **only one office area on one floor of the building will be investigated** so that both the floor area and number of staffs will be similar. The following table sums up the background information of these two offices:

Green Office in Kowloon Bay		Conventional Office in Chai Wan
Since	August 2005	April 2014
Floor Area	Around 2400 sq. ft.	Around 2000 sq. ft.
No. of Staffs	20/ Floor	18/ Floor
Shape of Office	Rectangular	Rectangular
Types of Work of Occupants	Paperwork, Vehicle Monitoring, Quality Control	Paperwork, Vehicle Monitoring, Quality Control
Cooling System	Ceiling Cassette Air Conditioners with Thermostats	Window Air Conditioners and Split Air Conditioners
Lighting Control	Daylight and Motion Sensors	Manual Switches

Table 2. Background Information of Two Office Buildings

3.2 Data Collection Methods

Two data collection methods will be applied in this study including (i) the usage of occupant questionnaires, a subjective way, and (ii) the observation of indoor environmental quality by using sensors installed in the office, an objective way.

(i) Occupant Questionnaires

The **distribution** of questionnaires will be separated into two stages: **Before** installing the sensors and **after** installing the sensors. In the mid of October, occupants answered the questionnaire based on the experiences and feelings in the past, then the sensors were installed in each office in the mid of January. After the installation of the sensors, occupants could obtain the real-time data of IEQ through the application installed in their mobile phone and corresponding bi-weekly IAQ reports were also provided. In the late March (after two months of the installation of the sensors), second questionnaire was distributed to the same occupants who responded the first questionnaire. The questionnaires were carried out via both web-based and paper version depends on the occupants' choices while the distribution of questionnaires was lasted for about one week in order to obtain as many samples as possible.

The questions in the questionnaire will be focused on mainly **three perspectives**, including the **satisfaction with IEQ**, occupant **engagement and knowledge** on both **building energy saving and IEQ**. The data collected was complied and analysed based on the objectives mentioned before.

(i) Observation - Usage of Sensors

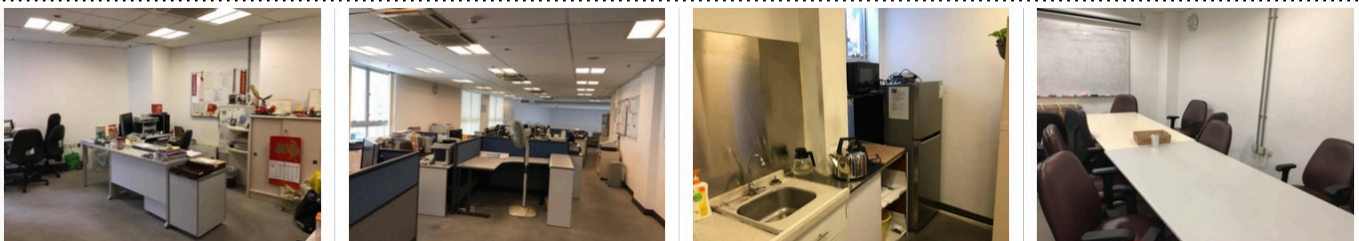


Figure 2. Sensors Location in the Green Office

Sensors were used in this study in order to **obtain the data of the IEQ** in the two offices respectively by sensing the temperature, humidity, carbon dioxide level, volatile organic compounds (VOCs) and dust particles. The data obtained can be acted as a complement to investigate the occupant behaviour and to discover that if the IAQ is different between the green building and the conventional building. **4 sensors** are proposed to be installed in each office, including the **head office** (private room), **open office**, **pantry** and **conference room**. The period of monitoring was two months from 23 January to 23 March and the real-time data was checked twice a week. A **bi-weekly IAQ report** was also provided to the corresponding offices, which

was posted on the notice board of each offices. After collecting all the data, the useful data was chosen, organised and analysed according to the objectives of this study. Figure 2 and 3 show the locations where the sensors were installed:

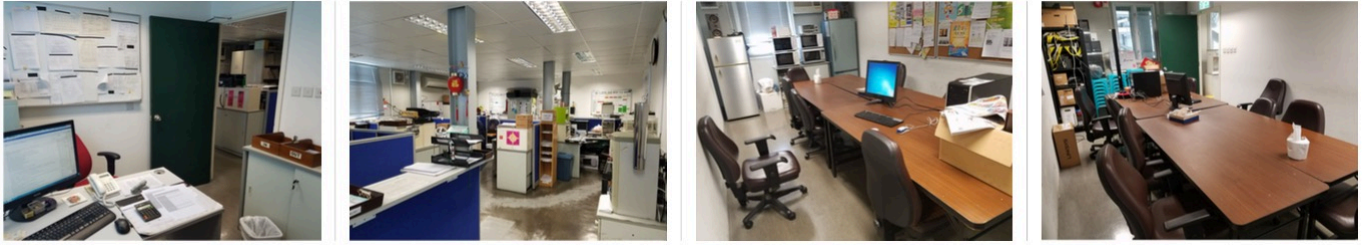


Figure 3. Sensors Location in the Conventional Office

4. Results and Discussion

In order to determine the objectives mentioned above, the following **hypothesis** will be tested.

1. Both real data set and occupant satisfaction with **IEQ** and **building performance in green building will be more acceptable** than that in the conventional building.
2. If the occupants have a **better acknowledgement** on IEQ and building energy and **providing real-time feedback** to them, their satisfaction rate will be affected and hence, they will be **more active to engage** in the building controls.
3. If occupants **understand and learn how to engage** in the building controls, **building energy can be saved** and their **workplace environment satisfaction can be elevated**.

4.1 Respondents Background Information

Totally 30 answered questionnaires were received from each office. Table 3 summarised the characteristics of respondents participated in the questionnaires from both the green and conventional offices. The characteristics vary in relation to the ages and location of the personal desk. The majority of respondents are male, stayed in the office 5 days or above per week, 7 to 9 hours per day and the motion was sitting.

Gender	Green Office					Conventional Office				
	Male	Female				Male	Female			
	80%	20%				87%	13%			
Age	18 - 29	30 - 39	40 - 49	50 - 59	60 or above	18 - 29	30 - 39	40 - 49	50 - 59	60 or above
	10%	27%	30%	30%	3%	20%	23%	30%	27%	0%
Time spent in the office per week	1 - 3 days	3 - 4 days	5 days or above			1 - 3 days	3 - 4 days	5 days or above		
	0%	7%	93%			3%	13%	84%		
Time spent in the office per day	1 - 3 hours	4 - 6 hours	7 - 9 hours	9 hours or above		1 - 3 hours	4 - 6 hours	7 - 9 hours	9 hours or above	
	0%	30%	60%	0%		13%	20%	63%	3%	
Location of the personal desk	Open office (core)	Open office (perimeter)	Private office (core)	Private office (perimeter)	Reception	Open office (core)	Open office (perimeter)	Private office (core)	Private office (perimeter)	Reception
	33%	43%	3%	10%	10%	30%	53%	10%	3%	3%
Motion in the office	Sitting	Standing	Walking			Sitting	Standing	Walking		
	87%	6%	7%			77%	7%	16%		

Table 3. Background Information of the Respondents

4.2 Real-time Data Set Obtained by the Sensors

By using the real-time data set obtained by the sensors in both offices, **four bi-weekly IAQ reports** were released to the corresponding occupants on 9 February, 23 February, 9 March and 23 March respectively. The reports were posted on the notice board in the offices so that all the occupants could read the information of it. The IAQ reports consist of **two components**, including (1) the **standard** of temperature range, humidity range, maximum amount of CO₂ concentration, chemicals and VoCs set by the Hong Kong Government; and (2) the **average value of those IAQ categories** in each area (private office, open office, pantry and conference room). Occupants could understand both IAQ standard and the IAQ in their offices thoroughly by reading the reports.

By looking at the IAQ data as a whole, it is noticeable that the **amount of chemicals and PM 2.5 in the green office was lower** than that of the conventional office, while the **amount of CO₂ in the conventional office is lower** than that of the green office.

The respective average amount of **chemicals** in the green and conventional office was 195 ppb and 219 ppb. Although chemicals amount in both offices did not meet the standard set by the Hong Kong Government (lower than 87 ppb), the **green office performed slightly better** in this aspect. The average amount of PM_{2.5} in the green and conventional office was 14.6 ug/m³ and 20 ug/m³ respectively. The best amount of **PM_{2.5}** set by the Hong Kong Government in the office should be lower than 20 ug/m³. In spite of the fact that both offices met the requirement, the **green office achieved a more satisfactory result** in this aspect. The average amount of **CO₂** in the green office and conventional office was 485.6 ppm and 447.2 ppm respectively. Even though both offices met the standard set by the government (less than 800 ppm), the **conventional office had a lower amount of CO₂** in the office. **Overall, the green office had a better performance in terms of IAQ**, which is similar to the result obtained in the previous studies.

4.3 Occupant Acknowledgement

There is a remarkable improvement of occupant acknowledgement on IAQ before and after the installation of sensors and the release of the bi-weekly IAQ reports. Figure 4 shows the samples of the bi-weekly reports posted in both offices. Before putting up the bi-weekly IAQ reports in both offices, none of the occupants knew the standard of the amount of PM 2.5 and chemicals set by the Hong Kong Government. However, after posting the bi-weekly IAQ reports in both offices, 92% of the occupants know these standards, which was a significant improvement. Less than half of the occupants (23%) knew that the IAQ in their offices was not good at all and 22% of the occupants thought the air in their offices was “very fresh” or “somewhat fresh” before the release of the bi-weekly IAQ reports. After the the release of the bi-weekly IAQ reports, none of the occupants thought that the air in their offices was “very fresh” or “somewhat fresh” since the real-time IAQ data indicated that the air in the offices was not satisfactory at all. However, the result was not that noticeable for the aspect of temperature. Although the occupants understood that the temperature in the offices were sometimes out of the range, their feelings on temperature conditions did not change much.



Figure 4. Samples of the Bi-weekly Reports in Both offices

4.4 Occupant Satisfaction Score on IEQ Categories

Because of the improved of the occupant acknowledgement, the occupant satisfaction rate changed significantly, especially in the conventional office.

Figure 5 and 6 show the result of the average satisfaction score on IEQ categories (overall, temperature, humidity and air quality) in the first and second questionnaire respectively.

In the first questionnaire (Figure 5), it is noticeable that occupants in the selected green building have a lower satisfaction with overall IEQ, especially on the aspects of temperature and air quality than that in the selected conventional building, which is different from the previous study related to this aspect: occupants in green buildings had a higher satisfaction with IEQ.

In the selected green building, 40% of occupants responded that they were somewhat dissatisfied with the overall environmental quality while 50% of occupants in the selected conventional said that they were somewhat satisfied with the overall environmental quality and only 7% of them were somewhat dissatisfied with this aspect. The satisfaction between the green building and conventional building in this part was divergent. For the occupant satisfaction with temperature and air quality, around 40% of the occupants in the selected green building stated that they were somewhat dissatisfied with the these aspects while around 40 % of the occupants in the conventional building were somewhat satisfied with only around 13% of occupants were somewhat dissatisfied.

In the second questionnaire (Figure 6), the occupant satisfaction rate dropped significantly in the conventional office while the occupant satisfaction rate only changed a little bit in the green office. Moreover, it is clear that the occupant satisfaction with air quality was lower than the other categories and it dropped sharply among the other IEQ categories. The occupant satisfaction rate on all IEQ categories in the green office this time was higher than that of the conventional building. For the occupant satisfaction with the overall quality and temperature, approximately 15% of occupants from the green office were more satisfy than that of the conventional office while roughly 5% of the occupant from the green office were more satisfied with the humidity and air quality.

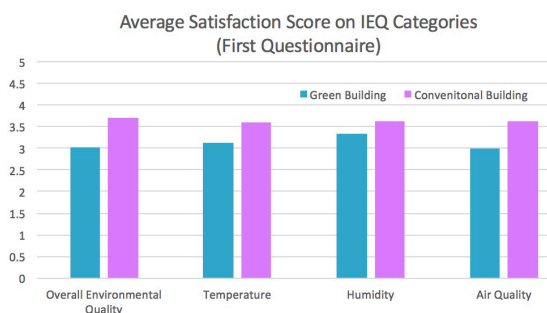


Figure 5. Average Satisfaction Score on IEQ Categories (1st)

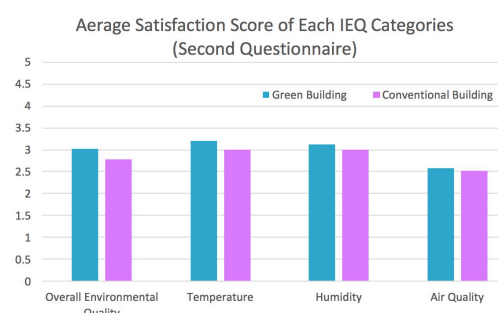


Figure 6. Average Satisfaction Score on IEQ Categories (2nd)

4.5 Occupant Feelings on IEQ Categories and Productivity

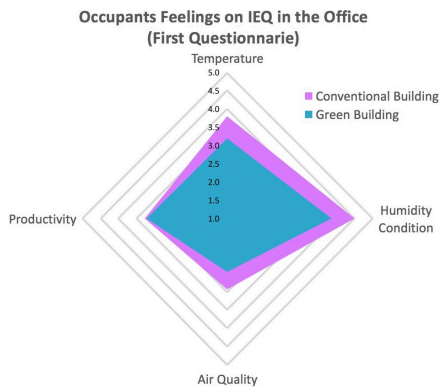


Figure 7. Occupant Feelings on IEQ Categories and Productivity (1st)

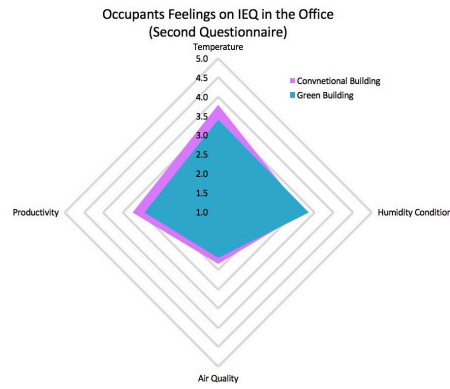


Figure 8. Occupant Feelings on IEQ Categories and Productivity (2nd)

who were dissatisfied with the temperature conditions claimed that the temperature in the office was too high, 60% of them felt hot in the office and only 40% were satisfied with the temperature conditions. For the occupants who were dissatisfied with the humidity condition, more occupants felt dry than those who felt humid in both offices. For the air quality, most of the occupants (77%) in the conventional building thought the air was fresh while only 33% of occupants in the green building thought the same thing, which is 2.3 times more. In spite of the occupant poor feelings with IEQ in the selected green building, the productivity rated by the occupants themselves were similar in both building. Most of them thought that their productivity were excellent (36.7%) and good (46.7% in green building and 53.3% in conventional building). Only a few of them thought that their productivity were poor or average. Although occupants in the green building had a lower IEQ satisfaction than that in the conventional building, the productivity rated by themselves did not have a huge difference, this can be indicated that the satisfaction with IEQ did not have a strong relationship with the productivity.

In the second questionnaire (Figure 8), same as the phenomenon of satisfaction rate in the previous section, the feeling score in the conventional office dropped in terms of temperature, humidity and air quality. Similar with the previous questionnaire, 40% of the occupants felt hot in the green office, which is 27% higher than those who felt hot in the conventional office. Compared with the previous questionnaire, occupants who felt “somewhat stuffy” from both offices increased, with 53% of the occupants from the conventional office and 60% of the occupants from the green office chose this answer. None of the occupants from both offices chose “very fresh” and “somewhat fresh”. For the productivity, 47% of the occupants from the conventional office chose “excellent” or above while only 30% of the occupants from the green office chose the same answer.

4.6 Occupant Feelings on IAQ Categories

Occupants Feeling in the Office (First Questionnaire) Occupants Feeling in the Office (Second Questionnaire)

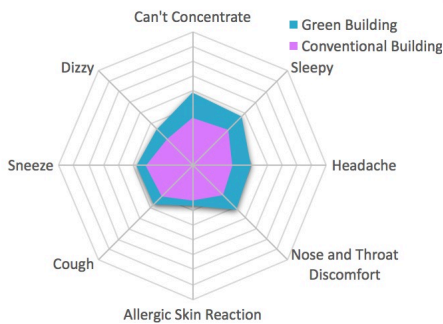


Figure 9. Occupant Feelings on IAQ Categories (1st)

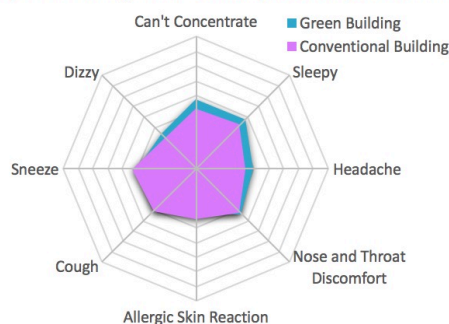


Figure 10. Occupant Feelings on IAQ Categories (2nd)

In the first questionnaire (Figure 9), it is clear that the occupants' feelings on IAQ categories in the conventional office are better than those in the green office, which means that the air quality in the conventional office might be more acceptable based on the review of the occupants. In the selected green office, 63% of occupants responded that they often/ sometimes could not concentrate and 60% of occupants often/ sometimes felt sleepy in the office, which may indicate that the CO₂ concentration in that office might too high. Although 63% of occupants said that their noses and throats often/ sometimes felt discomfort, most of them did not feel headache or have allergic skin reaction in the office, which may conclude that the amount of dust particles may be a bit higher than the standard. In spite of the fact that the majority of the respondents seldom/ never coughed, sneezed and felt dizzy in the office, the number of these respondents was lower than that in the conventional office.

However, in the second questionnaire (Figure 10), there is a significant change of feeling score in the conventional office, most of the categories become worse than before. The result of this questionnaire is more correlate to the real-time data obtained by the sensors. It is obvious that more occupants (around 11%) from the green office felt that they cannot concentrate, sleepy, headache and dizzy than those from the conventional office while more occupants (approximately 13 %) from the conventional office had allergic skin reaction and sneezed than those from the green office. The result from this questionnaire was correlated with the real time data obtained by the sensors: the average CO₂ concentration in the green office is higher than that in the conventional office while the amount of dust particles and VoCs in the conventional office were higher than that in the green office.

The improvement of the occupant acknowledgement not only affected the occupant satisfaction rate but also slightly affected their feelings on IEQ.

Figure 7 and 8 show the result of the average occupant feelings score on IEQ categories (temperature, humidity, air quality and productivity) in the first and second questionnaire respectively.

In the first questionnaire (Figure 7), it can be concluded that although the occupant satisfaction on IEQ in conventional building is higher than that in the green building, the productivity rated by themselves are similar. Most of the occupants in the selected green buildings

Occupant Acknowledgement also affected the occupant feelings on IAQ Categories. Each category indicate different symptoms of poor air quality. When CO₂ concentration is too high: Can't concentrate, Sleepy; When there are too many dust particles: Headache, Nose and throat discomfort, Allergic skin reaction; When there are too many VoCs: Cough, Sneezes, Dizzy. Figure 9 and 10 show the result of the average occupant feelings score on IAQ categories in the first and second questionnaire respectively.

4.7 ANOVA Test (First Questionnaire VS Second Questionnaire)

	Green Office				Conventional Office			
	Choice	Sig.	Choice	Sig.	Choice	Sig.	Choice	Sig.
IEQ Satisfaction Score	Overall Quality	1.000	Temperature	0.794	Overall Quality	0.000	Temperature	0.041
	Humidity	0.330	Air Quality	0.063	Humidity	0.013	Air Quality	0.000
IEQ Feelings Score	Temperature	0.610	Humidity	0.136	Temperature	1.000	Humidity	0.001
	Air Quality	0.184	Productivity	0.104	Air Quality	0.516	Productivity	0.871
IAQ Feelings Score	Can't Concentrate	0.714	Sleepy	0.603	Can't Concentrate	0.299	Sleepy	0.920
	Headache	1.000	Nose and Throat Discomfort	0.901	Headache	0.526	Nose and Throat Discomfort	0.809
	Allergic Skin Reaction	0.164	Cough	0.523	Allergic Skin Reaction	0.104	Cough	0.185
	Sneeze	0.541	Dizzy	0.707	Sneeze	0.129	Dizzy	0.430

Table 4. ANOVA Test Results on Each Answer (1st VS 2nd)

ANOVA testes were conducted on each choice in both the first and second questionnaire in order to analyse the variance of each response. Table 4 sums up the ANOVA test result of each choice.

The significance level was set to be 0.05. If the significance level was lower than 0.05, the responses were separated each other and the result was significant.

From Table 4, it is clear that **all ANOVA test results of "IEQ Satisfaction Score" in the conventional office were lower than 0.05**, which means that the **results obtained in the first questionnaire were separated from the results obtained in the second questionnaire and the results were significant** in this category.

However, the other ANOVA test results were higher than 0.05, which means that the results of "IAQ Feeling Score" and "IEQ Feeling Score" in both office and "IEQ Satisfaction Score" in the green office in the first questionnaire were not separated from the results obtained in the second questionnaire and the results were not significant.

4.8 Occupant Engagement - Building Energy & IEQ

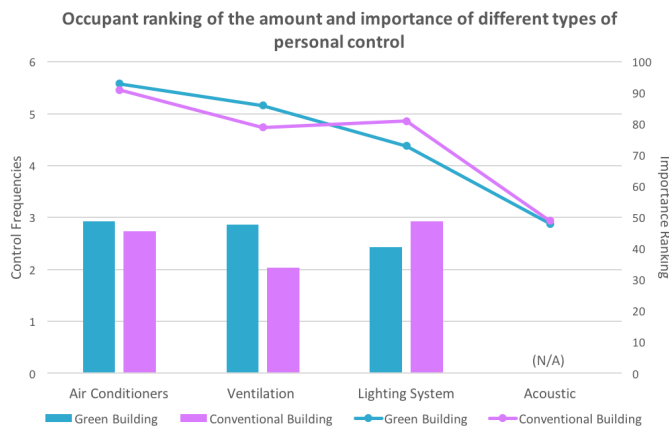


Figure 10. Occupant Ranking of the Amount and Importance of Different Types of Personal Control

For the IEQ aspect, when the occupants encountered different IEQ problems, only 28% of the occupants tried to solve those problems they faced while the majority of the occupants (72%) did not try to solve them, in which the ratio of occupants who did not try to solve the problems in the selected green building is higher. They believed that the problems were not serious enough (38%) and not their responsibilities (62%) to solve them. Among the occupants who tried to get the information on solving the problems, the most typical method is by their own knowledge (50%), followed by the internet (40%) and the experts (40%).

Figure 10 shows that **Thermal comfort was ranked the highest in both buildings in terms of control frequencies and importance of personal control**, with ventilation and lighting system a close second in green building and conventional respectively. In general, most of the occupants responded that noise control (acoustic) is the least important. Also, **occupants will control more on the system that they think it is more important**. Actually, the control

frequencies of the building controls by the occupants in both offices are quite similar. When asked to explain why they did not use the controls, the highest reason given in both buildings was "I don't need the control", which won a landslide victory (60%), followed by "the control doesn't exist" (14%). When asked to describe what kind of factors will affect their control on different system, most of them said that user-friendly was the most important (52%), followed by clear instructions (48%) and then accessibility (40%).

After the release of the bi-weekly IAQ reports (occupant acknowledgement), when the occupants knew that the IAQ was not good at all, **most of them (70%) intended to improve the IAQ** in their offices in which **air quality** was the category they **would like to improve most** while thermal comfort (temperature) was the second category they would like to improve.

For the **building energy** aspect, most of the respondents from both buildings were **willing to participate in eco-friendly activities** to make the office a better place for working. The main reason that drives them to engaged in the building controls related to building energy is that they wanted to save the earth and lower the carbon dioxide emission, following by the provision of better environment to the next generation (55%) and lower the cost of electricity bill (41%).

After the release of the bi-weekly IAQ reports (occupant acknowledgement), **68% of the occupants** responded in the second questionnaire that they **had changed their behaviours** on building energy by turning off the lights, computers and air-conditioners.

4.9 The Willingness of Occupants on Learning about Building Energy & IEQ

The **majority of the respondents** from both conventional and green office were **interested in receiving more information about IEQ and building energy** and also **willing to learn more** about these two aspects.

Regarding the interests in receiving more information about IEQ and building energy, about 70% of the occupants from both offices were interested. Overall, the number of occupants who wanted to receive more information about IEQ is slightly more than

those who wanted to receive more information about building energy. This may be due to the occupants will be directly affected by IEQ instead of building energy.

In the aspect of the willingness on learning more on building controls related to building energy, 77% of the occupants in the selected green building and 90% of the occupants in the selected conventional building were willing to learn more on the building controls related to energy saving. Generally, the respondents from both buildings were willing to participate in eco-friendly activities to make the office a better place for working.

Most of the occupants (90%) from both buildings thought that they will be profit from having a better workplace environmental quality. They thought they will have a better working performance and productivity (62%), more comfortable (65%) and reduce health care cost (50%) but not reduce absence (7%) when having a better workplace environmental quality. On the other hand, most of the occupants (93%) are willing to improve the workplace environmental quality is not good enough.

4.10 Discussion

By comparing the result obtained from the first and second questionnaire, there is a huge difference of the satisfaction rate on IEQ categories. In the first questionnaire, the occupants satisfaction rate of all categories from the conventional office was higher than that from the green office while in the second questionnaire, the occupants satisfaction rate from the conventional office dropped.

In the first questionnaire, by comparing the questionnaire results between the green office and conventional office, the occupant satisfaction rate in the green office was not higher than that in the conventional office. This result verified that people should not be too positive on green buildings [31, 32]. The investors and developers should aware that not all the green buildings perform better than the conventional buildings when they engage in the green design and construction.

Nevertheless, after providing the bi-weekly IAQ reports by using the real-time data obtained by the sensors, the occupant satisfaction rate in the green building was higher than that in the conventional office.

There were only two changes during the gap between the distribution of two questionnaires. The first one was the change of the weather and the other one was the installation of sensors with the put up of the bi-weekly IAQ reports. For the weather conditions, the first questionnaire was conducted in summer while the second questionnaire was conducted in winter. However, both green office and conventional office turned on the air-conditioners all year round and hence, the change in weather condition was not a main phenomenon to be considered. The second change was the acknowledgement of the occupants. The occupant from both green offices and conventional offices could understand the IAQ of their offices through the IAQ reports twice a week. The IAQ reports were prepared by using the real-time data obtained by the sensors installed in the offices. After this change in both offices, the occupants satisfaction rate with air quality of both offices dropped significantly. On top of that, the occupant satisfaction rate with temperature and humidity from the conventional office dropped remarkably. According to the real time data set, the air quality in both offices was not really excellent, especially in the amount of chemicals and VoCs. The occupants may be affected by this data and hence, none of them chose "very fresh" and "somewhat fresh" during the second questionnaire when asked to describe the air quality of their offices.

According to the result from the ANOVA test, there is a significant change between the first and second questionnaire in the category of "IEQ Satisfaction Score" in the conventional office but not in the green building. The occupants in the green office might have a higher expectation on IEQ since there are lots of paper claiming that green buildings are better than that of the conventional buildings in terms of both energy efficient and occupant satisfaction [16, 17, 26, 27, 28, 29, 30]. Therefore, before the release of the bi-weekly IAQ reports (occupant acknowledgement), they might not really satisfy with the working environment because of the high expectation and the satisfaction rate was lower than that in the conventional office. However, after the release of the bi-weekly IAQ reports (occupant acknowledgement), the occupants realised that the air quality was quite acceptable and even better than the air quality in the conventional office. The occupant satisfaction was then stable or improved a little bit in terms of the overall quality, temperature and humidity conditions. For the occupants in the conventional office, they might not expect much on IEQ because they were working in a conventional office and hence, they were satisfied before the release of the bi-weekly IAQ reports (occupant acknowledgement). However, the occupants realised that the IEQ was not of high quality and the satisfaction rate dropped significantly.

Although the the occupant satisfaction rate in the green office was higher than that in the conventional office, a huge difference of occupant satisfaction rate between the green building and conventional building cannot be perceived successfully in this study. This might be due to the small sample size and the short period of observation. The sample size should be increased in order to obtain a more accurate subjective result while the period of the installation of sensors should also be increased (both summer and winter). Further detailed study may be needed for this aspect.

Apart from the satisfaction with the IEQ, for the occupant engagement, in the first questionnaire, only 20% of the occupants had tried to solve the IEQ problem while in the second questionnaire, 44% of the occupants had tried to solve the IEQ problem. In addition, when the occupants knew that the IEQ was not good at all, most of them intended to improve the IEQ in their offices in which air quality was the category they would like to improve most. Apart from that, more than half of the occupants responded in the second questionnaire that they had changed their behaviours on building energy by turning off the lights, computers and air-conditioners.

This can be concluded that occupant acknowledgement not only affected the occupants satisfaction rate but also the willingness of occupants on engaging regarding the IEQ and building energy to a large extent.

5. Conclusion

In conclusion, two questionnaires (before and after the installation of sensors) based on the occupant engagement and occupant acknowledgement related to building energy saving and IEQ was conducted in both green building and conventional building. Real time IAQ data set was obtained from the sensors for two months and bi-weekly IAQ reports were also provided in both offices. There was sufficient evidence to support one of the hypotheses that if the occupants have a better acknowledgement on IEQ and building energy and providing real-time feedback to them, their satisfaction rate will be affected and hence, more active to engage in the building controls. However, a huge difference of occupant satisfaction rate between the green building and conventional building cannot be perceived successfully in this study. Therefore, further study with a larger sample size and longer period of the observation by the sensors is suggested to be conducted in the future.

6. Acknowledgement

I am grateful to Dr. Koo Choongwan, my supervisor, for the assistance with providing the real-time sensors for observation and comments that greatly improve the quality of this research paper. I also thank Mr. Wong Kai Chung for the support on the offices recruitment.

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I, Wong Wing Yin, Student no. 16004, certify that this paper is all my own work unless where referenced or acknowledged.

Wong Wing Yin

Author	Methodology	Building Sector	Building Type	Location	Results/ Finding
Occupant Engagement on IEQ					
Jorn Toftum (2009) [18]	Analysis via database	N/A	N/A	Denmark	• Although there were lots of sensors developed for full automated IEQ control, occupants should have degree of control themselves of their IEQ
Kamaruzzaman et al. (2010) [8]	Survey	Offices, School, Hotel	Historical	Malaysia	• The IEQ could be significantly improved if occupants engaged in the controls related to IEQ since the enhancement of the IEQ was based on the occupants' needs
Ahn and Park (2016) [19]	Real time monitoring (7 people only)	Laboratory room	Conventional	Korea	• IEQ was influenced by 'only a few' occupants in the room who were willing to control the environment
Occupant Engagement on Energy Saving					
Hoes et al. (2009) [6]	USSU model, SHOCC model	150 offices	N/A	Netherlands	• User behaviour was an important aspect in building energy performance
Ouyang and Hoka (2009) [20]	Survey	Residential	Conventional	China	• By improving occupant engagement through energy-education, 10% more of household energy could be saved
Masoso and Grobler (2009) [11]	Energy auditing equipment	Commercial	Conventional	Africa	• During non-working hours, more energy was used compared with the working hours since the occupants didn't turn off the equipment when they left the offices
Yu et al. (2011) [21]	Cluster analysis, case study	Residential	Conventional	Japan	• By improving the occupant behaviour, there was potential on building energy saving
Hong and Lin (2013) [10]	Energy Plus, Survey	Offices	Conventional	US	• The impact of occupant engagement on building energy use was significant • A simple work style consumed up to 50% less energy while wasteful work style consumed up to 90% more energy
Aghemo et al. (2014) [22]	Survey, Lighting sensors	10 offices	Building Automation	Italy	• With the automatic lighting system (with sensors), there was potential on energy savings and the occupant satisfaction could be increased
Sun and Hong (2017) [23]	BPS Program, ECMs	Office	Conventional	US	• There was a significant influence on building energy used according to the occupant engagement, energy spenders consumed up to 200% more energy
Perterson et al. (2007) [14]	Online survey, Automated data monitoring system	With Feedback	Student hall	US	• By providing real-time resource feedback and education on electricity uses to the occupants, 55% electricity use could be reduced
RK Jain et al. (2013) [24]	Provide eco-feedback (Emails)		Residential	US	• Eco-feedback system could have a significant impact on energy consumption engagement
Agha-Hossein et al. (2015) [25]	Online survey, Posting Posters (Persuasive feedback)		Office, Student hall	UK	• After posting the posters, there was a clear change in behaviour immediately but it only lasted of a few days. Providing a simple immediate acknowledgement/ award to occupants could be effective in motivating pro-environmental behaviour
Occupant Acknowledgement					
Day and Gunderson (2014) [13]	Expert interviews, Survey, Follow-up occupant interviews	56 buildings	N/A	Mainly in US	• Occupants who understood how to operate the controls related to comfort had a higher satisfaction with the environment than those who did not know how to use the controls • The productivity of occupants could also be elevated
Green Buildings VS Conventional Building					
Judith Heerwagen (2000) [26]	Research paper	N/A	Green	N/A	• Green buildings could provide cost reduction benefits, such as reduce in electricity cost, potential to improve IAQ and increase the occupants' satisfaction compared with non-green building
S Abbaszadeh et al. (2006) [16]	Survey	Offices	Conventional & Green	US	• Occupants in green buildings had a higher satisfaction on IEQ compared with non-green building especially on air quality and thermal comfort
Singh et al. (2010) [17]	Survey (Pre-move and Post-move)	Offices	Conventional to Green	US	• Green buildings could not only improved occupants' health and well-being, but also their productivity
Liang et al. (2013) [27]	Survey	Offices	Conventional & Green	Taiwan	• The overall IEQ satisfaction of occupants in green buildings were higher than the occupants in the conventional buildings
Gou, D Prasad and Lau (2013) [28]	BUS Occupant Survey	Offices	Conventional & Green	China	• Some green buildings had a higher satisfaction comfort while some green buildings had a lower satisfaction and comfort but overall satisfaction scores for green buildings were still higher • Occupants in green buildings were more forgiving of their building
Pei et al. (2014) [29]	Survey	Offices	Conventional & Green	China	• Green buildings in China had a significantly higher satisfaction level than the conventional buildings in terms of IEQ: thermal, visual, acoustic environment, IAQ and the overall environment
Lin et al. (2016) [30]	Survey	Offices	Green	China	• Regarding to occupant satisfaction about IEQ and building services performance, occupants in green buildings had a higher satisfactory level than those in the conventional building • Especially in the field of thermal comfort, IAQ and facilities

Table 1. Literature Reviews Table