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### INDOOR ENVIRONMENTAL QUALITY FOR REBUILDING PLACE IN COLONIAL COMMERCIAL BUILDINGS IN PENANG

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#### *Abstract*

The practice of adaptive reuse is a method of building conservation to maintain the physical property of the building with significant values, such as heritage-listed buildings. This paper studies the strategies for rebuilding places in colonial commercial building in George Town, Penang. The strategies are assessed according to the four main parameters of Indoor Environmental Quality (IEQ) (thermal, lighting, noise, and air quality). Other additional parameters are space planning and layout, office furniture, as well as building maintenance and cleanliness. Currently, there are numbers of heritage buildings in George Town which are in the state of poor maintenance according to the local authorities. Based on the building observation conducted, there were significant changes in the buildings themselves to suit the current purpose, particularly on the floor plan and the lighting quality. These changes were significantly affecting the quality of life to those who are occupying the buildings studied. Poor IEQ level also contributes to the occupants' well-being, which was shown by the satisfaction survey conducted. Hence, rebuilding place in heritage building needs to be considered to obtain a habitable space for the building occupants, in the form of intangible and tangible elements according to the IEQ standard. The strategies to rebuilding the places include the regularity of the maintenance, practising adaptive reuse based on the guidelines, complying with the Malaysia Green Building Index (GBI) rating tool for heritage buildings, and applying indoor vegetation to promote the biophilia experience as well as to increase the aesthetical value of the building.

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**Keywords:** Adaptive reuse, indoor environmental quality (IEQ), colonial buildings, rebuilding places.



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## 1. Introduction

The cause and effect of the indoor environment to the occupants' well-being has been studied for more than a decade. Environmental and psychosocial stressors are known to caused short and long-term effects, such as decreasing productivity level, Sick Building Syndrome (SBS) and other building-related illness. Previous studies also associated the indoor building conditions with mental health effects, obesity, respiratory disease, and other long-term illness ( Bluyssen, Janssen, van den Brink, & de Kluizenaar, 2011; Al Horr et al., 2016a; Xuan, 2018). The quality of the indoor environment *per se* is considered as the environmental stressors, i.e. thermal comfort, lighting, noise and Indoor Air Quality (IAQ). Meanwhile, the psychosocial stressors are related to the social environment, such as crowding, working conditions, social status and other human-related stressors (Bluyssen et al., 2011).

It has been studied by previous researchers that the physical building condition strongly affects the occupants' satisfaction (Bluyssen, 2013; Prihatmanti & Bahauddin, 2013; Al Horr et al., 2016b). In this modern era, people spend more than 90% in the indoor environment and it is important to understand that the condition in the indoor environment is less acceptable, in terms of the thermal comfort, lighting quality, noise exposure, and the indoor air quality. Buildings that have been undergone functional changes are at risk for having poor Indoor Environmental Quality (IEQ). These conditions commonly happened in adaptively reused buildings, as one of the ways to keep the building occupied (Prihatmanti & Bahauddin, 2014). This condition would be worse if the building was converted to be a tight building and relied on the air conditioning system. Unfortunately, not all designers and engineers are aware of this issue. It needs a feasible strategy to ensure the occupants' well-being after the buildings being altered. Hence, this paper aims to highlight the indoor environmental conditions of heritage-listed buildings to create a habitable space for the occupants.

### 1.1.The importance of Indoor Environmental Quality (IEQ)

As mentioned earlier, the indoor environment could be detrimental to the occupants' well-being. The anthropogenic effects due to the human activities have resulted in changes in the climate; therefore, artificial lighting, air conditioning system and other mechanical ventilation devices were installed to create a comfortable space for the occupants. This is crucial since the building occupants, particularly those who are working in an enclosed office environment. The office is one of the most visible indexes of economic activities, social and technological progress. Hence, these workers are required to be productive and healthy. In this research, open plan type offices were selected as the case studies. Open office is created to obtain more interaction and communications among the workers. However, this type of workplace could be problematic due to the indoor environment stressors. The tight building condition has made the occupants more likely exposed to the poor IEQ (Bluyssen et al., 2011; Kamaruzzaman et al., 2018).

Malaysia Green Building Index (GBI) which established by the Malaysia Green Building Confederation (2018) stated that IEQ is an important parameter that is included in the Non-Residential Existing Building (NREB): Historic Building rating tool. It contributes to the third biggest points which need to be fulfilled (refer to Table 1). As tabulated in Table 2, there are four parameters of IEQ as

assessed by the GBI. Those are (a) Air Quality, (b) Thermal Comfort, (c) Lighting, Visual & Acoustic Comfort, (d) Verification.

**Table 01.** NREB: Historic Building Rating Tool Assessment Criteria and Points

Assessment Criteria	Maximum Assessment Points
Energy Efficiency (EE)	24
<b>Indoor Environmental Quality (EQ)</b>	<b>16</b>
Sustainable Conservation & Management (SC)	15
Material & Resources (MR)	20
Water Efficiency (WE)	11
Innovation (IN)	14
Total Score	100

**Table 02.** Indoor Environmental Quality Assessment Details

IEQ Parameters	Details
Air quality	Minimum IAQ Performance
	Environmental Tobacco-Smoke (ETS) Control
	Indoor Air Pollutants
	Mould Prevention
Thermal comfort	Controllability of systems
	Daylighting
	Daylight glare control
	Electric lighting levels
	Visual comfort
	Acoustic comfort
Verification	IAQ Before/During Occupancy
	Occupancy Comfort Survey: Verification

▪ Air quality

A previous study conducted by Prihatmanti and Bahauddin, (2014), the result showed that air conditioned buildings tend to have poor IAQ level. Based on the survey conducted, it was in alarming conditions. During their working hours, the occupants were exposed to indoor airborne chemical pollutants such as carbon monoxide (CO), carbon dioxide (CO<sub>2</sub>), formaldehyde (HCHO/CH<sub>2</sub>O), and other Volatile Organic Compounds (VOCs). Moreover, they were also exposed to biological pollutants (fungi) from the dampness on the building fabrics and Particulate Matter (PM) or dust. One of the feasible strategies to obtain good air quality is by increasing the airflow to eliminate the airborne pollutants and to control the humidity. High level of humidity will cause mould development of the building fabrics. Exposure to the tobacco and smoke (Environmental Tobacco-Smoke/ETS) must be eliminated in all indoor environment to keep the air less polluted.

▪ Thermal comfort

Originally, heritage buildings were meant to be built to adapt with the local climate. As the temperature rises since a decade ago, Air Conditioner and Mechanical Ventilation (ACMV) are required to achieve a thermally comfortable indoor environment. The GBI NREB: Historical Building rating tool requires any air conditioner and other mechanical ventilation to be easily controlled by the occupants. This is to ensure that the occupants are in the state of a thermally comfortable indoor environment.

▪ Lighting, visual & acoustic comfort

Good lighting could be defined as having adequate lighting in the appropriate place. Previous studies discovered that indoor lighting quality has a positive correlation with employee's satisfaction and job performance (Osterhaus, 2005; Choi, Loftness, & Aziz, 2012). Appropriate quality and design of lightings are compulsory to provide the occupants' safety as well as to fulfil the conditions for various tasks. Obstructions in the openings could decrease the illuminance level inside the building. Changes in building layout by adding full-height partitions also affecting the light quality (Susan & Prihatmanti, 2017). Regardless of the alterations conducted, indoor illuminance level should be sufficient to prevent any visual discomfort. Acoustic comfort tends to be ignored compared to lighting and visual comfort. Many people did not realize that poor acoustics can cause great psychological and physiological dissatisfaction. Almost 30% of private office occupants agreed that acoustic quality is affecting their working productivity by interfering their ability to complete their tasks. According to them, irrelevant speech disrupts memory and affecting the concentration when in high workload. However, some occupants are more satisfied in an open office environment compare to those who are in working in a cubicle with noise and speech privacy Jensen, Arens, & Zagreus, 2005; Lee, 2010).

▪ Verification

The most effective way to investigate the occupants' satisfaction is by using a survey. It allows to objectively understand the performance of buildings and also helps to prioritise the steps needed to improve occupant satisfaction and workplace productivity. The GBI NREB: Historical Building rating tool also requires the occupancy comfort survey as well as the IAQ before and during occupancy. The Center of Built Environment (CBE) which was established by the University of California since 2000 has developed a web-based occupant satisfaction survey which covered the 9 key factors of the indoor environment that need to be assessed. Those are the general building, air quality, lighting, general workspace, maintenance, office furnishings, acoustic quality, thermal comfort, and office layout (Center for Built Environment, 2019).

## 2. Problem Statement

This research focuses on the IEQ condition in the buildings that have been adaptively reused into a modern office space in George Town, Penang. Due to its historical background, there are many heritage buildings with unique diversities as evidence of a multi-cultural and historical trading town in South East Asia. These varieties of cultural diversities have created a scope of remarkable values which embodied on the architecture and the built environment. Based on that, George Town was nominated as the UNESCO World Heritage Site because of its Outstanding Universal Value (OUV), criteria (ii), (iii), (iv). By that, the buildings within the World Heritage Site, both core and buffer zones, are ought to be preserved in an appropriate method in order to retain the World Heritage Site status which was inscribed since 2008. Nevertheless, after the inscription, George Town has been facing a crucial problem in heritage conservation practice. Regardless of the cultural significances, many of the heritage buildings are not well-maintained, being left abandoned, damaged and finally, they are demolished to be replaced into new properties.

Heritage buildings are legacy from the past that needs to be conserved to prevent from being lost forever. One conservation method that promotes sustainability is by adaptive reusing it. By adapting the old building into a new purpose, it helps to reduce the demand for virgin materials as well as reducing the carbon footprint. This is also agreed by Bullen (2007) and Kincaid (2002) that adaptive reuse is considered as the most sustainable conservation practice, as it involves physical, economical, and environmental aspects. However, adaptive reusing heritage building requires a high cost for the refurbishments (Ball, 2002). Due to the cost issue, the changes conducted are at risk in neglecting the occupants' comfort. Building occupants are compulsory to be comfortable and healthy while occupying the building, as required by the occupants' satisfaction survey by the GBI NREB: Historic Building assessment tool.

### 3. Research Questions

In this study, the research questions are as follows:

- What are the contributing indoor environmental factors that cause the occupants' dissatisfaction in adaptive reused buildings?
- What are the possible strategies to rebuilding place while maintaining the occupants' satisfaction in adaptive reused heritage buildings?

### 4. Purpose of the Study

Based on the problem statement, this study aims to investigate the quality of the indoor environment in the selected Colonial commercial heritage buildings which are located within the UNESCO World Heritage Site, George Town, Penang.

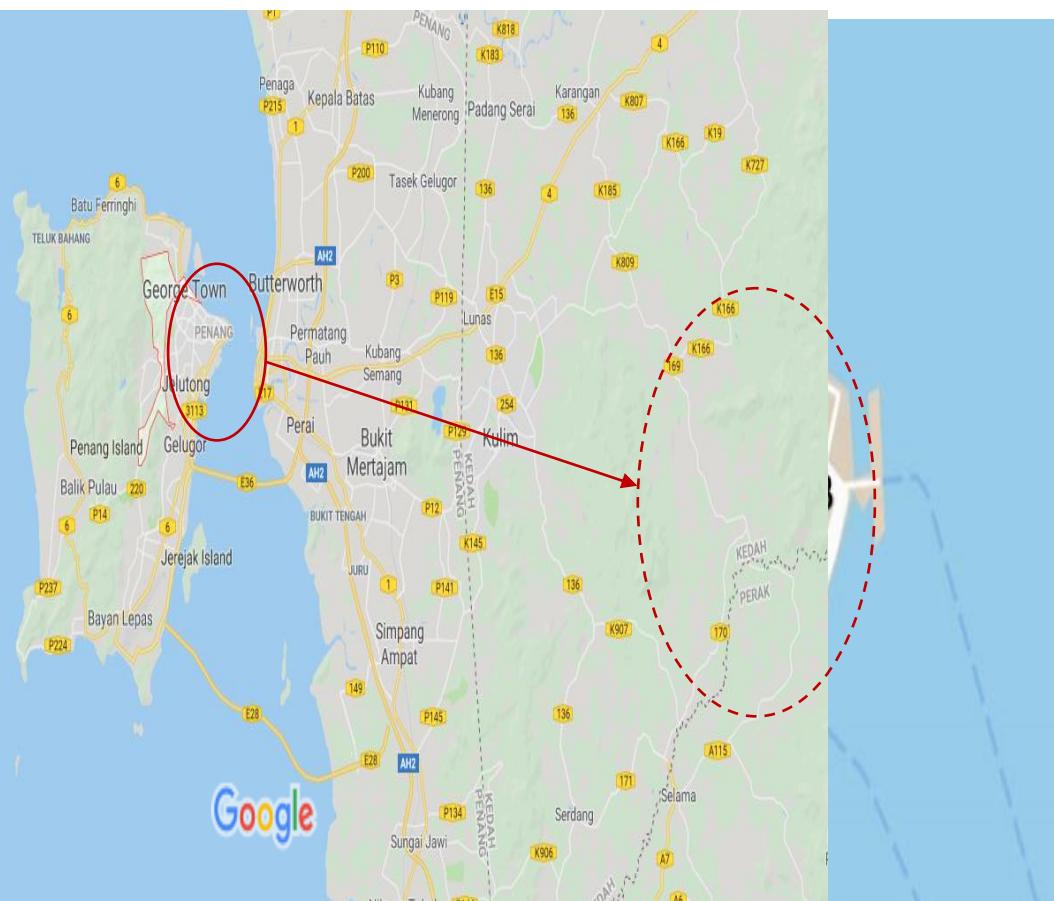
### 5. Research Methods

The problems associated with the indoor environment's dissatisfaction in heritage buildings are discussed in this paper. This study is intended to determine the feedback from the occupants who are occupying the studied adaptive reused buildings. The survey questions focused on the satisfaction level in the air-conditioned working environment during office hours.

#### 5.1. Selection of the case studies

Considering the feasibilities, there were four British colonial heritage buildings selected in this research. These buildings were selected according to the similarities in terms of the building function, materials, age, British Colonial architectural styles, types of ACMV installed, and occupied by the government agency. All of the studied buildings were gazetted either as Category I or II based on Malaysia's National Heritage Act (Act 645) and located inside the Core Zone of the UNESCO World Heritage Site in George Town, Penang (illustrated in Figure 1). To maintain its anonymity, these buildings were labelled as building A, B, C, and D.

## George Town



### ■ Building A

This building was categorised by the Malaysia Antiquities Act 1976 as a Category I building. It was constructed between the year 1900-1903 and previously it was an administrative office of the British government. Currently, Penang Municipal Council is located in this building.

### ■ Building B

This building was built in 1907 and listed under Category II building due to its antiquity, history, as well as the cultural significances. In the past, this double story building was functioned as a part of the British administrator office.

### ■ Building C

This corner building was built in 1890 and gazetted as the Category II heritage building according to the Malaysia National Heritage Act (Act 645). In the past, this double story building serves as the administrator of the police department.

### ■ Building D

This building has remained the same purpose since it was first constructed in 1908. Therefore, it has minimum interventions on the interior layout. The Malaysian government gazetted this building as a Category I due to the authenticity of its historic, cultural, and artistic values.

### 5.2. Occupants' satisfaction survey

The satisfaction survey was assessed by a self-administered questionnaire distributed to the occupants of the studied buildings during the office hour (N=88). The questions were adopted from the Centre for the Built Environment, University of California and focusing on the satisfaction of the thermal comfort, visual comfort, noise, air quality, personal workspace, and the overall of the indoor environment. The respondents' demographic profile is tabulated in Table 3. The male and female respondents are almost equal in numbers and more than 59% they are in their productive years. As much as 45.5% of the respondents have been working for more than 5 years and more than 79% have been occupying their current workspace.

**Table 03.** Respondents' demographic profile

	Gender		Age (year)				Working duration at the present office (year)				Working duration at present workspace (month)			
	Male	Female	<25	25-39	40-55	>55	<1	1-2	3-5	>5	<3	4-6	7-12	>12
N	42	46	9	52	24	3	14	14	20	40	5	4	9	70
%	47.7	52.3	10.2	59.1	27.3	3.4	15.9	15.9	22.7	45.5	5.7	4.5	47.7	79.5

## 6. Findings

According to the occupants' satisfaction survey that has been conducted, it was discovered that the occupants on the studied buildings showed their dissatisfactions towards their workplaces. All of the studied buildings were adapted into modern offices to accommodate the current demand. Retrofitting allows these buildings to be revitalised in different forms. However, these revitalisations had brought up new issues regarding the indoor environment condition, including the office furnishing, interior layout, as well as the cleanliness and maintenance issue. The occupants' dissatisfactions result is listed in Table 4 as follows.

**Table 04.** Occupants' dissatisfaction result

		Variables	N	%
Thermal comfort	Dissatisfied with the air temperature	27	30.7	
	Dissatisfied with the airflow speed	36	40.9	
	The thermal comfort does not enhance work	36	40.9	
Lighting and visual comfort	Dissatisfied with the amount of light	21	23.9	
	Dissatisfied with the lighting visual comfort	23	26.1	
	The light is not bright enough	37	42	
	The lighting quality does not enhance the work	14	15.9	
Acoustic comfort	Dissatisfied with the noise level	31	35.2	
	Dissatisfied with the sound privacy	31	35.2	
	Dissatisfied with people overhearing my conversation	18	20.5	
	The acoustic quality does not enhance work	9	10.2	
Office layout and space planning	Dissatisfied with the amount of individual work and storage	54	61.4	
	Dissatisfied with the visual privacy level	50	56.8	
	Dissatisfied with the office layout	52	59.1	
	Dissatisfied with the personal workspace	33	37.5	
	Personal workspace does not enhance work	21	23.9	

Office furniture	Dissatisfied with the office furnishing comfort	44	50
	Dissatisfied with the ability in adjusting the furniture	36	40.9
	Dissatisfied with the colours and texture of the office furniture	46	52.3
	The office furnishing does not enhance work	38	43.2
Cleanliness and maintenance	Dissatisfied with the general cleanliness	39	44.3
	Dissatisfied with the cleaning service	37	42
	Cleanliness and maintenance does not enhance work productivity	24	27.3
Overall of indoor the environment	The indoor environment condition does not increase productivity	24	27.3

Based on the survey, more than 50% of the respondents were dissatisfied with the office layout arrangement and space planning, as well as their office furniture. The amount of individual work and storage has the highest level of dissatisfaction (61.4%, N=54), followed by the dissatisfaction with the office layout (59.1%, N=52) and dissatisfied with the visual privacy level (56.8%, N=50). The condition of the office furniture also created dissatisfactions among the building occupants. There are 52.3% (N=46) dissatisfied occupants regarding the colours and texture of the office furniture and 50% (N=44) of them also dissatisfied with the office furnishing comfort. As much as 40.9% (N=36) of the occupants were unable to adjust their office furniture, hence they agreed that the office furnishing provided by the employer did not enhance their work (43.2%, N=38).

Building maintenance and cleanliness also contribute to the dissatisfactions of the building occupants. They were dissatisfied with the performance of the cleaning service provided (42%, N=37) and the general cleanliness of their workplace (44.3%, N=39). Moreover, the lighting quality was below their expectation. As much as 42% (N=37) of the occupants felt that the light was not bright enough. This caused by the blocked windows on the buildings studied due to the air conditioning system installation. Although the buildings studied are fully air-conditioned, 40.9% (N=36) of the occupants were dissatisfied with the airflow speed. They agreed that they are not thermally comfortable during the working hours and therefore, their working performance was not enhanced by the thermal condition. Another issue to highlight is the controllability of the air conditioning and mechanical ventilation system. Building A, B, and C are using the centralised air conditioning system; therefore, they have limited access to control the temperature. These dissatisfactions experienced by the occupants will reduce the work performance and affecting the productivity level.

Despite being adaptively reused, building occupants require a conducive indoor environment condition that could fully support the current demand and modern technologies, such as paper-based tasks and computer-intensive activities. This is also emphasised by Choi et al., (2012), stated that the occupant's physiological characteristics are strongly affecting their satisfaction towards their indoor environment. It has been studied that the indoor environmental design *per se* influenced the overall well-being of the building occupants. In a long-term, it will also affect the quality of life. To enhance the quality of life in their workplace, the availability of indoor plants also contributes to the visual comfort to the building occupants. A previous study conducted by Bringslimark, Hartig, and Patil, (2009) agreed that indoor vegetation could minimise stress as well as increase pain tolerance. Moreover, other researchers also stated that viewing nature could reduce stress and discomfort symptoms, improve human mood and emotions, as well as to enhance the biophilia experience (Adachi, Rohde, & Kendle, 2000;

Chang & Chen, 2005). Hence, by having nature in buildings, it will provide positive impacts on human well-being, psychologically and physiologically.

## 7. Conclusion

Adaptive reuse is one of the ways to extend the building's life with its historical atmosphere and cultural significances from the past to the next generation. However, there are several things to consider when retrofitting heritage buildings with modern function. It needs to accommodate modern needs while maintaining the occupants' comfort. The condition of the indoor environment must be fully considered to create a habitable workplace. People spend more than 90% of their life indoors and it is important to understand that the IEQ is significantly affecting their well-being. In this study, after the buildings have been adaptively reused into modern offices, there were many new issues need to be highlighted.

Based on the occupants' satisfaction survey, they were dissatisfied with the IEQ elements in their workplace. The space planning and the arrangement of the office furniture were also not enhancing their work performance. This condition made worse with the irregularity of the building maintenance and cleaning schedule. It could be concluded that the improper practice of adaptive reuse could create an inhabitable workplace. In the long term, it could be a potential loss for the company due to the decreasing work performance. Creating a habitable space based on the occupants' satisfaction survey is one of the feasible strategies for rebuilding places in adaptively reused heritage buildings. Other strategies are practising the adaptive reuse based on the guidelines, complying the newly retrofitted building according to the GBI NREB: Historical Tool, and applying indoor vegetation. This can maximise the building life to retain the World Heritage Site status as well as creating comfortable workplaces.

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