A CORRELATION STUDY BETWEEN INDOOR ENVIRONMENTAL QUALITY AND WORK PRODUCTIVITY IN MALAYSIA

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A project report submitted in partial fulfilment of the requirements for the award of Master of Project Management

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DECLARATION

I hereby declare that this project report is based on my original work except for citations and quotations which have been duly acknowledged. I also declare that it has not been previously and concurrently submitted for any other degree or award at UTAR or other institutions.

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APPROVAL FOR SUBMISSION

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ABSTRACT

Indoor environmental quality (IEQ) is a major factor contributing to the health, comfort, and well-being of building occupants. IEQ are broadly divided into four categories including: thermal comfort, indoor air quality (IAQ), visual comfort, and thermal comfort. Meanwhile, work productivity is the primary indicator of an organization's performance. Business owners strive to acquire productive workers for maximum profit generation. Existing studies found that there was correlation between IEQ satisfaction and work productivity (Mujan, et al., 2019; Ganesh, et al., 2021). Therefore, this study aims to further explore the correlation between IEQ and work productivity in office buildings in Klang Valley, Malaysia. Questionnaire surveys were distributed to office occupants in January 2022. Next, statistical analyses were performed using IBM SPSS Statistics 26 to process raw data into useful statistics. Descriptive statistics showed that office occupants in Klang were generally satisfied with the IEQ conditions in their workplace. Besides, they were known to have high work productivity. Spearman's correlation test was also conducted to investigate the correlation between IEQ and work productivity. Spearman's results showed that the IEQ parameters had strong and positive correlation with work productivity. Acoustic comfort had the strongest correlation with work productivity followed by visual comfort, IAQ, and thermal comfort. With these findings, the author wishes to create awareness to building designers, policy makers, and business owners regarding the importance of IEQ on work productivity, and therefore, to contribute effort in improving office IEQ.

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LIST OF SYMBOLS / ABBREVIATIONS

β	standardized regression coefficient
r	Spearman's correlation coefficient
n	sample size
p	probability value

ACMV	air conditioning and mechanical ventilation
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning
BCBT	Backward Corsi block tapping
BOSSA	Building Occupants Survey System Australia
CCTs	correlated colour temperatures
CFF	critical flicker frequency
DOSH	Department of Occupational Safety and Health
ECG	electrocardiogram
HVAC	heating, ventilation, and air-conditioning
IAQ	indoor air quality
IE	indoor environmental
IEQ	indoor environmental quality
JKR	Jabatan Kerja Raya
MVOCs	microbial volatile organic compounds
NIOSH	National Institute of Occupational Safety and Health
PPD	predicted percentage dissatisfied
SBS	sick building syndrome
SPOES	Sustainable Post-Occupancy Evaluations Survey
STI	speech transmission index
TVOCs	total volatile organic compounds
UBBL	Uniform Building By-laws
VOC	volatile organic compound
VOCs	volatile organic compounds
VRT	visual reaction time

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CHAPTER 1

INTRODUCTION

1.1 Research Background

Mujeebu (2019) defined indoor environmental quality (IEQ) as "a domain that encompasses diverse sub-domains that affect the human life inside a building." The National Institute for Occupational Safety and Health, NIOSH (2013) described IEQ as "the quality of a building's environment in relation to the health and well-being of those who occupy space within it". Jabatan Kerja Raya (JKR, 2021) defined IEQ as the "character of the indoor environment that contribute to the health and comfort of occupants inside office buildings".

Indoor environmental quality covers a wide variety of parameters in a building such as temperature, air flow, relative humidity, concentration of pollutants, spatial density, lighting, noise, etc. Generally, IEQ can be categorized into four major groups including thermal comfort, indoor air quality, visual comfort, and acoustic comfort (Federation of European Heating, Ventilation and Air Conditioning Associations, 2010). Firstly, thermal comfort is expressed by the satisfaction level of the office occupants with the surrounding thermal conditions. Thermal comfort can be assessed in thermal sensation, thermal acceptability, and thermal preferences (Langevin, et al., 2013). Indoor air quality is determined by the concentration of carbon dioxide, particulate matter, and volatile organic compound within the building space (Stetzenbach, et al., 2004). Visual comfort is achieved when there are ample task visibility and fewer strain on the occupants' sight. Acoustic comfort is the quality of the building to block out surrounding noises from the occupants which allowing them to communicate without any extra effort (Kapoor, et al., 2021).

Literature has proven that IEQ has significant effects on the well-being and productivity of the occupants. Poor IEQ can lead to a variety of sick building syndrome (SBS) such as building-related allergies, dizziness, sneezing, running nose, eyes irritation, itching, etc (Kishi and Araki, 2020). In workplace, IEQ plays an important role in increasing the employee's satisfaction and eventually increase productivity, reduce turnover, and yield higher organisational outcomes (Seppänen and Fisk, 2006; Veitch, et al., 2007; Bae, et al., 2021). It is advised not to neglect the importance of IEQ in a commercial building because it is one of the key measures of the operational functionality of the building. Hence, this study aims to study the correlation between indoor environment quality and work productivity in Malaysia.

1.2 Problem Statement

Schweizer, et al. (2007) found that, in modern times, urban population spent more than 90% of their time indoor consisting of 50-60% in dominant locations, 30% in work or school indoors, and 5% in other indoors such as transportation and public buildings. Hence, indoor environmental quality (IEQ) would surely have direct consequences to the occupants' health, general well-being, and performance. Research has been conducted on the occupants' performance related to the IEQ in various buildings such as schools, universities, factories, and offices. Kapoor, et al. (2021) stated that poor IEQ has negative impact on the concentration and performance of the occupants in educational buildings. Bae, et al. (2021) concluded that poor IEQ leads to dissatisfaction of the employee and eventually lower their work performance and health. Recently, Malaysia has re-implemented the movement control order (MCO) where physical outings are prohibited and employee is required to work from home, unless necessary. During the MCO, the number of occupants in an office building will certainly decrease due to the lesser need to attend physically to work. However, to the author's knowledge, there is limited research investigated the perceived IEQ satisfaction in partially occupied offices. Consequently, this constitutes the need of this research to investigate the employee satisfaction towards IEQ in the office amidst the pandemic, and its correlation with work productivity.

By far, there were substantial amount of IEQ studies conducted around the globe. In England, Richardson, et al. (2018) examined the work productivity of office occupants under various thermal conditions. In Tanzania, Katabaro and Yan (2019) studied the effects of lighting quality on productivity of workers in office buildings. In China, Kang, et al. (2022) investigated the impact of acoustic satisfaction on productivity in different sizing of open-plan office. Nevertheless, the research works are limited to countries with four seasons, and different geographical location. Unlike four seasons countries, Malaysia is located at the equator, and having hot and humid climate year-round. Although IEQ is tested indoor, but outdoor climates could also have impact to the occupants' perceived IEQ satisfaction. Therefore, this study is performed to assess the occupants' satisfaction level towards IEQ in Malaysia offices.

Profitability is always the paramount concern to entrepreneur in building a successful business. Meanwhile, work productivity happens to be a key factor contributing to the maximization of profits. Work productivity could vary depending on the physical and mental health conditions. Satisfying indoor environment is certainly important to maintain the health, comfort, and well-being of the occupants (Rohde, et al., 2019). The author speculates that IEQ might have significant impact on work productivity. Hence, this study is initiated to verify the correlation between IEQ and work productivity

1.3 Aim and Objectives

This study aims to conduct a correlation study between indoor environment quality and work productivity in Malaysia. The study objectives are listed as follows:

i. to investigate office occupants' satisfaction towards indoor environmental quality in their workplace.
ii. to determine the work productivity of the occupants.
iii. to analyze the correlation between indoor environmental quality and work productivity.

1.4 Scope of Study

This study is conducted using questionnaire survey as a quantitative analysis approach to acquire data from the target respondents. The scope of study includes:

i. the indoor environment selected is in office buildings.
ii. the survey is conducted in Klang Valley.
iii. the target respondents are aged at least 18 years old.
iv. the indoor environmental quality to be evaluated includes thermal comfort, indoor air quality, visual comfort, and acoustic comfort.
v. work productivity is measured through stress level, concentration at work, monthly absenteeism, and presence of symptom and illness.

This study investigates the satisfaction level and work productivity of occupants in office buildings. Office buildings are selected because work productivity is a prominent factor in office buildings, and it is linked to an organization's benefit and profitability. All kind of office buildings are covered, involving traditional offices, high-rise offices, co-working spaces, creative offices, etc. The location of survey is Klang Valley because Klang Valley is a metropolis with high density of office buildings. Respondents are required to be at least 18 years old and above to exclude employment of "young person" who has attained the age under eighteen years and is regulated under the Children and Young Persons (Employment) Act 1966 (The Commissioner of Law Revision Malaysia, 2019). Four major groups of indoor environmental quality including thermal comfort, indoor air quality, visual comfort, and acoustic comfort are tested (Mujan, et al, 2019). Work productivity is measured subjectively through stress level, concentration at work, monthly absenteeism, and presence of symptom and illness (Yazdanirad et al., 2021).

1.5 Outline of the Report

This study consists of five chapters covering: introduction, literature review, research methodology, results and discussions, and conclusion and recommendations.

Chapter 1 provides a general introduction to the topic studied. Also, it describes the problem statements that initiated this study. The study's aim and objectives are highlighted in this chapter, along with the scope of study.

Chapter 2 contains a detailed review of substantial literature in the past to obtain deeper understanding on indoor environmental quality (IEQ), and its influence on occupants working in office buildings. Research gap was identified to support the problem statement and objectives of the study.

Chapter 3 outlines the methodology applied in this quantitative research. A general flow of study is established to describe the three main parts of the research including survey development, data collection, and data analysis.

Chapter 4 discusses the outcomes of the study in detail. IBM SPSS Statistics 26 graphics are attached to explain the results obtained from the analyses of demographic, reliability, normality, descriptive, and correlation.

Chapter 5 concludes the study and summarizes the outcomes based on the discussions in Chapter 4. This chapter also identifies the inadequacy and limitations of this study. Recommendations are provided to improve and resolve the shortcomings in this study for further research purposes.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Historically, there were limited research on indoor environmental quality (IEQ) as compared to other construction topics such as structural aspects, material, and energy consumption. However, lately, IEQ has growing popularity in research, policymaking, standardization, and building regulations. Furthermore, there are increasing numbers of discussion regarding the correlation between IEQ and occupant health, comfort, and well-being (Rohde et al., 2019). IEQ can not only determine the overall building performance, but also affect occupant physical, cognitive, and psychosocial development.

Generally, IEQ is segmented into four major categories covering thermal comfort, indoor air quality, visual comfort, and acoustic comfort. The following sub chapters include elaborations of each IEQ parameter and literature review on the relationship between IEQ and occupant health, comfort, and well-being. Existing indoor environment design standards in Malaysia are discussed to recognize the allowable limits for each IEQ parameter in office buildings. Lastly, several field studies are explained to extend the understanding of occupant satisfaction on IEQ and the correlation between IEQ and practical performance.

2.2 Indoor Environmental Quality

Currently, plenty of research has been done to study a building's indoor environmental quality (IEQ) in relation to the health, comfort, and well-being of the building occupants. According to Rohde, et al. (2019), the terms 'Health', 'Comfort', and 'Well-being' are domains that define the building of having good IEQ that affects occupants' satisfaction. However, researchers had yet to come into a general consent for the definition of the terms. These terms are often interchangeable the literature without having a solid terminology. Also, Merriam-Webster Dictionary and Oxford Dictionary are having overlapping meanings for these three terms. Ambiguous definition of these domains may result in confusion within IEQ research, vague IEQ assessments, and unclear implications for occupants. In view of this, Rohde, et al. (2019) reviewed a substantial amount of literature to provide suggest for formal definitions of the domains. As a results, the author suggested the indoor environmental comfort to be defined as "IE conditions that facilitate a state of satisfaction of bodily wants in occupants, based on their individual preferences and their given activity, and that limit physical stressors causing annoyance" (Rohde, et al., 2019). Besides, indoor environmental health is defined as "IE conditions that promote physical resilience and restitution of occupants, and limit physical stressors causing infirmity, disease, and years of potential life lost" (Rohde, et al., 2019).

Well-being is often be confused with comfort and health. In the existing IE well-being assessments, the predominance of focus was on the absence of negative stimuli in the environment. On the contrary, the author considered the presence of positive stimuli such as fragrances, natural sceneries, and warm lighting for the environmental well-being, as shown in Figure 2.1. Accordingly, the author defined environmental well-being as "IE conditions that afford mental resilience and restoration, offer variation, provide controllability, and advance positive stimuli to improve occupant happiness" (Rohde, et al., 2019).

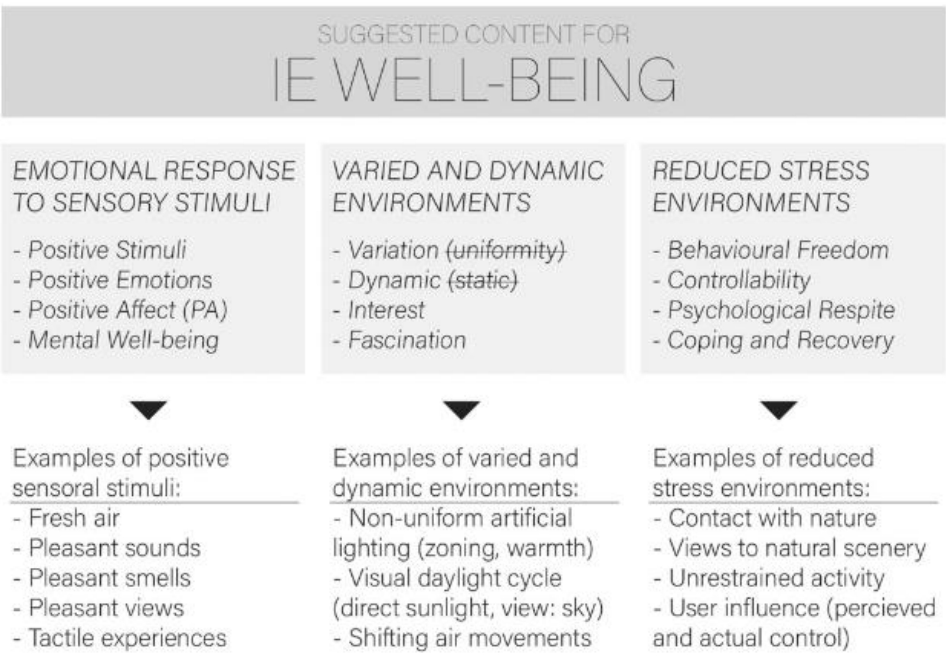

Figure 2.1: Summary of the Suggested Indoor Environmental Well-Being based on the Presence of Positive Stimuli (Rohde, et al., 2019).

Conclusively, the research by Rohde, et al. (2019) provided a credible and precise framework to differentiate between health, comfort, and well-being of the indoor environment, thus facilitating the investigation of the building occupants' perception towards indoor environmental quality of the workplace.

2.2.1 Thermal Comfort

According to the American Society of Heating (ASHRAE) Standard 55 (2017), thermal comfort is defined as the state of mind that expresses satisfaction with the thermal environment and is evaluated subjectively. Judgement of thermal comfort is a cognitive process that incorporates physical, physiological, psychological, and other processes. Hypothalamus in the brain is the central control of human thermoregulation. Thermal comfort is achieved by energy balancing between the environment and human body. Heat is lost from body in various ways including sensible heat loss, evaporative heat loss, and respiratory losses. Imbalance of heat loss may lead to overheating (hyperthermia) or coolness (hypothermia).

There are six main parameters that affects thermal comfort of occupants including air temperature, relative air humidity, air velocity, mean radiant temperature, metabolic rate, and clothing insulation (ASHRAE, 2017). Among the six parameters, four of them are related to the building environmental, while another two are human factors. Human metabolic rate can be determined based on heat transfer when performing various activities. Besides, clothing insulation varies depending on the selection of garment. Apart from the primary factors, there are secondary factors affecting thermal comfort which include day-to-day variations, age, adaption, sex, and seasonal and circadian rhythms. According to ASHRAE (2017), women have lower metabolic rate and skin temperature, and therefore women often favour higher ambient temperatures than men. Moreover, women are more sensitive to thermal changes which caused them to less comfortable than men in a controlled indoor environment.

Building occupants may feel uncomfortable when either part of the body is too warm or too cold, this is known as thermal nonuniformity. Thermal nonuniformity can cause by asymmetric thermal radiation, draft, vertical air temperature difference, and warm or cold floors (ASHRAE, 2017). Asymmetric thermal radiation is the difference in radiant temperature between an object and the environment. In offices, asymmetric thermal radiation is usually caused by cold windows or ceiling heating panels. Draft is undesired cooling of body due to excessive air movement. Vertical air temperature difference makes a person feels discomfort at the head or cold at the feet because temperature increases with height above the floor. Similarly, floor materials of a building can also cause the occupants to too warm or too cold at the feet. ASHRAE (2017) provided guidelines to quantify and predict thermal nonuniformities, therefore mitigating these nonuniformities.

Thermal comfort is a subjective feeling, however there are researchers that utilize objective factors such as thermal sensitivity, thermal acceptance, and thermal priority to assess thermal comfort (Mujan, et al., 2019). ASHRAE (2017) established a 7-point thermal sensation scale to objectively describe the sensual perception of a person towards the indoor thermal environment. The ASHRAE thermal sensation scale includes hot (+3), warm (+2), slightly warm (+1), neutral (0), slightly cool (-1), cool (-2), and cold (-3). Besides, Fanger (1970) developed the PMV-PPD model to generate more numerical and rigorous predictions of thermal comfort. Predicted mean vote (PMV) is the average response of the building occupants according to the ASHRAE thermal sensation scale, while the predicted percent dissatisfied (PPD) is the percentage of people who are not satisfied with the thermal environment and have given the vote +3, +2, -2, or -3. The PMV-PPD model is popular in a variety of field assessment related to thermal comfort conditions. After that, Gagge, et al. (1986) developed the two-node model to predict physiological responses or responses to transition between extreme thermal environments. Then, Brager and de Dear (1998) created the adaptive acceptance model of comfort to predict the adaptivity of the occupants to feel comfortable under almost constant conditions. This model believes that people may make adaptive adjustments such as adjusting clothing, posture, and working habit to mitigate discomfort and physiological strain in a constant environment. Generally, the PMV-PPD model, two-node model, and adaptive model are designed to predict the average comfort level within a large group of occupants. However, thermal comfort depends on large interpersonal variability which is greatly affected by individual preferences. Therefore, researchers have created plenty of personal comfort models or systems to predict an individual’s thermal comfort response. These personal comfort models incorporated several variables that were absent in the previous models such as body mass index, sex, etc (Mujan, et al, 2019).

ASHRAE (2017) found that there is a correlation between thermal comfort and productivity. Productivity is usually highest under comfort conditions. Optimal comfort temperature is a range of temperatures that the occupants feel comfortable. ASHRAE (2017) collected data from 11 field studies in offices to represent the relationship between overall real-world productivity and deviation from optimal temperature, as shown in Figure 2.2. Figure 2.2 shows that when temperature rises 12 K higher than the optimal temperature, the productivity drops by 15%. The results conclude that the productivity of the occupants is greatly affected when the environment is too warm or too cold. Nevertheless, Figure 2.2 shows the results of individual studies scatter about the line, indicating a high level of uncertainty. Hence, this constitutes the need of performing a correlation study between indoor environmental quality and work productivity in Malaysia.

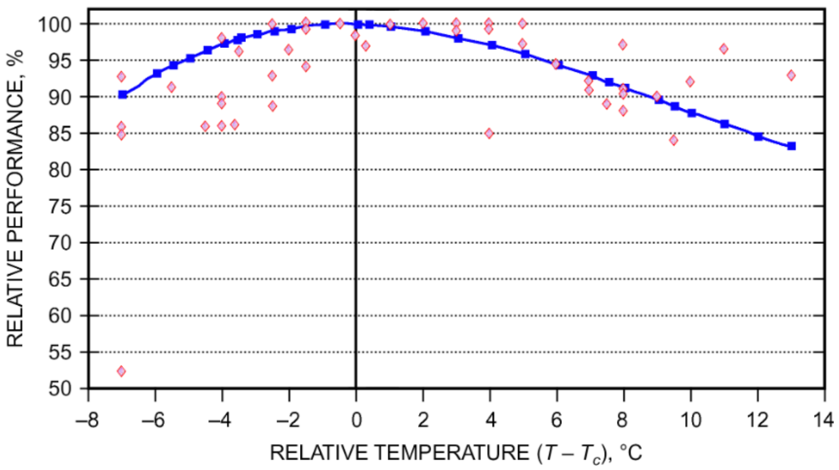

Figure 2.2: Relative Performance in Offices against Deviation from Optimal Comfort Temperature (ASHRAE, 2017).

2.2.2 Indoor Air Quality

Indoor air quality (IAQ) is the air quality in a building which has significant impact to the health, comfort, and well-being of the building occupants. Poor IAQ can result in various health problems, reduced productivity, and occupants' dissatisfaction. Generally, IAQ is measured based on the parameters including: "carbon monoxide, carbon dioxide, nitrogen dioxide, sulfur dioxide, volatile organic compounds, relative humidity, temperature, oxygen, ozone, ammonia, air velocity, formaldehyde and levels of particulate” (Mujan, et al., 2019). Some of these parameters are noted as indoor air pollutants which are harmful to the building occupants. Table 2.1 tabulates the sources of each indoor air pollutant.

Table 2.1: Sources of Indoor Air Pollutants (Paleologos, et al., 2021).

Indoor Air Pollutant	**Source**
Carbon monoxide	Product of incomplete combustion.
Carbon dioxide	Product of combustion and respiration.
Nitrogen dioxide	Product of combustion.
Sulfur dioxide	Product of combustion of fuels containing sulfur.
Formaldehyde	A type of volatile organic compound (VOC). Paints, adhesive resins, plastics, insulators, etc.
Acetaldehyde	A type of VOC. Product of wood or kerosene combustion, floorings, paints, varnishes.
1,1-Dichloroethene	A type of VOC. Incense smoke.
Ozone	Electrostatic appliances running at high voltage.
Ammonia	Environmental tobacco smoke, refrigeration units, household cleaners.
Particulate matter (PM_{10}, $PM_{2.5}$, PM_1)	Product of combustion, resuspension of particles by cleaning, aerosol product use.
Bacteria	Natural air-borne microorganisms
Mold	Humid and damp construction materials.
Spores	Asexual reproduction products by plants, algae, fungi, and protozoa.

Indoor air quality (IAQ) of building is primarily depending on the work and life processes activities in the building. In addition, IAQ is also affected by the external environment, the building construction processes, the efficiency of the heating, ventilation, and air-conditioning (HVAC) system, and the spatial layout of the workplace (Mujan, et al., 2019). An acceptable IAQ is deemed to have air in which the concentrations of air-borne contaminants are lower than the established standards and with which 80% or more of the occupants are satisfied with the air quality. ASHRAE Standard 62 (2019) introduced three general procedures: ventilation rate procedure, IAQ procedure, and natural ventilation procedure to control the IAQ at an acceptable level and meet the regional standards. Ventilation rate produce formulates the outdoor air intake rates based on the building type, building purposes, floor area, and occupancy level. IAQ procedure determines the outdoor air intakes and other system design parameters depending on the pollutants sources, the allowable concentrations, and the occupants' perceived tolerance of the indoor air. Natural ventilation procedure guides the design for the direct intake of outdoor air through openings to any part of the building, given that adequate mechanical ventilation systems are provided (ASHRAE, 2017).

Indoor air quality (IAQ) is important to create healthy environment for occupancy. Poor IAQ can cause sick building syndrome (SBS) especially in office buildings. Dominant symptoms of SBS includes irritation of the nose, throat, eye, and skin. Also, there are some general symptoms such as headache, fatigue, dizziness, and difficulty concentrating (Kishi and Araki, 2020). Indoor air pollutants such as aldehydes, volatile organic compounds (VOCs), dampness, and mold are some major causal factors of SBS. According to Saijo (2020), in 2003, Japan changed the Building Standard Act to include formaldehyde-abatement measures and 24-h mechanical ventilation in the house construction. This amendment was made to reduce the formaldehyde levels in dwellings, thus reducing the risk of SBS symptoms. Saijo (2020) also argued that any form of dampness such as water leakage, visible mold, or moldy odor can increase the odds ratios of SBS symptoms. Dampness also promotes growth of microbial which further increase the risk of infectious and allergic effects. Moreover, molds and bacteria can generate microbial volatile organic compounds (MVOCs) that increase the risk of SBS symptoms.

Likewise, indoor air quality (IAQ) has significant impact to productivity of occupants in office buildings. Wargocki (2019) claimed that people working in an environment with good air quality would have: lesser illness and sick leave, higher productivity, and better work quality. The author suggested that a minor 1% of additional work done can offset 10% of the costs of air quality control. Consequently, 10% increase in productivity is sufficient to breakeven the entire costing, and the payback is generally completed within 2 years. Hence, indoor air quality control is certainly a beneficial investment in office buildings.

2.2.3 Visual Comfort

Visual comfort is a subjective perception of the visual well-being to the surrounding visual environment. Visual comfort can influence a person's physiological and psychological health and processes (Ganesh, et al., 2021). Human eyes can detect light within the electromagnetic spectrum between 380 nm and 780 nm, but only sensitive to green-yellow light at about 555 nm under bright conditions, and to blue-green light at about 505 nm under dim conditions. Human eyes respond to luminous stimuli and provide the function to receive a wide range of lighting scenes, focus on different scenes, adjust quickly to lighting level changes, and interpret colours. Lighting performance of a building is assessed by either quantitative or qualitative aspects. Quantitative aspects of lighting include its ability to provide sufficient illumination for visual task performance yet achieve a balance between energy consumption for lighting and heating or cooling needs. Qualitative aspects emphasize on the visual comfort and satisfaction to assure the health and well-being of the occupant (Altomonte, et al., 2017).

Lighting design comprises of several measuring parameters. Daylight factor is one of the most widely used measurement that defines the ratio between external and internal illuminance into a space, including direct light source, reflectance of light from external sources, and reflection from internal sources (Mujan, et al., 2019). Moreover, a lighting design can also be described by parameters such as luminous efficacy of radiation, colour temperature, chromaticity, special colour rendering index, general colour rendering index, lighting energy numeric indicator, mean room surface exitance, and ambient illumination ratio (Altomonte, et al., 2017). These parameters provide a standard to establish effective lighting designs or strategies.

Daylight plays an important role in creating a comfortable visual environment. Daylight assures the function of human's biological clock and supports the physical and mental activity during day times. Normally, daylight enters a building through windows, therefore proper design of windows can achieve visual comfort. Physical properties, geometry, and orientation of windows affect the illumination of a building. Altomonte, et al. (2017) found that wide windows at high level allows more natural lighting and solar energy penetration than low vertical windows. Improper installation of windows might cause direct irradiation of sunlight and accumulate unpleasant heat that warms up the space. Hence, additional cost is incurred to install physical shading barriers, or to cool down environment. Other than that, the balance between daylight and artificial lighting is another major factor in the design of lighting systems. The intensity and spectral composition of daylight varies across a day. Based on that, an artificial lighting system should have dynamic control over the colour and lighting levels to synchronize with the natural daylight. Others factors to be considered in an artificial lighting system are the function of the space, and the psychological impressions of the occupants over warmth, relaxation, clarity, etc (Altomonte, et al., 2017). Balancing between daylight and artificial lighting can effectively provide an optimal visual comfort and yet achieving energy efficiency.

Improper design of windows and lightings let in glare that causes visual discomfort and tiredness. Glare has three categories, firstly, disability glare originated from excessive luminance which cannot be adapted by human eyes, thus impairing the vision of the occupants. Secondly, veiling glare that produced by reflections on specular or diffusive materials that reduce the contrast and visibility of tasks. Thirdly, discomfort glare which is unnoticeable and does no physical disturbance to the vision, however, after long exposure, the occupants may experience psychologically discomfort such as headache or eyestrain (Altomonte, et al., 2017).

Apart from providing visual illumination to perform physical activities, the nonvisual effects of light must not be overlooked. In the short term, light can suppress the production of melatonin to prevent sleepiness, reduce the production of cortisol to relieve stress, regulate heart rate, core body temperature, and neurophysiological process. While in the long term, light can synchronize the body’s endogenous circadian rhythm to the daily light-dark cycle, and control neurobehavioral functions such as attention and emotional responses (Altomonte, et al., 2017). In light of the nonvisual effects of light, visual comfort can certainly influence the productivity and well-being of the occupants indoor. According to Mujan, et al. (2019), companies that have implemented effective daylight strategies was reported to have absenteeism decreased by 15% and employees’ productivity increased by 47%. Moreover, workers are found to be more attentive in performing monotonous jobs, thus increasing their productivity. Ganesh, et al. (2021) also agreed that visual comfort is vital for the general health of the occupants. The author found that when people are working in low light conditions, regardless of their age, gender, climatic, conditions, and task performed, they suffer from insomnia and serious occupational damages.

2.2.4 Acoustic Comfort

Acoustic comfort is a subjective state of satisfaction to the acoustic or aural environment. A comfortable acoustic environment is a space that protects occupants from the nuisance caused by unwanted noise (Ganesh, et al., 2021). Sound is a medium for people to communicate, express moods and emotions, and interact with the surrounding. People listen, analyse, and respond to the environment of sound, known as a soundscape. The design of soundscape has direct impact to the health, comfort, and well-being of the occupants. In fact, sound affects human's psychology, emotions, behavior, social interactions, identify, and relationship in various time, and space (Altomonte, et al., 2017).

People are living in a space full of gases, liquid, and solids which possess the property of elasticity. When this medium is disturbed and deformed, wave of energy is generated from the source, and is transmitted to intercept the hearing system. Acoustic transmission involves three components, where sound wave is: generated from a sound source, travelled in a transmission path, and collected by the receiver. Sound generation is the conversion of energy from the source of excitation into the wave field as pressure fluctuations. Pressure fluctuations, Pa of sound represent amplitude or loudness of the sound. The decibel system, dB is commonly used to quantify the perception of the loudness of sound. Frequency, Hz is the number of complete wave cycles within a second to describe the sharpness of sound. Along the transmission path, sound undergoes reflection, transmission, and diffraction, making it more complex and difficult to predict. The acoustic intensity decreases to a quarter of its value as the distance from the source is doubled. Lastly, the human hearing system receives the sound wave and performs two major tasks to either: magnify subtle sounds or estimate the direction where the sound is traveling from. The hearing system can sense very low sound pressures and tolerate very high sound pressures, ranging from 10^{-5} Pa to 102 Pa. In terms of frequency content of a sound wave, human can hear frequencies from 20 Hz to 20000 Hz and being most sensitive to frequencies contained within a speech which is about 120 Hz to 4000 Hz (Altomonte, et al., 2017).

Design of an acoustic environment considers the impulse response where the signal is recorded after a sound pulse of sound is discharged into a space. Impulse response can be derived into reverberation time which defines the time taken for the sound pressure to decay by 60 dB. Reverberation time is longer in a larger space, or space with lesser absorption. Hence, the selection of room volume and construction material with different reflective, absorptive, and diffusive properties should be considered to best suit the function of the venue. As in a space for speech, the design aims to minimize extraneous sources of noise and is generally measured by speech transmission index (STI) and speech intelligibility. Speech transmission index represents the effectiveness of the space for speech in the presence of any background noises, while speech intelligibility represents the human perception of speech. Generally, physical barriers are installed to external noises by changing the path length and reducing the sound pressure. Effectiveness of sound barriers are related to their mass and continuity where heavy and multi-layered sound barriers provide greater level of insulation (Altomonte, et al., 2017).

Acoustic discomfort can result in psychological effects such as nervousness, decreased concentration, increased stress, anxiety, and high blood pressure (Mujan, et al., 2019). Therefore, achieving acoustic comfort is crucial in the office space to maintain the employee’s productivity. According to Yang, et al. (2017), short term exposure (less than 30 minutes) to noise has barely minimal effect to the occupants, however long term exposure (more than 120 minutes) can have significant impact. As a comparison between acoustic comfort and thermal comfort, when noise is increased by 2.6 dB to 2.9 dB, the dissatisfaction caused is equivalent to 1˚C change in the optimal temperature (Mujan, et al., 2019). Also, Ganesh, et al. (2021) found that irregular and unexpected noises such as people speaking nearby, and doorbells create more discomfort than regular noises with constant frequency.

2.3 Sick Building Syndrome (SBS)

Sick building syndrome (SBS) is defined a condition where building occupants have feelings of discomfort, and numbers of health symptom that could not be associated with any specific cause or illness, however these conditions would greatly relieve after they exited the building. Some common symptoms of SBS are headache, sore throat, eyes and nasal irritation, asthma, skin dryness, fatigue, dizziness, etc (Paleologos, et al., 2021).

Paleologos, et al. (2021) stated that poor indoor air quality (IAQ) practices are the primary contributors to SBS, for example, low ventilation rate, biological contamination of the HVAC system, and intrusion of outdoor pollutants. Poor IAQ practices can lead to accumulation of air-borne pollutants emitted from household materials, furnishings, paintings, and electronics. Typical air-borne pollutants are formaldehyde, volatile organic compounds (VOCs), and microbial volatile organic compounds (MVOCs). Other than IAQ, long-term exposure to poor visual environment can also trigger SBS symptom such as general malaise. Saijo (2020) also included personal factors and social factors as the causes of SBS. Examples of personal factors are gender, age, occupation, intrinsic allergies. Examples of social factors are social circle, social status, educational level, support from supervisors and colleagues.

SBS is a major challenge in building management. Other than sensory irritations, SBS can also affect psychosocial reactions such as decreased productivity, and absenteeism (Paleologos, et al., 2021). Wargocki (2019) found that SBS symptoms can cause difficulty in concentrating, distress, and interrupted mental performance. He found that there was a loss of 2-3 working days of each worker per annum and was approximately equivalent to $50 million. Conversely, business acquired savings from maintaining good IEQ and reducing the odds of SBS.

2.4 Work Productivity

Work productivity indicates how much “work” can be done over a specific period, or the measures of output per unit of input. Work productivity has direct impact to a company’s growth and profitability. Hence, research has been done to study several causes that affect employee’s work productivity such as work stress and absenteeism.

Work stress is one of the most common work-related health problems. Work stress is originated from various sources such as working environment, family and social life, and self-assessment. The cost of work stress is significant to a personnel and organization. In personal, work stress has severe negative impacts on a person's health state or, worse still, lead to depression disorders (Netterstrom et al., 2008; Houndmont et al., 2010). Petreanu et al. (2013) claimed that stress at work factors comes across as an emerging risk that deteriorates the work quality and productivity in Romanian companies. Yazdanirad et al. (2021) discovered that hypochondria disorder which is one of the psychological concerns of Covid-19 pandemic could reduce the productivity of employees by increasing work stress and reducing their resilience.

Employee absenteeism is defined as "any failure to report for or remain at work as scheduled, regardless of reason" (Cascio and Boudreau, 2010). Absenteeism can be disruptive and costly to a business operation because additional resources are required to be allocated immediately to fill the vacancy, and yet work is done less efficiently by others. Common forms of absenteeism are skipping, illness, and strike or wilful absence. Society for Human Resource Management (SHRM, 2014) found that in 2014, the productivity loss due to absenteeism was significant, including 31.1% in the United States, 25.5% in China, 19.9% in Australia, 22.7% in Europe, and 29.3% in India.

2.5 Office Building

This correlation study only focusses on the indoor environmental quality (IEQ) in office buildings in Malaysia, including both high-rise and landed offices. Some iconic office buildings in Malaysia are the 85 Tranquerah, MindValley, Genovasi, Leaderonomics, etc. Department of Occupational Safety (DOSH, 2010) defined 'office' as "a room, set of rooms or building where people work, usually sitting at desk". Uniform Building By-laws 1984 (UBBL, 1984) defined 'office' as a space for the purposes of administration, clerical work, financial operation, and telecommunication functions.

Generally, an office building may have various functional spaces including employee or visitor support spaces, administrative spaces, and operation and maintenance spaces. Different spaces serve for specific purposes as listed in Table 2.2 (Conway, 2021).

Table 2.2: Functional Spaces in Office Building (Conway, 2021).

Space	Function
Employee or visitor support spaces	
Lobby	Space with controlled access to welcome and direct visitors to other spaces in the office.
Joint use retail	Retail space used to provide products and services.
Atrium	Architectural feature that allows infusion of natural light, and public circulation.
Cafeteria	Space for food production and services.
Washroom	Space for sanitary, and grooming.
Childcare centres	Space for childcare that allows employees to effectively respond to their work and family role.
Physical fitness area	Space for physical trainings to maintain employees' health and wellbeing.
Parking	Monitored space for placement of vehicles.
Administrative support spaces	
Administrative offices	Space for administrative activities such as meetings, file storage, clerical works, telecommunication, etc.
General storage	Storage for equipment, and machineries.
IT closets	Automated data processing centre to store and distribute business data.
Maintenance closets	Storage for maintenance hardware and supplies.

In the design of an office buildings, there are several important criteria to be considered including accessibility, aesthetics, cost effectiveness, functionality, flexibility, location, technical connectivity, safety, sustainability, and productivity. Practically, employees' salary is one of the greatest costs in a business, which is often higher than the lease and energy cost of a facility. Hence, the health, comfort and well-being of employee appear to be the paramount concerns to yield high productivity and generate profits for the organization. Indoor environmental quality (IEQ) of the office has direct relationship with the productivity of employees. Strategies such as increased natural ventilation rates, the specification of non-toxic and low-polluting materials and systems, and air quality monitoring are utilized for good indoor air quality. Besides, employees are provided with individualized climate control to adjust the localized temperature, ventilation rate, and air movement according to their personal preferences. Diffusion of natural light and access to external views also provide motivation to the employee for better working efficiency. Lastly, acoustic environment of the office is supported with effective noise control approaches and masking white noise so that employees to create adequate separation of individual occupants, yet increasing their concentration (Conway, 2021).

2.6 Indoor Environmental Quality Standard in Malaysia

Indoor environmental quality (IEQ) has significant impact to the health, comfort, and well-being of building occupants. Good IEQ can improve the productivity and satisfaction at the workplace, while poor IEQ can lead to various illness, decreased concentration, and sick building syndrome. Effective design and management provide the best solution to control and maintain IEQ in buildings at desirable levels. Jabatan Kerja Raya (JKR) Malaysia (2021) established the JKR standard for indoor environmental quality for office buildings to provide guidance on improving the IEQ of air-conditioned office buildings based on indoor air quality, acoustic comfort, thermal comfort, and visual comfort in line with the existing technical requirements and best practices.

Section 5.1 of the JKR standard (2021) stated the requirements on indoor air quality (IAQ). Matters discussed in this section include air conditioning and mechanical ventilation (ACMV) design requirements, mould prevention, indoor air pollutants control, building flush-out, air treatment, and IAQ requirements. Indoor air quality requirements are acceptable limits of physical parameters, indoor air pollutants, and biological parameters which shall comply with the Industry Code of Practice on Indoor Air Quality established by the Department of Occupational Safety and Health (DOSH, 2010), as listed in Table 2.3.

Table 2.3: Acceptable Limits for IAQ Parameters (DOSH, 2010).

Parameter	**Unit**	**Acceptable Range/ Limits**
Physical parameters		
Air temperature	˚C	23 – 26
Relative humidity	%	40 – 70
Air movement	m/s	0.15 – 0.50
Chemical contaminants		
Carbon monoxide	ppm	10
Formaldehyde	ppm	0.1
Ozone	ppm	0.05
Respirable particulates	mg/m^3	0.15
Total volatile organic compounds (TVOC)	ppm	3
Biological contaminants		
Total bacterial counts	cfu/m^3	500
Total fungal counts	cfu/m^3	1000
Ventilation performance indicator		
Carbon dioxide	ppm	C1000

Section 5.2 of the JKR standard (2021) included the recommended internal noise level limits in different areas in an office building, as tabulated in Table 2.4. JKR (2021) also provided mitigation actions to reduce noise produced by office equipment and external sources.

Table 2.4: Recommended Internal Noise Level Limits (JKR, 2021).

Area	**Maximum Desirable Levels**	
	NC-RC Level	**L_{Aeq} (dBA)**
Board rooms	30	35
Conference rooms	35	40
Teleconference room	25	30

Table 2.4 (Continued)

Executive offices	40	45
General offices	40	45
Reception rooms	45	50
General open offices	45	50
Drafting room	45	50
Halls and corridors	60	65
Tabulation and computation area	50	55
Multi-purpose halls	30	35
Musalla/ praying room	35	40
Cafeterias	50	55
Gymnasiums	45	50
Outside mechanical plant room	70	75

Section 5.3 of the JKR Standard (2021) highlighted the need of high-level control of the thermal regulatory system by an individual occupant of by specific groups. Physical parameters such as temperature, relative humidity, air movement that affect the thermal comfort shall follow the requirements stated in the Industry Code of Practice, as shown in Table 2.3. Besides, effective operation and maintenance activities such as regular inspection, and re-balancing of the ACMV air distribution system are encouraged to achieve thermal comfort in the building.

Section 5.4 of the JKR Standard (2021) aims to achieve visual comfort by preventing severe direct glare and allowing natural light diffusion into the building. Several strategies are recommended such as encourage North-South orientation for better lighting, install shading devices and blinds to prevent direct solar radiation and glare, and narrower building layout for even daylight distribution. Regarding illumination in offices, MS 1525 (DOSM, 2019) stated that the average luminance level to perform task in general or drawing offices is 300 – 400 Lux. Furthermore, the standard included guidelines for the view of building, glare control, and artificial lighting. The standard provided the design values for quantifiable parameters of illuminance, discomfort, glare, and colour rendering, as tabulated in Table 2.5.

Table 2.5: Design value for Good Visual Comfort in Offices (JKR, 2021).

Factor	Fluorescent	LED
Wattage	14 – 54	8 – 22
Output (lumens)	1200 – 4450	1000 – 3000
Efficacy (lumen/watt)	60 – 105	100 - 150
Lumen maintenance	70	70
Lamp life (hours)	12000 – 24000	40000 – 50000
CRI	70 - 90	70 – 90

2.7 Indoor Environmental Quality in Office Building

Indoor environmental quality (IEQ) has direct impact on the occupant comfort, health, and well-being, as agreed in the literature (Yang, et al., 2017; Mujan, et al., 2019; Ganesh, et al., 2021). Moreover, relevant government agencies such as Jabatan Kerja Raya (JKR) and the Department of Occupational Safety (DOSH) established design standards to regulate IEQ in office buildings. As for business owners, office buildings were built, operated, and maintained in accordance with the standards to create an ideal indoor working environment, thus maximizing organizational profits. However, Rohde, et al. (2019) argued that, in practice, meeting design standards do not necessarily produce satisfied occupants because IEQ is a subjective perception that varies among individuals. Hence, it is crucial to conduct field studies to examine the actual perspective of occupants towards IEQ. Also, field studies can provide clearer insights for the correlation between IEQ and productivity in office buildings. This subchapter will discuss several field studies regarding IEQ in office buildings via quantitative research, qualitative research, and laboratory experiments.

Leder, et al. (2016) conducted two large-scale field studies in Canada and the United States to investigate the effect of IEQ towards environmental and job satisfaction. The first study collected data from 779 open-plan workstation in nine conventional office buildings. The second study collected 2545 questionnaires responses from 24 office buildings (12 green and 12 conventional) encompassed open-plan and private offices. The data is analyzed using stepwise regression to examine the relationships between employees' satisfaction level and the IEQ parameters related to thermal, air quality, visual, and acoustic. As a result, the study found that acoustic and privacy satisfaction were affected by the size and office type. Larger-sized workstations and full-height walls and doors were recommended to achieve better acoustic and privacy satisfaction. Job satisfaction was greatly affected by the office type such as cellular office or open landscape. Another important IEQ factor was indoor air quality which is indicated by the CO_2 and respirable particulate levels. Improved external view via windows and reduced glare were major factors in satisfaction with lighting. Thermal qualities were found to be least significant among all IEQs. Conclusively, Leder, et al. (2016) agreed that improved indoor environmental and job satisfaction would results in increased organizational productivity and organizational payoffs.

Sakellaris, et al. (2016) assessed the relationship between perceived IEQ and occupant comfort in eight European countries including Finland, France, Greece, Hungary, Italy, The Netherlands, Portugal, and Spain. Digital questionnaire surveys using a seven-point Likert scale were distributed to 7441 workers in 167 “modern” office buildings which were new or retrofitted lately within 10 years. The collected data was analyzed using the proportional odds ordinal logistic regression analysis method. Odd ratios were used to rank the significance of each IEQ parameter towards the occupants’ comfort. From the results, majority of the office workers were satisfied with the IEQ in their work environment, especially for light comfort. Strongest association was found between noise and the overall perceived comfort followed by air quality, light, and thermal comfort. Precisely, internal noises within the building and from the building systems were more concerning than external noises. Other than that, the comfort perception was found to be varied according to individual characteristics as well as building characteristics. Male and elderly had higher relation between comfort and noises. Likewise, the relation between comfort and noise was higher in private offices as compared to shared or open-plan offices. Lastly, privacy specifically for speech seemed to be significant for office occupants in practical situations. Partitioned and larger workstations were suggested to improve workplace privacy.

Candido, et al. (2016) performed a multidimensional post-occupancy evaluation using the holistic Building Occupants Survey System Australia (BOSSA) Time-Lapse and BOSSA Snap-Shot questionnaire. Four regression analysis models were established to examine the correlation between nine IEQ factors and four overall building performance indicators including work area comfort, building satisfaction, productivity, and health. Correlation between IEQ factors and performance indicators were ranked based on the standardized regression coefficient (*β*). Occupant productivity had the highest correlation with spatial comfort (β = 0.32) followed by noise distraction, (β = 0.31) and indoor air quality (β = 0.24). Whereas, work area comfort, building satisfaction, and health had the highest correlation with spatial comfort had high correlation with spatial comfort (β = 0.40), building image and maintenance (β = 0.51), and indoor air quality (β = 0.32). Consequently, this study created a seven-point BOSSA Time-Lapse benchmark baseline based on the correlations to evaluate the overall performance of a building. The benchmarking scores were computed as follows: spatial comfort (4.24), indoor air quality (4.39), personal control (2.44), noise distraction and privacy (3.04), connection to outdoor environment (4.35), building image and maintenance (4.42), individual space (5.09), thermal comfort (4.27), and visual comfort (4.69).

Kim, et al. (2016) investigated the influence of non-territorial working on employee workplace satisfaction, perceived productivity, and health. This study was mixed methods research integrating quantitative data collected from the Building Occupant Survey System Australia (BOSSA) using seven-point bipolar rating scale, and qualitative data obtained from open-ended comments. The first part of this study analyzed 3974 individual responses from 20 office buildings regarding their satisfaction levels for IEQ factors such as thermal comfort, IAQ, acoustics, visual, perceived productivity, etc. The results of the survey showed that flexi desk users were usually more satisfied with their indoor environment compared to fixed desk users, as shown in Figure 2.3. Dissatisfaction of flexi desk users on ‘storage space’ might be caused by implemented policies and centralised locker facilities. Besides, a t-test was conducted to know the occupant responses under identical indoor environment. The t-test results indicated higher satisfaction levels from flexi desk users than fixed desk users despite they were working under equivalent ambient conditions supplied by the same HVAC system. The second part of this study collected 371 open-ended comments from the survey respondents to further explore their views on workplace related issues. However, the supplementary qualitative data discovered an opposite finding where most negative comments were concerning flexi-desking arrangements. Insufficient desks (26.8%) and difficulty to locate colleagues (21.6%) were the leading complaints among all. These problems may result in time wastage in finding vacant desks or colleagues, and eventually causing delayed work progress and decreased productivity. Figure 2.4 shows a schematic diagram that provided a good insight on the negative impacts of non-territorial working on the productivity and collaborations among employees.

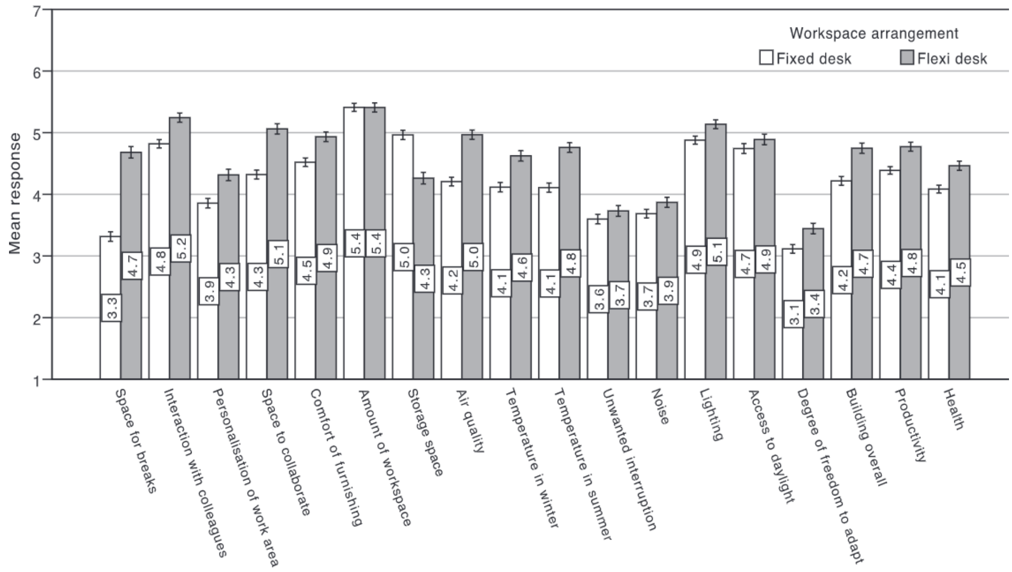

Figure 2.3: Mean Rating Scores for Questionnaires between Fixed Desk Users and Flexi Desk Users (Kim, et al., 2016).

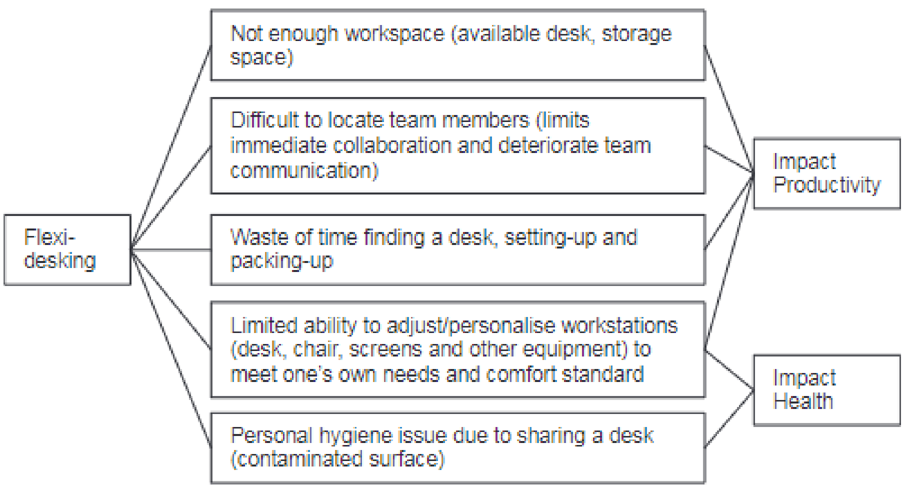

Figure 2.4: Schematic Diagram of Negative Comments regarding Flexi-desking Arrangements (Kim, et al., 2016).

Wang and Luo (2016) organized a laboratory experiment to study the effect of LED lighting on office work performance. Fourteen participants were employed to work under three correlated colour temperatures (CCTs, 4000K, 6500K, 8000K), and three illuminance levels (350lx, 550lx, 750lx). Work performance of the occupants were tested based on visual acuity, attention, typing, reading, critical flicker frequency (CFF), electrocardiogram (ECG), emotion and questionnaires. The experiment found that different CCTs and illuminance levels favour different tasks. Higher illuminance level at 750lx increased attention and typing speed, while higher CCTs at 6500K and 8000K improve visual capability. Hence, participants felt less fatigue and attentive while typing under 750lx 6500K lighting condition, therefore having the highest work performance. On the other hand, 750lx 4000K was deemed as the most comfortable lighting condition for most participant to have low eye fatigue and feel more relax and warmer.

Geng, et al. (2017) explored the effects of thermal environmental on occupant IEQ perception and productivity. The study was conducted in a controlled office environment at Tsinghua University in Beijing, China. Seven groups of experiments were performed involving 21 participants. The independent variable was the indoor temperature from 16˚C to 28˚C with 2˚C increment. While the dependant variables were other IEQ factors (indoor air quality, lighting, and acoustic comfort), and productivity. Digital questionnaire survey using ASHRAE 7-point scale was used to measure the occupant IEQ perception. Productivity of the occupants was tested by three physical tasks which are “Icon Matching”, “Number Summing”, “Text Memory and Typing”. Collected data were analyzed using the Shapiro-Wilk test, t-test, analysis of variance, and the Spearman or Pearson correlation coefficient over three processing stages. The findings showed that the optimum temperature was 24˚C. The participants showed higher tolerance to warm or hot conditions as compared to cool or cold conditions. Thermal environment had comparative impacts on other IEQ factors. The comfort expectation of other IEQ factors was weakened if the thermal environment was unsatisfactory, causing less dissatisfaction with other IEQ factors. Conversely, the comfort expectation on other IEQ factors was raised if the thermal environment was satisfying. Concerning productivity, the occupants were the most productive when they felt "neutral" or "slightly cool", as voted to 0 or -1 respectively in Figure 2.5. Also, Figure 2.6 indicates a positive correlation between thermal satisfaction and productivity, there was a significant 14.2% increment of productivity from thermal unsatisfactory (-3) to satisfying (3).

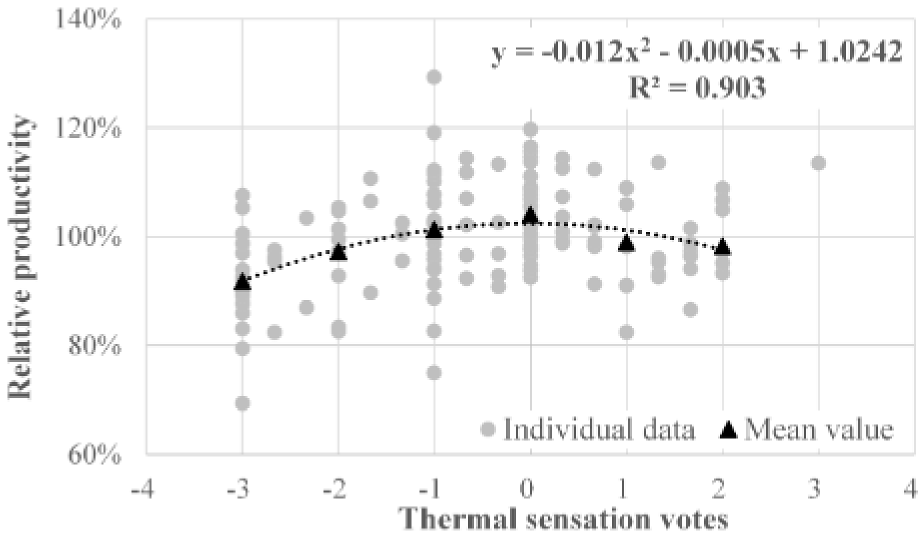

Figure 2.5: Thermal Sensation and Productivity (Geng, et al., 2017).

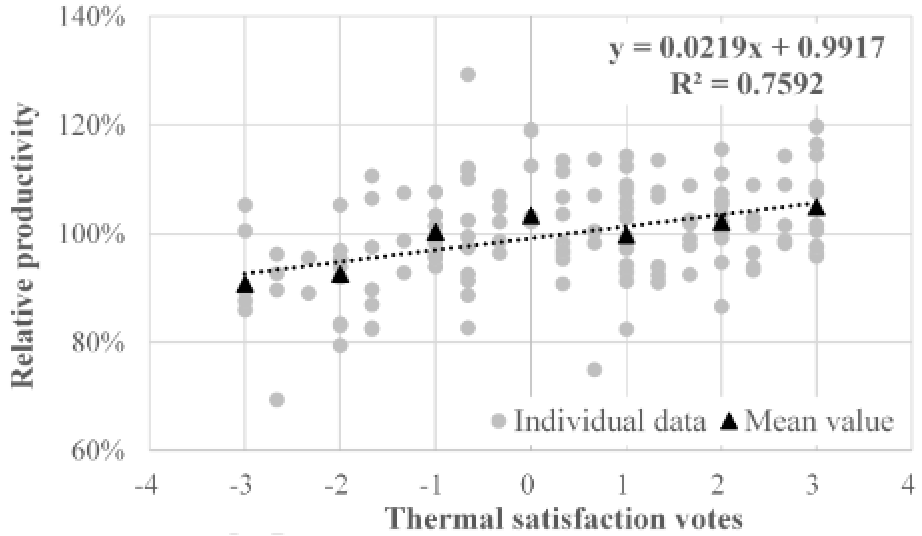

Figure 2.6: Thermal Satisfaction and Productivity (Geng, et al., 2017).

Hong, et al. (2018) conducted a laboratory experiment to observe the integrated task performance of building occupants under various CO_2 concentration and IEQ condition changes. The author recruited 22 building occupants to experience changes before and after working 8 hours in scenarios with different CO_2 concentration, operative temperature, and relative humidity, as listed in Table 2.6. Task performance of the occupants were measured using six cognitive tasks including visual reaction time (VRT), subitizing, Stroop test, Backward Corsi block tapping (BCBT), N back, and typing. The experiment results indicated that the occupant satisfaction peaked at neutral operative temperature (25.00˚C, predicted percentage dissatisfied (PPD); 5%), and they disliked either too cold (18.70 ˚C, PPD: 66%) or too warm (28.80˚C, PPD; 31%) environment. Additionally, the occupants achieved the highest integrated task performance score (0.187) in Scenario 1-2[b] at 25.00˚C and 985.8 ppm CO_2 concentration. Conclusively, managers should keep the operative temperature at neutral 25˚C, and CO_2 concentration below 1000 ppm to ensure maximum task performance.

Table 2.6: Experimental Conditions of Each Scenario (Hong, et al., 2018).

Scenario	Indoor environmental quality condition			
	CO_2 concentration	Operative temperature	Relative humidity	Air speed
Unit	ppm	˚C	%	m/s
Scenario 1-1[a]	998.1	18.70	33.40	0.1
Scenario 1-2[b]	985.8	25.00	28.20	0.1
Scenario 2-1[a]	2414.2	28.80	31.30	0.1
Scenario 2-2[b]	2357.5	25.30	27.80	0.1
Scenario 3-1[a]	2407.8	25.45	32.90	0.1
Scenario 3-2[b]	993.3	25.21	27.47	0.1

Mansor and Low (2020) carried out qualitative research to identify the impact of indoor environment on occupant well-being. Over 200 pieces of literature were reviewed to identify appropriate IEQ criteria and parameters associated with occupant well-being in office buildings. Semi-structured interviews were conducted with professionals from the relevant Malaysia government agencies and building management and consulting industry. The collected data was processed through Thematic analysis using NVivo software version 12.0 plus. Thematic analysis summarized and grouped the raw data into four preliminary themes used to define occupant well-being which include comfort, health, adaptation behaviour, and safety preparedness. As a result, ‘occupant health’ was the most significant criterion (50.0%) for occupant well-being followed by ‘occupant comfort’ (27.5%), ‘occupant adaption’ (12.5%), and occupant safety (10.0%), as shown in Figure 2.7. The inner circle of the figure represents the significance of an IEQ factor to a well-being criterion. For instance, ‘indoor air quality’ (27.5%) had considerable effects on occupant health and was directly related to the occupant well-being. Based on fifteen IEQ parameters and four well-being criteria, a conceptual model was developed for policy makers to preserve a good indoor environment for better occupant well-being, and eventually improving the productivity of the employee.

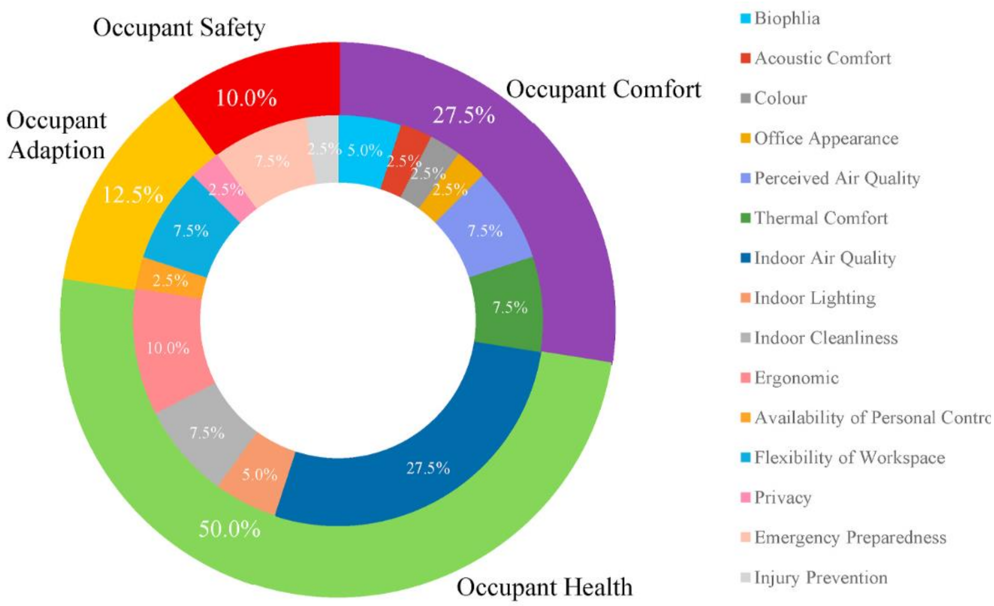

Figure 2.7: Well-being and IEQ Parameters (Mansor and Low, 2020).

Bae, et al. (2021) conducted an 11-year-benchmark study to obtain workplace occupants’ responses to 26 indoor IEQ factors related to thermal, indoor air quality, visual, and acoustic conditions. From 2009 to 2019, the survey was responded by 2386 occupants from 41 workplaces in the state of Minnesota, United States. Sustainable Post-Occupancy Evaluations Survey (SPOES) using a 7-point Likert scale was used in this study. The study results revealed that the occupants were satisfied to most of the IEQ factors in their primary workplace, except for the adjustability of the lighting and thermal conditions. They claimed that satisfying IEQ had positive impact on their work performance and health. Based on the results shown in Figure 2.8, losing the ability to hear desired sounds was found to be the paramount factor causing the occupants to dislike their primary workplace. Ability to hear desired sounds also being the key factor affecting the health of occupants. Apart from that, the lack of overall privacy caused the occupants to perceive negative on their work performance followed by other acoustical qualities. IEQ factors such as the thermal conditions, and cleaning and maintenance were the least significant to the dissatisfaction and a negative impact. Hence, Bae, et al. (2021) suggested that improving the acoustic and privacy would give the highest return to the organization in terms of increased satisfaction level and improved productivity.

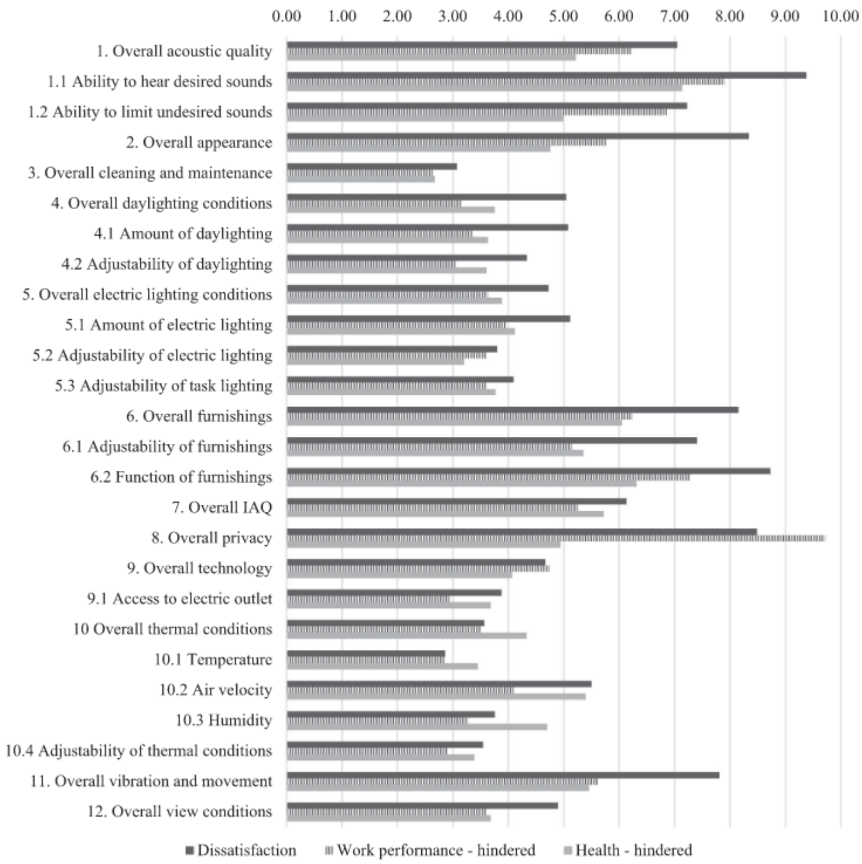

Figure 2.8: Correlation between IEQ Factors with Dissatisfaction Level, Work Performance, and Health (Bae, et al., 2021).

2.8 Summary

Conclusively, Chapter 2 elaborated the knowledge of four indoor environmental quality (IEQ) parameters including thermal comfort, indoor air quality, visual comfort, and acoustic comfort. The effects of the IEQ parameters on occupant health, comfort, and well-being were explored in literature (Yang, et al., 2017; Mujan, et al., 2019; Ganesh, et al., 2021). Furthermore, design standards established by Jabatan Kerja Raya (JKR, 2021) and the Department of Occupational Safety (DOSH, 2020) were discussed to understand the allowable limits for each IEQ parameter in office buildings. The last part of this chapter included several field studies to examine the actual behaviour of occupants towards IEQ, and IEQ effects on practical performance. Upon completion of Chapter 2, the author acquired substantial knowledge on indoor environmental quality to proceed with the study. Research gap was identified through this literature review where none of the research conducts a correlation study between indoor environmental quality and work productivity in Malaysia.

CHAPTER 3

METHODOLOGY

3.1 Introduction

This study adopted quantitative research in the process of data collection and data analysis. Data was analyzed to examine the correlation between indoor environmental quality (IEQ) and work productivity in office buildings. The primary reason choosing quantitative approach for a correlation study was because it fits the study purpose to test the strength of association between IEQ and work productivity.

The general flow of this study is presented in Figure 3.1. The research methodology was referred to a framework published by Andargie and Azar (2019) which consist of three main stages. The first stage was the development of the questionnaire survey after identifying the necessary metrics to be surveyed. A pilot test was conducted to check the feasibility of the survey prior to deployment. The second stage was data collection from the targeted respondents. Digital questionnaire survey using five-point Likert Scale was distributed to the respondents via Google Forms. The third stage was a data analytical process where reliability test, normality test, descriptive statistics analysis, and correlation analysis were performed using IBM SPSS Statistics 26. Upon completing the analysis, comprehensive reviews were made to discuss the results in detail followed by a conclusion and recommendations.

3.2 Survey Development and Testing

The first stage of the research involved entire development process of the questionnaire survey, and the testing held before the distribution of the survey. Development of survey started with identification of necessary metrics related to the study followed by a review of the designated questions.

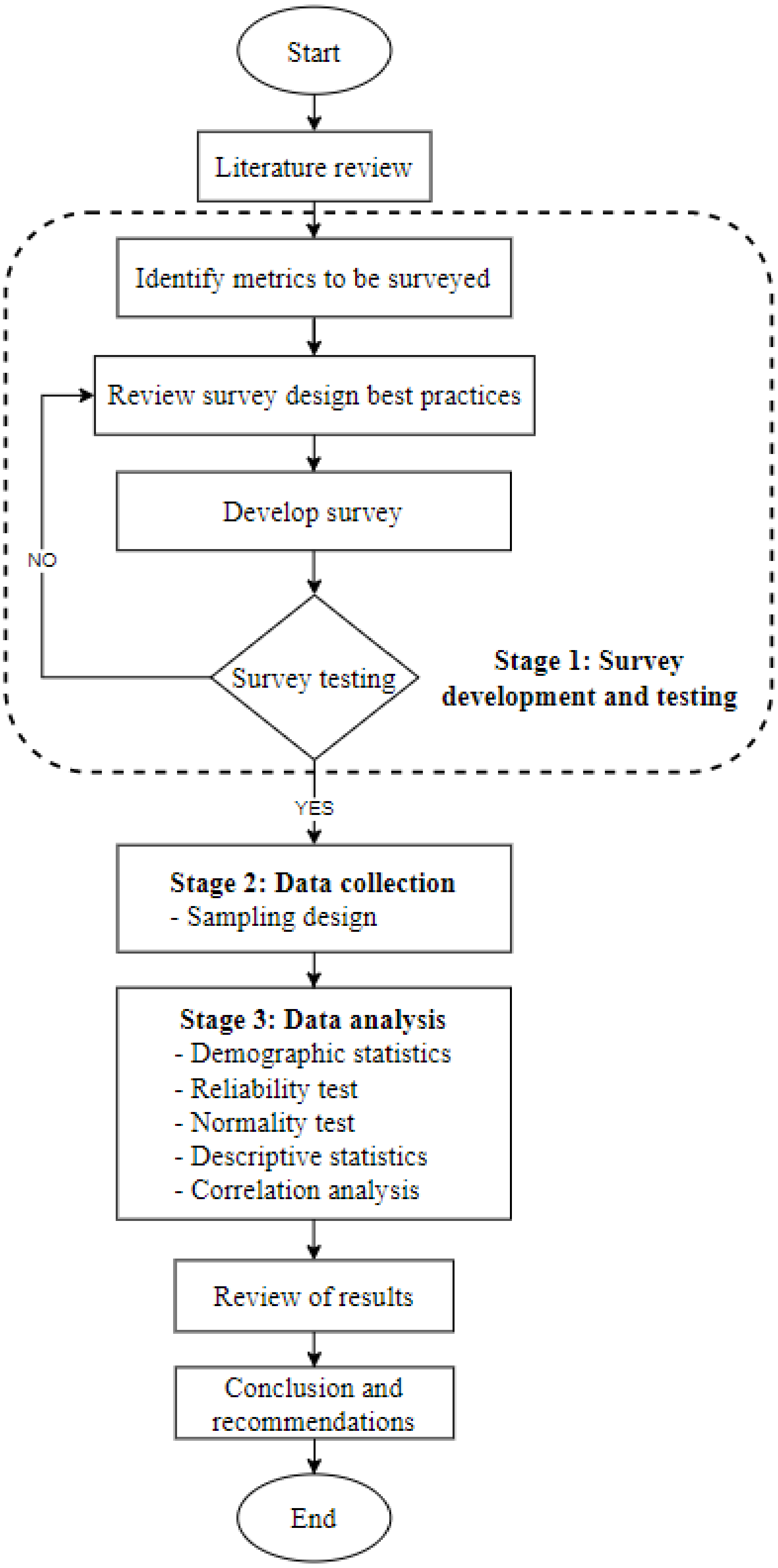

Figure 3.1: General Flow of the Quantitative Research.

3.2.1 Identify Metrics

Identification of metrics was the first step in the development of survey. Necessary metrics were outlined based on the literature by Sakellaris, et al. (2016), and Attia, et al. (2019), covering thermal, indoor air quality, visual, and acoustic. The metrics were revised to fit the objectives of this study and tabulated in Table 3.1.

Table 3.1: Metrics in the Survey (Sakellaris, et al., 2016; Attia, et al., 2019).

Category	**Survey Metric**
Demographic information	• Gender • Age
Thermal comfort	• Clothing level • Temperature • Humidity • Thermal satisfaction
Indoor air quality	• Odor • Ventilation • Indoor air quality satisfaction
Visual comfort	• Natural lighting • Artificial lighting • View from windows • Visual satisfaction
Acoustic comfort	• Noises from external environment • Noises within working space (e.g., phone calls, chatting, human movement, etc) • Noises from building systems (e.g., plumbing, heating, ventilation, etc) • Acoustic satisfaction

Table 3.1 (Continued)

Work productivity	• Work stress • Concentration at work • Monthly absenteeism • Symptom or illness (e.g. Irritation, dry cough, dizziness, headache, etc.) • Overall productivity

3.2.2 Develop Survey

Questionnaire survey was developed to evaluate the subjective perception of occupants with each identified metric. Five-point Likert scale was used to measure the strength of the perception where ‘1’ indicates unsatisfied, and ‘5’ indicates satisfied. The questionnaire was created using Google Forms so that it can be efficiently distributed online regardless of the pandemic restrictions. All the survey responses were time-stamped for documentation purposes. The estimated time taken to complete the survey was 8 to 10 minutes.

There were four major sections in the questionnaire survey. First section was to collect the demographic information of the occupants including their gender and age. Second section consist of questions to assess the perceived satisfaction on the IEQ metrics related to thermal comfort, indoor air quality, visual comfort, and acoustic comfort. Scaling and identification of the questionnaire items were referred to the literature by Sakellaris, et al. (2016) and ASHRAE (2017). Third section covered questions to assess the work productivity of the occupants. In practice, work productivity was usually measured by conducting physical tests within a defined period such as icon matching, number summing, and text memory and typing (Geng, et al., 2017). However, amidst Covid-19 pandemic, physical contacts were prohibited, making productivity testing difficult to be conducted. Therefore, in this study, the occupant work productivity was assessed by the perceived work stress, concentration to work, and monthly absenteeism. To finish, the fourth section was a participant consent form that outlines the purposes, procedures, risks, and confidentiality of the research. It was an important agreement between the researcher and the respondent to protect the rights and benefits of both parties. The preliminary items of the questionnaire survey are listed in Table 3.2.

Table 3.2: Questionnaire Items (Sakellaris, et al., 2016; ASHRAE, 2017).

Survey Metric	**Questionnaire Item**
Gender	Male, Female
Age	18 – 29, 30 – 39, 40 and above
Clothing level	Formal (e.g., suit jackets, long-sleeved shirt, trousers), Smart casual (e.g., long-sleeved shirt, trousers), Casual (e.g., short-sleeved collared shirt, trousers)
Temperature	Unsatisfied (1) – Satisfied (5)
Humidity	Unsatisfied (1) – Satisfied (5)
Thermal satisfaction	Unsatisfied (1) – Satisfied (5)
Odor	Unsatisfied (1) – Satisfied (5)
Ventilation	Unsatisfied (1) – Satisfied (5)
Indoor air quality satisfaction	Unsatisfied (1) – Satisfied (5)
Natural lighting	Unsatisfied (1) – Satisfied (5)
Artificial lighting	Unsatisfied (1) – Satisfied (5)
View from windows	Unsatisfied (1) – Satisfied (5)
Visual satisfaction	Unsatisfied (1) – Satisfied (5)
Noise from external environment	Unsatisfied (1) – Satisfied (5)
Noises from building systems	Unsatisfied (1) – Satisfied (5)
Noise within working space	Unsatisfied (1) – Satisfied (5)
Acoustic satisfaction	Unsatisfied (1) – Satisfied (5)
Work stress	Low (1) – High (5)
Concentration at work	Low (1) – High (5)
Monthly absenteeism	None (1) – Frequent (5)
Symptom or illness	None (1) – Frequent (5)
Overall productivity	Low (1) – High (5)

3.2.3 Survey Testing

Pilot test was performed to assess the competency of the survey, and the clarity, necessity, and intrusiveness of the questions (Andargie and Azar, 2019). Sample size for the pilot test was 10 and selected from the respondents discussed in Section 3.3.1. Any feedback from the respondents was recorded and adopted into consideration to modify and improve the survey.

After the pilot test, the feedback showed that the survey questions were generally clear, and sufficient to represent the field of study. A few comments were received and highlight in Table 3.3 with associated modification. Once the modification was deemed adequate, the survey can proceed to data collection using the finalized survey questionnaire attached in Appendix A.

Table 3.3: Comments Received in Pilot Test.

Comments	**Commented by**	**Modifications**
Unclear purpose of each section	Respondent 1, 3, 9, 10	Detail description was added to explain the purpose of each section.
Unclear options of "Clothing level".	Respondent 1, 4, 7, 9	Examples of clothing ensembles were added to each option.
Unclear meaning of "Symptom or illness".	Respondent 4, 7	Examples of SBS symptoms were added to the question.

3.3 Data Collection

Data collection was continued after the final survey was tested and reviewed. Data collection covered only office buildings in Klang Valley. The data collection period started on 1st January 2022 and ended on 31st January 2022. Throughout this period, digital questionnaire survey was distributed to the targeted respondents via Google Forms. Respondents were given 1 week to complete the survey and the completion date and time were time-stamped. Prior to start the data collection process, the researcher was required to sign the "Application for ethical clearance to involve human subjects in research" required by Universiti Tunku Abdul Rahman, to ensure the survey is ethically conducted in accordance with the industry best practices.

3.3.1 Sampling Design

Sampling is a process that retrieves a subset from a targeted population. Sampling design is crucial to ensure the approached group of respondents is capable to make inference about a population or generalize the relation of an existing theory (Taherdoost, 2016). The targeted population for this study included part-time, full-time, internship office workers who are currently stationed in Klang Valley. Concerning the sample size, Attia, et al. (2019) clarified that the rule-of-thumb for a survey is where the sample size should be at least five times as the number of questionnaire items in the survey. This statement was proven by Kim, et al. (2016) and Haapakangas, et al. (2018) who conducted identical quantitative research related to IEQ. Hence, in this study, the sample size required was set to 120, covering 22 questionnaire items.

Sampling technique used in this study was a type of non-probability sampling, known as snowball sampling. By snowball sampling, the few subjects recruited by the researcher will aid to distribute and spread the questionnaire survey within their social network for additional responses. The main reason of using snowball sampling was due to the difficulty in reaching a huge number of subjects during the Covid-19 pandemic movement constrained period. Hence, snowball sampling was an effective approach to obtain sufficient responses within the time constraint and physical restrictions.

3.4 Data Analysis

Data analysis is a process to transform the collected raw data into meaningful information for further interpretations and discussions. IBM SPSS Statistics 26 was the main tool to perform data analysis in this study. SPSS can perform various inferential statistical tests and yield quantitative results along with graphical representations. The following subchapters explain the data preparation processes and statistical tests involved in this study.

3.4.1 Data Preparation

First of all, the response rate of the questionnaire survey was calculated by dividing the number of responds received over the total number of distributed surveys, which is 120. Low response rates can lead to serious biasness in the results. Therefore, adequate response rate is important to draw valid and reliable research findings (Fellows and Liu, 2015).

After that, each survey metric included in the questionnaire survey was transformed into separate variable for data analysis. Prior to analysis, the variables were entered into SPSS with defined variable name, data type, and data measurement, as tabulated in Table 3.4.

Table 3.4: SPSS Variables.

Variable Name	**Data Type**	**Measurement**
Gender	Numeric	Nominal
Age_group	Numeric	Nominal
Clothing_level	Numeric	Nominal
Temperature	Numeric	Scale
Humidity	Numeric	Scale
Thermal_satisfaction	Numeric	Scale
Odor	Numeric	Scale
Ventilation	Numeric	Scale
IAQ_satisfaction	Numeric	Scale
Natural_lighting	Numeric	Scale
Artificial_lighting	Numeric	Scale
View_from_windows	Numeric	Scale
Visual_satisfaction	Numeric	Scale
External_noises	Numeric	Scale
Internal_noises	Numeric	Scale
Noise_from_building_systems	Numeric	Scale
Acoustic_satisfaction	Numeric	Scale
Stress_level	Numeric	Scale
Concentration_on_work	Numeric	Scale
Monthly_absenteeism	Numeric	Scale
Symptom_or_illness	Numeric	Scale
Overall_productivity	Numeric	Scale

3.4.2 Reliability Test

Reliability indicates the consistency of the survey responses. Also, reliability reflects the robustness of the questionnaire, particularly, it can yield consistent findings at different time frames and under different conditions (Saunders, et al., 2019). Internal consistency is one of the reliability measures, by correlating the consistency between multiple variables. Cronbach's alpha coefficient is used to check the reliability of the questionnaire. Table 3.5 shows the internal consistency rating of a data set based on different Cronbach's alpha coefficient ranges. According to Collis and Hussey (2014), the questionnaire is deemed reliable, if the Cronbach's alpha coefficient is greater than 0.8. Before running the Cronbach's alpha test, all the negatively worded variables were recoded to positive scores to make sure all the variables were tested under similar scaling approach. The ratings of 'stress level', 'monthly absenteeism', and 'symptom or illness' were converted from 1, 2, 3, 4, 5 to 5, 4, 3, 2, 1, respectively.

Table 3.5: Cronbach's Alpha Coefficient (Collis and Hussey, 2014).

Cronbach's Alpha	Internal Consistency
$\alpha \geq 0.9$	Excellent
$0.9 > \alpha \geq 0.8$	Good
$0.8 > \alpha \geq 0.7$	Acceptable
$0.7 > \alpha \geq 0.6$	Questionable
$0.6 > \alpha \geq 0.5$	Poor
$0.5 > \alpha$	Unacceptable

3.4.3 Normality Test

Normality test verifies the clustering of data values around the variable's mean in a bell-shaped pattern, forming a symmetrical frequency distribution condition (Saunders, et al., 2019). Kolmogorov-Smirnov test, and Shapiro-Wilk test are two common normality tests in quantitative research. According to Mishra, et al. (2019), the Shapiro-Wilk test is recommended for small sample size that is less than 50, while Kolmogorov-Smirnov test is recommended for larger sample size that is more than 50. The sample size of this study was 120. Hence, Kolmogorov-Smirnov test was selected to check the normality of the data. The Kolmogorov-Smirnov test creates a null hypothesis declares that the normal distribution of the data. When P is larger than 0.05 ($P > 0.05$), the null hypothesis is accepted, and the data are deemed normally distributed.

Additionally, the skewness and kurtosis of the data distribution were tested. Skewness represents the degree of asymmetry of the distribution, while kurtosis indicates the peakedness of the distribution. A distribution is deemed approximate normal if the value of skewness and kurtosis were both ranged between –1 and +1. However, for sample size that is less than 300, it is recommended to test normality using the Z score of skewness and kurtosis. For medium-sized sample ($50 \leq n \leq 300$), distribution is concluded normal if the absolute Z score was ± 3.29 (Mishra, et al., 2019).

3.4.4 Descriptive Statistics

Descriptive statistics provide statistical descriptions and comparisons between variables' data values. Descriptive statistics summarize the data values in a more compact form that can be visualized in histograms, charts, and other form of graphics. Univariate descriptive analysis was carried out to explore the data from individual variables. The central tendency of the distribution was measured using mode, median, and mean. Mode indicates the value that has the highest frequency, median indicates the middle value of the data set, and mean computes the average of all the data values. Furthermore, variance and standard deviation were measured to describe the variability of the data values from the mean (Saunders, et al., 2019). Descriptive statistics results were used to explore the first and second objective of this study, which is to investigate office occupants' perception towards IEQ, and to determine their work productivity.

3.4.5 Correlation Analysis

Correlation analysis is a type of inferential statistics that verify the presence of relationships between pairs of numerical variables. Furthermore, the strength of the relationship is determined by the magnitude of the correlation coefficient. Correlation coefficient is ranged between +1 and –1. The strength of correlation of respective correlation coefficient is tabulated in Table 3.6 (Saunders, et al., 2019). Pearson's correlation and Spearman's correlation are two common methods in correlation analysis. Pearson's correlation is recommended for parametric distribution, while Spearman's correlation is recommended for non-parametric distribution. Spearman's correlation was chosen in study because the normality test results showed that the data was non-parametric.

Table 3.6: Correlation Coefficient (Saunders, et al., 2019).

Correlation Coefficient, r	**Correlation strength**
$r = 1$	Perfect
$1 > r \geq 0.8$	Very strong
$0.8 > r \geq 0.6$	Strong
$0.6 > r \geq 0.35$	Moderate
$0.35 > r \geq 0.2$	Weak
$0.2 > r \geq 0$	None

3.5 Summary

There were three main stages in the research methodology. The first stage was survey development and testing. Relevant survey metrics were identified covering thermal comfort, indoor air quality, visual comfort, acoustic comfort, and work productivity. Digital questionnaire survey was created using Google Forms with a Five-point Likert scale. A pilot test was performed in a size of 10. Then, the second stage was data collection. Surveys were distributed to office occupants working in Klang Valley, and the sample size was 120. Lastly, the third stage was data analysis using IBM SPSS Statistics 26. Four statistical analyses were performed including: reliability test, normality test, descriptive statistics analysis, and Spearman's correlation analysis.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

This study implemented quantitative research methodology using questionnaire survey. The raw data collected from the survey was analyzed using IBM SPSS Statistics 26. Statistical tests were performed to obtain information including respondents' demographic, internal reliability, normality, descriptive statistics, and variables' correlation. Statistical results were interpreted to examine the occupants' satisfaction towards IEQ, overall productivity, and the correlation between IEQ and work productivity. The findings were published and discussed with relevant literature in this chapter.

4.2 Response Rate

Response rate was computed by dividing the number of responses collected over the total number of surveys distributed. Based on Table 4.1, there were 104 valid responses collected out of 120 distributed surveys, and the response rate was 86.67%. According to Saunders (2019), response rates of approximately 50% are reasonable and sufficient for academic studies. Therefore, the response rate of this study was concluded satisfying, and the study was valid.

Table 4.1: Response Rate of Survey.

	Frequency	**Precent**
Valid responses	104	86.67
Missing responses	16	13.33
Total	120	100.00

4.3 Demographic Statistics

Demographic statistics elaborates population-based information such as the gender and age of the respondents. Demographic statistics were included in to understand the background characteristics of the respondents, thus, improving the relevancy of the later discussions. Demographic statistics were visualized into graphical form using SPSS templates. Table 4.2 and Figure 4.1 show the gender distribution of the respondents. There were 80.8% of male respondents, and 19.2% female respondents participated in the survey. Imbalance of the gender distribution can be explained due to most of the surveys were distributed to construction offices where more males are involved. Table 4.3 and Figure 4.2 show the age group of the respondents. There were 66.3% respondents aged 18 to 29, 27.9% aged between 30 to 39, and 6% aged 40 and above.

Table 4.2: Gender Distribution of Respondents.

		Frequency	**Percent**	**Valid Percent**	**Cumulative Percent**
Valid	Male	84	80.8	80.8	80.8
	Female	20	19.2	19.2	100.0
	Total	104	100.0	100.0	

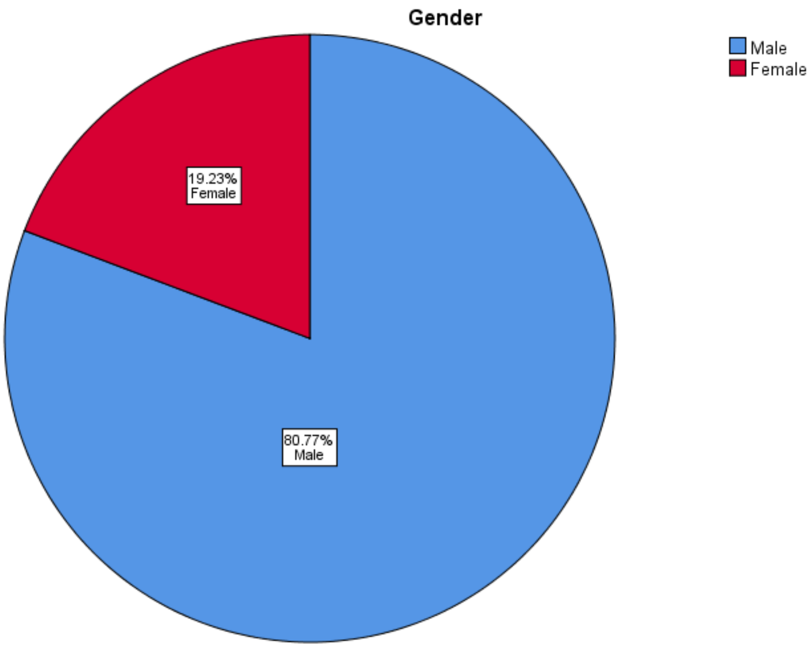

Figure 4.1: Gender Distribution of Respondents.

Table 4.3: Age Group Distribution of Respondents.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	18-29	69	66.3	66.3	66.3
	30-39	29	27.9	27.9	94.2
	40 and above	6	5.8	5.8	100.0
	Total	104	100.0	100.0	

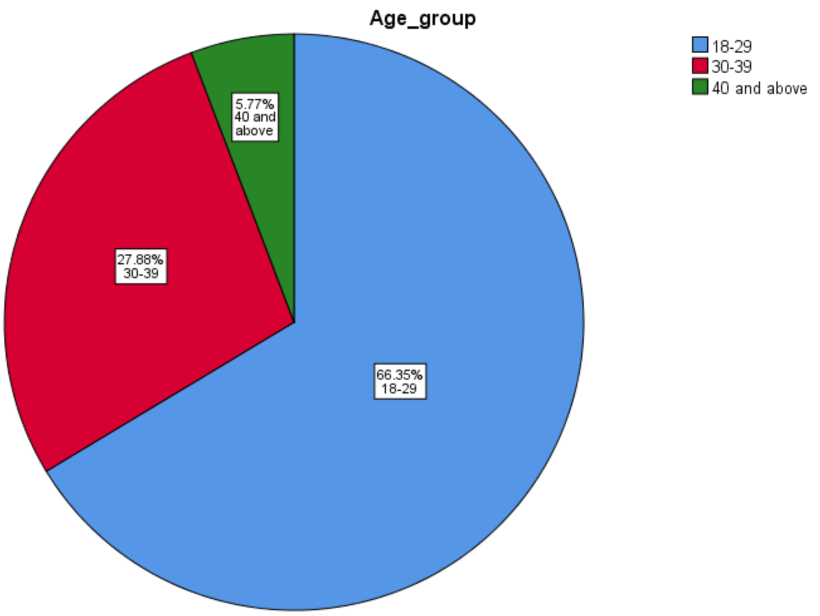

Figure 4.2: Age Group Distribution of the Respondents.

4.4 Reliability Test

Reliability test was performed in SPSS, and the results are shown in Table 4.4. A total of 20 questionnaire items were tested. Cronbach's Alpha coefficient that employs the covariance among the items was 0.916, while the Cronbach's Alpha based on standardized items coefficient that employs the correlations among the items was 0.919. Both Cronbach's Alpha coefficients were greater than 0.9. The variables were deemed to have excellent internal consistency; therefore, the results were accepted and reliable.

Table 4.4: Cronbach's Alpha Coefficient.

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.916	.919	20

4.5 Normality Test

Normality test was completed using SPSS to yield both Kolmogorov-Smirnov and Shapiro-Wilk statistics. Kolmogorov-Smirnov results were utilized in this study because the sample size was 120, which was larger than 50. Kolmogorov-Smirnov test declared a null hypothesis stated that a distribution is normal when P is larger than 0.05. Based on Table 4.5, none of the data variables had P larger than 0.05, hence, the data was not normally distributed.

Additionally, based on Table 4.6, the skewness and kurtosis Z-scores further verified that the distribution is not normal because the Z scores were greater than the absolute value of ± 3.29. Besides, the IEQ variables and overall productivity had negative skewness that indicates a left-skewed distribution. Variables such as 'stress level', 'monthly absenteeism', and 'symptom and illness' had positive skewness that indicates a right-skewed distribution. Based on the skewness of the data, it can be reasonably deduced that the occupants in Klang Valley are satisfied with the IEQ in their office, working with high productivity, and having low stress, monthly absenteeism, and symptoms. These conditions gave a brief response regarding the first two objectives of this study, which are to examine the IEQ satisfaction and work productivity of the occupants. In-depth investigation of these objectives was carried out in the following analyses.

Table 4.5: Normality Test Results.

	Kolmogorov-Smirnov		**Shapiro-Wilk**	
	Statistic	**P**	**Statistic**	**P**
Clothing level	0.463	0.000	0.548	0.000
Temperature	0.307	0.000	0.726	0.000
Humidity	0.317	0.000	0.719	0.000
Thermal satisfaction	0.340	0.000	0.698	0.000
Odor	0.317	0.000	0.728	0.000
Ventilation	0.317	0.000	0.735	0.000
IAQ satisfaction	0.294	0.000	0.738	0.000
Natural lighting	0.315	0.000	0.697	0.000
Artificial lighting	0.363	0.000	0.683	0.000
View from windows	0.288	0.000	0.737	0.000
Visual satisfaction	0.356	0.000	0.693	0.000
External noises	0.365	0.000	0.672	0.000
Internal noises	0.358	0.000	0.680	0.000
Noises from building systems	0.350	0.000	0.674	0.000
Acoustic satisfaction	0.363	0.000	0.668	0.000
Stress level	0.333	0.000	0.701	0.000
Concentration at work	0.364	0.000	0.673	0.000
Monthly absenteeism	0.368	0.000	0.662	0.000
Symptom or illness	0.364	0.000	0.673	0.000
Overall productivity	0.375	0.000	0.659	0.000

Table 4.6: Skewness and Kurtosis Results.

	Skewness		Kurtosis	
	Statistic	**Z-score**	**Statistic**	**Z-score**
Clothing level	-1.809	-7.633	1.977	8.342
Temperature	-1.563	-6.595	2.967	12.519
Humidity	-1.584	-6.684	2.662	11.232
Thermal satisfaction	-1.676	-7.072	2.845	12.004
Odor	-1.344	-5.671	1.426	6.017
Ventilation	-1.248	-5.266	1.453	6.131
IAQ satisfaction	-1.294	-5.460	1.519	6.409
Natural lighting	-1.741	-7.346	3.589	15.143
Artificial lighting	-1.548	-6.532	1.819	7.675
View from windows	-1.483	-6.257	3.236	13.654
Visual satisfaction	-1.678	-7.080	3.121	13.169
External noises	-1.818	-7.671	3.529	14.890
Internal noises	-1.752	-7.392	3.020	12.743
Noise from building systems	-1.837	-7.751	3.605	15.211
Acoustic satisfaction	-1.834	-7.738	3.408	14.380
Stress level	1.504	6.346	2.032	8.574
Concentration at work	-1.778	-7.502	3.086	13.021
Monthly absenteeism	1.812	7.646	3.027	12.772
Symptom or illness	1.778	7.502	3.086	13.021
Overall productivity	-1.833	-7.734	3.231	13.633
Skewness Std, Error 0.237				
Kurtosis Std, Error 0.469				

4.6 Descriptive Statistics

Descriptive statistics were generated using SPSS with useful information such as mean, standard deviation, and variance, as shown in Table 4.7. Mean captures an average value of all the survey responses. Mean was used to describe the occupants' satisfaction level on office IEQ, and their productivity level during work, which was related back to first two objectives of the study. Furthermore, standard deviation and variance were used to assess the dispersion of data. Small dispersion of the data implies the mean represents the data effectively, while large dispersion implies the mean is inadequate to represent the dispersed data values (Collis and Hussey, 2014). The descriptive statistics showed that the standard deviation and variance were less than 1, thus, the mean was concluded representative. In the following subchapters, the descriptive statistics of each IEQ parameters and work productivity were discussed.

Table 4.7: Descriptive Statistics.

No.	Item	N	Mean	S.D.	Var.
(1)	Temperature	104	4.38	0.815	0.664
(2)	Humidity	104	4.38	0.850	0.722
(3)	Thermal satisfaction	104	4.41	0.855	0.730
(4)	Odor	104	4.38	0.815	0.664
(5)	Ventilation	104	4.40	0.744	0.554
(6)	IAQ satisfaction	104	4.35	0.798	0.636
(7)	Natural lighting	104	4.40	0.819	0.670
(8)	Artificial lighting	104	4.45	0.823	0.677
(9)	View from windows	104	4.36	0.775	0.600
(10)	Visual satisfaction	104	4.45	0.811	0.658
(11)	External noises	104	4.47	0.824	0.679
(12)	Internal noises	104	4.44	0.857	0.735
(13)	Noises from building systems	104	4.45	0.835	0.697
(14)	Acoustic satisfaction	104	4.46	0.847	0.717
(15)	Stress level	104	1.58	0.797	0.635
(16)	Concentration at work	104	4.45	0.858	0.736
(17)	Monthly absenteeism	104	1.55	0.880	0.774

Table 4.7 (Continued)

(18)	Symptom or illness	104	1.55	0.858	0.736
(19)	Overall productivity	104	4.47	0.859	0.737

4.6.1 Thermal Comfort

Table 4.8 shows the clothing level of the office occupants. Three types of clothing ensembles were assessed: formal, smart casual, and casual. The insulation value for casual wear is 0.57 clo, smart casual wear is 0.61 clo, and formal wear is 0.96 clo (AHSRAE, 2017). In Klang Valley offices, 76.9% of the occupants were casually dressed in light clothing such as short-sleeved collared shirt and trousers; 14.4% were dressed in moderate clothing such long-sleeved shirt and trousers; and 8.7% were dressed formally in suit jackets. Formal clothing had the least percentage, and it can be due to the fact that the local weather is too hot to dress formally. Conversely, most of the office occupants were dressing casually to feel more comfortable. This finding is in line with the study by Fukawa, et al. (2021) which found that majority of office occupants wore light clothing ensembles (0.30 – 0.59 clo) hot and humid climates of Asia.

Item (1), (2), and (3) reveal the occupants' perception towards thermal comfort. The mean of temperature, and humidity were both 4.38. Subsequently, high satisfaction level on temperature and humidity resulted in high thermal satisfaction level with a mean of 4.41. A similar conclusion was reached by Ganesh, et al. (2021) who stated that in humid tropical climates, occupants were thermally satisfied at optimum indoor temperature between 23.5 °C and 26.8 °C with a relative humidity of 60%.

Table 4.8: Clothing Level of Respondents.

		Frequency	**Percent**	**Valid Percent**	**Cumulative Percent**
Valid	Formal	9	8.7	8.7	8.7
	Smart casual	15	14.4	14.4	23.1
	Casual	80	76.9	76.9	100.0
	Total	104	100.0	100.0	

4.6.2 Indoor Air Quality

Item (4), (5), and (6) show the occupants' perception towards indoor air quality. Mean of odor and ventilation were 4.38, and 4.40 respectively. This confirmed that the offices in Klang Valley had low odor intensity and sufficient ventilation intensity which could be achieved by having effective HVAC systems, and natural ventilation channels. Mean of IAQ satisfaction was 4.35. It had also proven that the occupants were satisfied with the IAQ in their offices. These findings are consistent with Kraus and Senitkova (2019) showing that the perceived air quality was more satisfying when odor intensity was decreased, and ventilation intensity was increased.

4.6.3 Visual Comfort

Item (7), (8), (9), and (10) show the occupants' perception towards visual comfort. The occupants were satisfied with both natural lighting and artificial lighting where the means were 4.40 and 4.45 respectively. This showed that sufficient illumination was acquired through penetration of sunlight from windows and the building lighting systems. External views through windows were deemed satisfying and had a mean of 4.36. Consequently, fulfilment of these three factors lead to a high visual satisfaction level with a mean of 4.45. Likewise, the findings are directly in line with Altomonte, et al. (2017) which found that an effective design of lighting system was a combination of proper daylight strategies, mechanical lightings, and the presence of external views.

4.6.4 Acoustic Comfort

Item (11), (12), (13), and (14) show the occupants' perception towards acoustic comfort. External noises such as traffic noises had a mean of 4.47; internal noises such as conversations between colleague had a mean of 4.44; and noises from building systems such as HVAC systems had a mean of 4.45. It was obvious that the occupants were satisfied with the acoustic environment in their offices, therefore, the overall acoustic satisfaction had a mean of 4.46. These results are broadly in line with Kang, et al. (2022) who stated that noise level is an important index to assess the acoustic comfort in open-plan offices. Jegen and Chevret (2017) discovered a negative relationship was found between perceived noise level, and indoor environment satisfaction. Office occupants felt more discomfort when noises such as intelligible conversations and telephone calls were generated continuously and loudly.

4.6.5 Work Productivity

Item (15), (16), (17), (18) and (19) show the occupants' work productivity statistics. Mean of 4.45 indicated that the occupants can pay high concentration at their work in the offices, thus they were more productive. This is consistent with what has been proposed by Ueda, et al. (2017) where improving the depth of concentration can effectively improve the intellectual productivity of more complex tasks. Conversely, stress level, monthly absenteeism, and presence of symptom or illness were worded negatively. Hence, low mean values indicated a more favourable condition for these parameters. In fact, the occupants were working in a less depressing environment as shown by the mean of 1.58. Mean of monthly absenteeism and presence of symptom were both 1.55. This revealed that the occupants were less likely to have SBS symptoms or illnesses during work, and therefore could always attend to work. Conclusively, the office occupants were generally working with high productivity with a mean of 4.47. These findings lead to similar conclusion where the tested parameters can substantially assess work productivity. Yazdanirad, et al. (2021) found out that during a pandemic, workers had reduced productivity due to increased job stress increased and decreased workers' resilience. Uribe, et al. (2017) stated that absenteeism made up to 43 hours of productivity losses in Cities of Columbia, and it was accounted to US $840 million. Studies also confirmed that sick building syndrome (SBS) comprises of various symptoms and illnesses was a significant problem that caused a decrease in productivity of office occupants. (Joshi, 2008; Redman, et al., 2010).

4.6.6 IEQ Satisfaction between Genders

Table 4.9 shows the satisfaction level towards IEQ between male and female. The results of mean clearly show that male had lower satisfaction towards IEQ than female. Besides, as compared to female, male was found to have higher stress level, monthly absenteeism, and likelihood to have SBS symptoms. Consequently, the results deduced that male was more sensitive to hygiene factors in the indoor environment, and therefore had lower satisfaction towards

IEQ than female. This finding was supported with the study by Sakellaris, et al. (2016) stating that male was more sensitive to IEQ than female. Male was found to have higher association with visual and acoustic parameters such as “noise from the building systems” and “view from the windows”. On the other hand, the difference of satisfaction between genders could be attributed to the imbalance of gender distribution of the respondents. As discussed in subchapter 4.3, majority of the respondents in this study were male (80.8%) rather than female (19.2%). Hence, higher population of male might cause more dissatisfaction results to be captured in this study.

Table 4.9: IEQ Satisfaction between Genders.

No.	**Item**	**N**	**Male Mean**	**Female Mean**
(1)	Temperature	104	4.32	4.60
(2)	Humidity	104	4.31	4.65
(3)	Thermal satisfaction	104	4.36	4.65
(4)	Odor	104	4.32	4.60
(5)	Ventilation	104	4.37	4.55
(6)	IAQ satisfaction	104	4.27	4.65
(7)	Natural lighting	104	4.33	4.70
(8)	Artificial lighting	104	4.39	4.70
(9)	View from windows	104	4.30	4.60
(10)	Visual satisfaction	104	4.37	4.80
(11)	External noises	104	4.38	4.85
(12)	Internal noises	104	4.36	4.80
(13)	Noises from building systems	104	4.39	4.70
(14)	Acoustic satisfaction	104	4.38	4.80
(15)	Stress level	104	1.63	1.35
(16)	Concentration at work	104	4.37	4.80
(17)	Monthly absenteeism	104	1.61	1.30
(18)	Symptom or illness	104	1.63	1.20
(19)	Overall productivity	104	4.32	4.60

4.7 Correlation Analysis

Correlation analysis was performed using SPSS to analyze the effect of indoor environment quality towards work productivity, which fulfilled the third objective of this study. Spearman's correlation was implemented instead of Pearson's correlation because the data was determined to be non-parametric, and monotonic. Furthermore, Spearman's correlation is recommended for ranked values for each variable such as Likert scale data which are ordered from unsatisfactory to satisfactory (Saunders, et al., 2019). The correlation between each IEQ parameters and work productivity were presented in Table 4.10.

Table 4.10: Correlation between IEQ and Work Productivity.

No.		**Spearman's Coefficient, *r***	**Sig. (2-tailed)**	**N**
Correlated to: Overall productivity				
(1)	Temperature	0.720**	0.000	104
(2)	Humidity	0.749**	0.000	104
(3)	Thermal satisfaction	0.794**	0.000	104
(4)	Odor	0.739**	0.000	104
(5)	Ventilation	0.713**	0.000	104
(6)	IAQ satisfaction	0.779**	0.000	104
(7)	Natural lighting	0.790**	0.000	104
(8)	Artificial lighting	0.894**	0.000	104
(9)	View from windows	0.762**	0.000	104
(10)	Visual satisfaction	0.941**	0.000	104
(11)	External noises	0.936**	0.000	104
(12)	Internal noises	0.894**	0.000	104
(13)	Noises from building systems	0.841**	0.000	104
(14)	Acoustic satisfaction	0.904**	0.000	104

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

4.7.1 Correlation between Thermal Comfort and Work Productivity

Item (1), (2), and (3) show the correlation between thermal comfort and work productivity. Spearman's correlation coefficient revealed that there were strong, positive, and statistically significant correlation between temperature and work productivity (r = 0.720, n = 104, p < .001), between humidity and work productivity (r = 0.749, n = 104, p < .001), and between thermal satisfaction and work productivity (r = 0.794, n = 104, p < .001). Strong and positive correlations between thermal comfort parameters and work productivity confirmed that office occupants would be more productive when they were satisfied with the temperature, humidity, and the overall thermal environment of their offices. Overall, these findings are in accordance with findings reported in previous studies. Geng, et al. (2017) experimented that, in China offices, occupants were working under optimal productivity at 24 °C, and the increase of thermal satisfaction had positive influence on productivity. Richardson, et al. (2018) conducted research in England, and revealed that office occupants feel more productive in a warm condition ranged between 23.5 °C and 26.8 °C than a cold environment. Additionally, Kaushik, et al. (2020) reported that temperature and relative humidity were the most important parameters that influenced the perception of thermal comfort and occupant productivity in office buildings.

4.7.2 Correlation between Indoor Air Quality and Work Productivity

Item (4), (5), and (6) shows the correlation between indoor air quality (IAQ) and work productivity. Strong, positive, and statistically significant correlation were identified between odor and work productivity (r = 0.739, n = 104, p < .001), between ventilation and work productivity (r = 0.713, n = 104, p < .001), and between IAQ satisfaction and work productivity (r = 0.779, n = 104, p < .001). Likewise, these strong and positive correlations showed that occupants were more productive when the IAQ was at satisfaction level. Hence, pleasant odor, high ventilation rates, and satisfying overall IAQ were deemed to be three important elements in creating a productive working environment. A similar pattern of results was obtained in previous studies related to IAQ and work productivity. Wargocki (2019) found that unpleasant odor and poor IAQ created cognitive issues such as distress, distraction, anxiety, and demotivation to both employee and the employer, which had eventually caused reduced work productivity. Furthermore, he also found that ventilation was equally important such that effective exchange of indoor polluted air with outdoor fresh air had distinct improvement to the work productivity. Studies also discovered that high CO_2 concentrations due to ineffective ventilation can cause declination in work productivity (Hong, et al., 2018; Azuma, et al., 2018). Lastly, Snow, et al., (2019) highlighted the severity of poor IAQ that deteriorated the occupants' ability on decision-making, learning, and performing cognitive tasks.

4.7.3 Correlation between Visual Comfort and Work Productivity

Item (7), (8), (9) and (10) show the correlation between visual comfort and work productivity. Strong, positive, and statistically significant correlation were identified between natural lighting and work productivity ($r = 0.790$, $n = 104$, $p < .001$), and between view from windows and work productivity ($r = 0.762$, $n = 104$, $p < .001$). Meanwhile, stronger correlations were found between artificial lighting and work productivity ($r = 0.894$, $n = 104$, $p < .001$), and between visual satisfaction and work productivity ($r = 0.941$, $n = 104$, $p < .001$). The results demonstrated two findings: firstly, it was undeniable that visual environment had significant impacts on work productivity in offices; secondly, the difference in correlation strength revealed that artificial lighting and overall visual satisfaction seems to be more prominent, compared to natural lighting and external view through windows. Under knowledgeable inferences, the second finding was construed as artificial lighting can create greater and clearer illuminance for task performance, as well as overall visual satisfaction. Moreover, penetration of natural lighting was uncertain and unpredictable depending on weather conditions such as cloudy days and during the sunset. There were also limited fascinating views through windows since the offices were in the city centre of Klang Valley. Nonetheless, the first finding is clearly in line with findings in previous studies. Wang and Luo (2016) stated that occupants working under optimum lighting condition could have increased typing speed, improved visual capability, less fatigue, and improved alertness and concentration level. Conversely, Katabaro and Yan (2019) found that poor lighting design techniques in Tanzania offices had led to severe declination in work productivity. Additionally, it also carried detrimental health issues to the occupants such as eyestrain, headache, and ergonomic injuries. Kogo, et al. (2019) the combined effect of satisfying indoor temperature and ambient illuminance could minimize the drowsiness level of office occupants and escalate their work productivity. Lastly, Deng, et al. (2021) and Hwang, et al. (2022) agreed that adequate illuminance had positive effects on occupants' work engagement, health, well-being, and productivity.

4.7.4 Correlation between Acoustic Comfort and Work Productivity

Item (11), (12), (13) and (14) show the correlation between acoustic comfort and work productivity. Unlike other IEQ parameters, all the acoustic comfort parameters had very strong, positive, and statistically significant correlation with work productivity including correlation between external noises and work productivity (r = 0.936, n = 104, p < .001), between internal noises and work productivity (r = 0.894, n = 104, p < .001), between building systems noises and work productivity (r = 0.841, n = 104, p < .001), and between overall acoustic satisfaction and work productivity (r = 0.904, n = 104, p < .001). These results showed that acoustic comfort was paramount to occupants' work productivity, compared to other IEQ parameters. It is reasonable to conclude that external noises such as traffic noises and internal noises such as conversations between colleague had considerable effect on work productivity. These noises can potentially distract occupants from their work and interrupt their work progress. Meanwhile, noises from the building systems such as the HVAC system had relatively lower impact on work productivity because part of these noises were considered as masking noises. Masking noises are sometimes beneficial in working environment in improving concentration and work productivity (Vassie and Richardson, 2017). Strong correlation between acoustic comfort and work productivity can also be supplemented by existing studies. Jahncke, et al. (2011) and Akbari (2013) reported that occupants who working in noisy environment might have declined memory performance, more tiredness, less motivation, and less productive. Jegen and Chevret (2017) found that office occupants were affected by surrounding noises and had their concentration disrupted from on-going tasks. Kang, et al. (2017) showed that among various IEQ aspects, acoustic comfort appeared to have the greatest impact on work productivity. Specifically, conversation noises were the most disturbing factor, while quietness was the leading criterion in achieving acoustic comfort. Kang, et al. (2022) also reported that acoustic inference can cause lost in concentration and decreased problem-solving speed.

4.8 Summary

Chapter 4 included statistical results generated using IBM SPSS Statistics 26, along with detail discussions and interpretation of the results. The chapter was started with the survey response rate followed by demographic statistics of the respondents. Cronbach's Alpha reliability test was performed and proven that the results were consistent and reliable. After that, Kolmogorov-Smirnov normality test was performed and proven that the data was non-parametric. Descriptive statistics were generated to answer the first and second objective of this study. Based on the descriptive statistics, the office occupants in Klang Valley were observed to have high satisfaction level on perceived indoor environmental quality (IEQ) in their offices, and high work productivity. Lastly, Spearman's correlation analysis was performed to investigate the correlation between IEQ and work productivity. The results showed that all the IEQ parameters had at least strong, positive, and statistically significant correlation with work productivity. Acoustic comfort appeared to be the most impactful factor affecting work productivity followed by visual comfort, IAQ, and thermal comfort. Current findings were supported with relevant literature to improve the credibility of the study.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

In conclusion, quantitative research was completed using digital questionnaire survey, and statistical results were generated using IBM SPSS Statistics 26. Four major indoor environmental qualities (IEQ) including thermal comfort, indoor air quality (IAQ), visual comfort, and acoustic comfort were investigated. Occupants' satisfaction towards IEQ and overall productivity were examined in the survey. Eventually, the quantitative data was used to analyze the correlation between the IEQ and work productivity.

The first objective is to investigate office occupants' satisfaction towards indoor environmental quality in their workplace. Occupants were requested to indicate their satisfaction level using a Five-point Likert scale. Collected data was then processed into descriptive statistics in Chapter 4. Based on Table 4.7, all the IEQ parameter had mean value greater than 4. Hence, it can be concluded that the office occupants were generally satisfied with the IEQ in their offices.

The second objective is to determine the work productivity of the occupants. Work productivity was measured in terms of stress level, concentration at work, monthly absenteeism, and presence of symptoms or illnesses during work. Similarly, the perceived work productivity of the occupants was determined using Five-point Likert scale and analyzed using descriptive statistics. Based on Table 4.7, the occupants were known to have less stress, high concentration at work, low monthly absenteeism, and less likely to have SBS symptoms or illnesses during work. Subsequently, they were being productive during work.

The third objective is to analyze the correlation between IEQ and work productivity. Spearman's correlation analysis was performed using SPSS. According to the results tabulated in Table 4.10, the correlation between all the IEQ parameters and work productivity were discovered to be strong or very strong, positive, and statistically significant. Strong and positive confirmed that satisfying IEQ can result in higher work productivity. Additionally, acoustic parameters such as external noises and internal noises were paramount factors affecting work productivity. Visual comfort was ranked second followed by IAQ and thermal comfort.

The accomplishment of all the study objectives had contributed to the achievement in the study's aim to conduct a correlation study between IEQ and work productivity in Malaysia.

This study looks forward to providing an insight for building designers, policy makers, and business owners regarding the vital effect of IEQ on work productivity in office buildings. It is suggested that work productivity could be considered as a prominent factor in the design of office buildings. Typically, business owners would contribute least effort in IEQ due to the additional costs incurred for systems installation and maintenance, and increased energy consumption. However, good IEQ can improve the occupants' health, comfort, well-being, as well as their work productivity. Subsequently, these productive workers can generate more profit for an organization in a long run.

5.2 Recommendations

Notwithstanding the findings of this study, there is room for improvements and modifications to match various aims and objectives in future studies. Hence, the following recommendations are proposed.

Firstly, there are limitations in that quantitative approach using digital questionnaire survey could be insufficient for in-depth exploration of the occupants' satisfaction towards IEQ. Questionnaire survey does not provide the opportunity for the occupants to generate detail explanation regarding their feelings. It is suggested that qualitative method such as face-to-face interview as a supplement approach to improve the integrity of the study. Mixed method research by Kim, et al. (2016) is a good reference. The author had first distributed questionnaire to the targeted respondents to record the occupants' satisfaction levels for key IEQ related workplace issues. After that, the survey respondents were asked to elaborate their opinions on these issues via open-ended questions on a voluntary basis.

Secondly, recommendations are proposed to improve the completeness of the first objective of this study. In this study, four major IEQ parameters including thermal comfort, IAQ, visual comfort, and acoustic comfort were measured. In fact, there are other IEQ parameters that could influence the occupants' satisfaction levels and work productivity. For instance, Candido, et al. (2016) revealed that spatial comfort was a key factor in improving the occupants' perceived IEQ satisfaction. Besides, Kaushik, et al. (2020) found that temperature and relative humidity outside the building could also affect occupants' perception towards IEQ. Hence, it is recommended that future studies could include additional environmental quality parameters to produce more comprehensive discussions.

Thirdly, amidst the Covid-19 pandemic, workers are having lesser time to attend physically to the office. Time spent of the workers in the office would be a decisive factor affecting their satisfaction towards office hours. According to Yang, et al. (2017), long term exposure to noise had adverse impact to the occupants' acoustic satisfaction as compared to short term exposure which that was negligible. Thus, the future studies could include a question to capture the information of working hours spent in the office. Furthermore, analysis could be performed to observe the relationship between working hours spent and IEQ satisfaction.

Lastly, modifications to the work productivity assessment method are proposed to answer the second objective of this study. In this study, occupants' work productivity was assessed subjectively using questionnaire survey. However, subjective evaluation of work productivity might contain dishonesty caused by external factors such as fear of superiors' supervision and peer pressure. Therefore, it is recommended to carry out physical tests in the assessment of work productivity. Geng, et al. (2017) provided several examples of productivity tests such as icon matching, number summing, text memory, and typing. Result of these productivity tests is believed to be more accurate and reliable to conclude work productivity.

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APPENDICES

APPENDIX A: Questionnaire Survey

A Correlation Study between Indoor Environmental Quality and Work Productivity

Good day, Sir/ Madam, I am Ho Hong Yeu, a postgraduate student from Universiti Tunku Abdul Rahman. I am conducting a research, namely "A Correlation Study between Indoor Environmental Quality (IEQ) and Work Productivity", and is led by Puan Naziatul Syima Binti Mahbob (syima@utar.edu.my).

The aim of this research is to investigate how IEQ factors such thermal comfort, indoor air quality, visual comfort, and acoustic comfort affect the overall work productivity in Malaysia offices. The questions will acquire information regarding your perceived IEQ satisfaction levels and measures of work productivity. The entire questionnaire survey takes approximately 8 to 10 minutes to complete.

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The first section of this questionnaire survey will obtain the demographic information of the respondents regarding the gender and age.

hohongyeu98@gmail.com (not shared) Switch accounts

*Required

Gender *

- ○ Male
- ○ Female

Age group *

- ○ 18 - 29
- ○ 30 - 39
- ○ 40 and above

Section 2.1 - Thermal Comfort

The second section of this questionnaire survey will obtain the information about the perceived satisfaction levels on the indoor environmental quality (IEQ) in the office. IEQs are indoor building factors in relation to the health and comfort of occupants. Generally, IEQ is can be categorized into four major groups including thermal comfort, indoor air quality, visual comfort, and acoustic comfort. Each of the category will be covered in the following sub-sections.

Questions will be answered in a 5-point Likert scale where '1' indicates the worst condition, '3' indicates neutral condition, and '5' indicates the best condition.

Clothing level *

- ◯ Formal (e.g., suit jackets, long-sleeved collared shirt, trousers)
- ◯ Smart casual (e.g., long-sleeved shirt, trousers)
- ◯ Casual (e.g., short-sleeved collared shirt, trousers)

Temperature *

	1	2	3	4	5	
Unsatisfied	◯	◯	◯	◯	◯	Satisfied

Humidity *

	1	2	3	4	5	
Unsatisfied	◯	◯	◯	◯	◯	Satiesfied

Thermal satisfaction *

	1	2	3	4	5	
Unsatisfied	◯	◯	◯	◯	◯	Satisfied

Section 2.2 - Indoor Air Quality

Odor *

	1	2	3	4	5	
Unsatisfied	○	○	○	○	○	Satisfied

Ventilation *

	1	2	3	4	5	
Unsatisfied	○	○	○	○	○	Satisfied

Indoor air quality satisfaction *

	1	2	3	4	5	
Unsatisfied	○	○	○	○	○	Satisfied

Section 2.3 - Visual Comfort

Natural lighting *

	1	2	3	4	5	
Unsatisfied	○	○	○	○	○	Satisfied

Artificial lighting *

	1	2	3	4	5	
Unsatisfied	○	○	○	○	○	Satisfied

View from windows *

	1	2	3	4	5	
Unsatisfied	○	○	○	○	○	Satisfied

Visual satisfaction *

	1	2	3	4	5	
Unsatisfied	○	○	○	○	○	Satisfied

Section 2.4 - Acoustic Comfort

Noise from external environment *

	1	2	3	4	5	
Unsatisfied	◯	◯	◯	◯	◯	Satisfied

Noise within working space *

	1	2	3	4	5	
Unsatisfied	◯	◯	◯	◯	◯	Satisfied

Noises from building systems *

	1	2	3	4	5	
Unsatisfied	◯	◯	◯	◯	◯	Satisfied

Acoustic Satisfaction *

	1	2	3	4	5	
Unsatisfied	◯	◯	◯	◯	◯	Satisfied

Section 3 - Work Productivity

The third section of this questionnaire survey is regarding work productivity, which is a measure of the amount of work done over a specific period. Work productivity has direct impact to the growth and profitability of a company. In this research, work productivity is examined based on the work stress level, concentration on work, and monthly absenteeism in each employment. Likewise, questions will be answered in a 5-point Likert scale.

Stress level *

	1	2	3	4	5	
Low	○	○	○	○	○	High

Concentration at work *

	1	2	3	4	5	
Low	○	○	○	○	○	High

Monthly absenteeism *

	1	2	3	4	5	
None	○	○	○	○	○	Frequent

Symptom or illness (e.g. Irritation, dry cough, dizziness, headache, allergies, etc.) *

	1	2	3	4	5	
None	◯	◯	◯	◯	◯	Frequent

Overall productivity *

	1	2	3	4	5	
Low	◯	◯	◯	◯	◯	High

Participant Consent

Thank you for your participation.

By completing this section, I confirm the following:
- I understand that I will not benefit directly from participating in this research
- I understand that all information I provide for this study will be treated confidentially.
- I have been given oral and written information for the above study and have read and understood the information given.
- I understand that I am free to contact any of the people involved in the research to seek further clarification and information.
- I understand that my participation is voluntary and I can at anytime free withdraw from the study without giving a reason.

Are you agree with the statement mentioned above. *

◯ Yes, I agree.

◯ No, I disagree.