CONCEPTUAL RETROFIT DESIGN OF A GREEN BUILDING OFFICE FROM AN EXISTING BUILDING

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This report is submitted
in fulfillment of the requirement for the degree of
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DECLARATION

I declare that this project report entitled "Conceptual Retrofit Design of A Green Building Office From An Existing Building" is the result of my own work except as cited in the references.

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APPROVAL

I hereby declare that I have read this project report and in my opinion this report is sufficient in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering.

Signature : ....

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Date : ....

DEDICATION

My humble effort I dedicate to my loving father and mother for their endless love, support and encouragement along my life.

ABSTRACT

Green building is superior in carbon savings and cost savings. Green buildings use lower energy and are healthy for occupant during living or working inside as compared to a conventional building. One of the green building criteria is to achieve good indoor environmental quality. The main objective of this study is to conduct a comparative analysis on the retrofit design of sustainable green building office by determining the indoor environment condition in term of temperature, relative humidity and carbon dioxide on Centre for Languages and Human Development (PBPI) building located at the UTeM's main campus. Thermal comfort and indoor air quality analysis were conducted to evaluate the indoor environment quality of the lecture room. The analysis consists of physical measurement and subjective measurement. Physical parameter data are collected in two sessions which is from 9 am to 12 pm and from 2 pm to 5 pm with a gap of 5 second interval for 5 minutes in each zone. Physical measurements were conducted with occupancy and no occupancy condition while subjective measurement was carried out through the questionnaire. The result shows that the indoor air quality in term of carbon dioxide of the building is more than 1000 ppm during occupancy, hence it is not within the GBI Standard. The total average relative humidity was recorded 58.35% within GBI Standard (55%-70%). The average operating temperature was recorded 22.21°C less than GBI Standard (23°C - 26°C). Based on the findings, the indoor environment quality improvement retrofit design are proposed with a green building element.

ABSTRAK

Bangunan hijau lebih baik dalam penjimatan karbon dan penjimatan kos. Bangunan hijau menggunakan tenaga yang lebih rendah dan sihat untuk penghuni yang tinggal atau bekerja di dalamnya berbanding dengan bangunan konvensional. Salah satu piawai bangunan hijau adalah untuk mencapai kualiti keadaan persekitaran dalaman yang baik. Objektif utama kajian ini adalah untuk menjalankan analisis komparatif mengenai pengubahsuaian reka bentuk bangunan pejabat hijau yang mampan dengan menentukan keadaan persekitaran dalaman dari segi suhu, kelembapan dan karbon dioksida di dalam bangunan Pusat Bahasa dan Pembangunan Insan (PBPI) yang terletak di kampus Utama UTeM. Kajian keselesaan terhadap suhu dan mutu udara dalaman dijalankan untuk menilai mutu keadaan persekitaran dalaman bilik kuliah. Analisis ini terdiri daripada pengukuran fizikal dan pengukuran subjektif. Maklumat pengukuran fizikal dikumpulkan dalam dua sesi iaitu dari 9 pagi hingga 12 malam dan dari pukul 2 petang hingga 5 petang dengan jurang selang 5 saat selama 5 minit dalam setiap zon. Pengukuran fizikal dijalankan dalam dua bentuk, iaitu semasa mempunyai penghuni dan semasa tiada penghuni manakala pengukuran subjektif dijalankan melalui soal selidik. Hasilnya menunjukkan bahawa mutu udara dalaman dari segi karbon dioksida bangunan lebih tinggi daripada 1000 ppm semasa mempunyai penghuni, oleh itu ia tidak mematuhi Piawaian GBI. Jumlah kelembapan purata dicatatkan 58.35% iaitu mematuhi piawaian GBI (55% -70%). Suhu operasi purata dicatatkan 22.21°C, iaitu lebih rendah daripada Piawaian GBI (23°C - 26°C). Berdasarkan hasil kajian, mencadangkan pengubahsuai reka bentuk untuk meningkatkan keadaan persekitaran dalaman dengan mengambil kira unsur bangunan hijau.

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LIST OF ABBEREVATIONS

ASHRAE	American Society of Heating, Refrigerating and Air Conditioning Engineer
BEAM Plus	Building Environment Assessment Method
BREEAM	Building Research Establishment Environmental Assessment Methods
CASBEE	Comprehensive Assessment System Built Environment Efficiency
DOSH	Department of Occupational Safety and Health
EER	Energy Efficiency Ratio
EPA	Environmental Protection Agency
GBCA	Green Building Council of Australia
GBI	Green Building Index
HVAC	Heating, Ventilation and Air Conditioning
IAQ	Indoor Air Quality
IEQ	Indoor Environmental Quality
IGBC	Indian Green Building Council Rating
IoT	Internet of Things
ISO	International Organization for Standardization
LEED	Leadership in Energy and Environmental Design
MGBC	Malaysia Green Building Confederation
MS	Malaysia Standard
NASA	National Aeronautics and Space Administration
PBPI	Pusat Bahasa dan Pembangunan Insan
PPM	Parts per million
SALL	Self-Access Language Laboratories
USGBC	United State Green Building Council
UTeM	Universiti Teknikal Malaysia Melaka
VOC	Volatile Organic Compounds
WGBC	World Green Building Council

LIST OF SYMBOLS

CO_2	-	Carbon Dioxide
°C	-	Degrees Celsius
m^2	-	Square meter
ppm	-	parts per million
%	-	Percentage
≤	-	Less than or equal to in value
≥	-	Greater than or equal to in value
V	-	Voltage
Ph	-	Phase
Hz	-	Hertz
Ft	-	Feet
W	-	Watt
kW	-	kilowatt
hr	-	Hour
BTU	-	British thermal unit
TR	-	Tones Refrigerant

CHAPTER 1

INTRODUCTION

1.1 Background of study

Public are now talking of how to make their buildings green. They want to have a place like a house or work in the building which has less harmful effect to environment and human health. That is because buildings have a significant and continuously increasing the effect to the environment through carbon dioxide (CO_2) releases. Green building criteria include efficiently using energy, water, other resources and reducing waste to environment. Besides, protecting occupant health and have a good indoor air quality (Ramachanderan, Venkiteswaran and Chuen, 2017).

The human activities such as deforestation, vast use of electricity and burning fossil fuels has made the (CO_2) increase to 409 parts per million (ppm) in year 2018. Recent researches show that global temperature has increase quickly, the year 2016 ranks as the warmest on record. In fact, the risen of global temperature will cause land ice melts, it adds freshwater to the oceans causing sea levels to rise. Besides that, global average sea level has risen nearly 178mm over the past 100 years with rate of change 3.2 ppm (NASA, 2018). The temperature rises will also increase the frequency of severe storms, droughts, floods and climatic changes.

The population of the world in year 2017 has risen to 7378 from 133 countries; representing 16.9 percent of the global population compare to year 2015 has population of 7025 from 99 countries; representing 11 percent of the global population (UN Environment, 2018). Undoubtedly, this growth in population is associated with higher demand for water, energy and natural resources which in return will overburden the ecosystems and increasingly deteriorates the environment. Besides that, continually uses of natural resources will has ability to affect future generations.

One of the ways to minimize the global warming of the Earth is to conserve the energy uses globally. Research shows that the existing building consumes around 30 percent of the accumulated energy uses in modern countries and will produce almost 30 percent of carbon emissions due to energy use (Eurostat, 2009). As being demonstrated in previous works (Ciulla, Galatioto and Ricciu, 2016) that green retrofit of existing building can improve their energy efficiency, which is essential for the promotion of environmental sustainability (Ma *et al.*, 2012). Research shows that the green building is cheaper than conventional building by save up to 10 percent of energy consumption (Tang, 2018).

1.2 Problem Statement

Powering building can make up to 75 percent of a city's carbon pollution, yet much of that energy is wasted through drafty windows and outdated technology (NRDC, 2018). By research, the existing building have consumed 30 percent of the heap up energy uses in modern countries and may produce almost 30 percent of carbon emission due to energy use (Eurostat, 2009). One of the criteria in green building is efficient use of energy. A green building is essential to achieve an optimal energy efficiency by reducing the energy wastes impact toward academic building. Improving the energy efficiency of the existing building may reduce the carbon emission.

This project aims to conduct comparative analysis on the retrofit design of academic building in Universiti Teknikal Malaysia Melaka (UTeM) and to provide design methodology improvement of the existing building.

1.3 Objectives

The objectives of the project are:

i. To conduct a comparative analysis on the retrofit design of a sustainable Green Building Office.

ii. To conduct indoor environment in term of temperature, carbon dioxide and relative humidity measurement as baseline for green retrofit designs.

iii. To develop and propose the retrofit design with green building elements based on the current existing building.

1.4 Scope of Project

This study will focus on the academic building in Universiti Teknikal Malaysia Melaka (UTeM). The selected building consists of an air conditioning system as where the Indoor Environmental Quality (IEQ) and energy consumption will be observed. In this study, the case study building will be in building of Centre for Languages and Human Development (PBPI).

1.5 General Methodology

The methodology that will be carried out to achieve the objectives in this project are outlined below as shown in **Figure 1.1**.

1. Select the academic building in UTeM

   Choose the building that has air conditioning.

2. Study the building system and conduct literature review

   Journals, articles, or any materials regarding the project will be reviewed.

3. Measure Indoor Environmental Quality

Prepare the measurement equipment then conduct the physical measurement. The measurement will be conducted at the air conditioning area.

4. Choose proper criteria

   The data measurement will be analyzed. Solutions will be proposed based on the analysis.

5. Building improvement

   Design concept of existing building will be proposed.

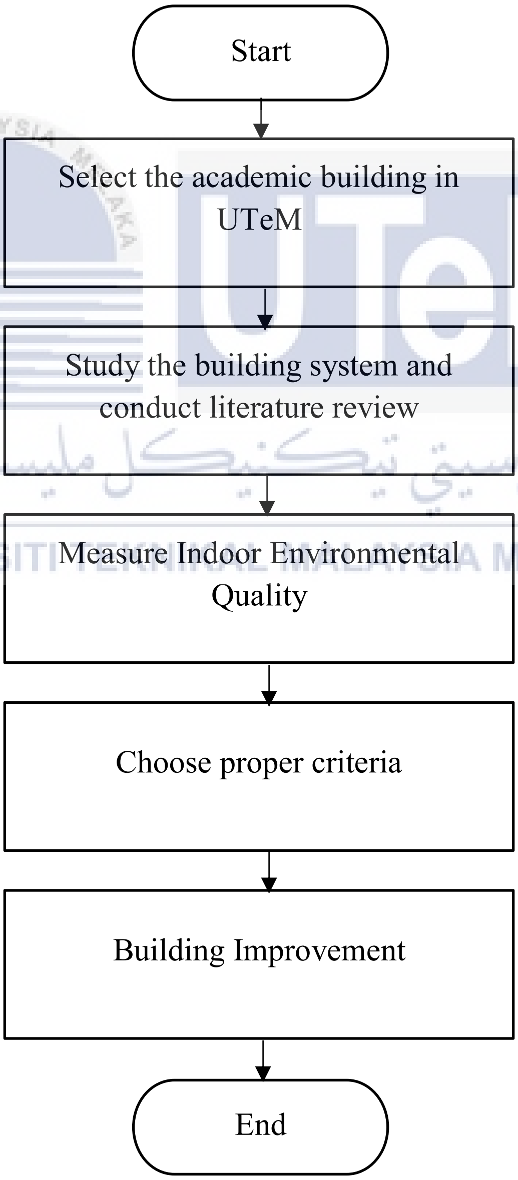

Figure 1.1: Project flow chart

1.6 The Importance of The Study

Throughout this research, the prospect of retrofitting the green building design on the current university existing building can be evaluated and determined whether it meets the required design. The measurement data on the indoor environment will also contribute to the evaluation on the current condition in term of healthy environment to the occupants. It is hoped that this study will be a benchmark study for future implementation of green building design in university buildings.

1.7 Project Outcome

At the end of this project, analysis of indoor environment and energy consumption as part of green building criteria will be done. The data measurement result of the building will be recorded. Besides that, building retrofit design based on green building criteria for existing building also will be proposed.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In this chapter, literature review was made based on retrofit design of green building. Information is sought through material in books, journals and the internet as a reference. The literature search includes not only literature relevant to the topic but methodological approaches on a particular topic. However, the literature review focuses mainly on the further details of the indoor environmental quality and energy consumption on the building. This chapter also represents a brief description about the Literature published before the relevant works. Literature review that went to work on in order to understand indoor environment quality and energy consumption of existing academic building in UTeM.

2.2 Green Building Theory

2.2.1 Green building

According to United States Environmental Protection Agency (EPA), green building is the practice of increasing the efficiency of the building and the sites use resources including energy, water and materials while reducing building impacts on human health and the environment during the building's lifecycle, through better siting, design, construction, operation, renovation, and reuse. Green building is also known as a sustainable or high-performance building (EPA, 2008). Further, green building is defined by Green Building Index Malaysia as a building focuses on maximizing the efficiency of resource use of energy, water and materials, while minimizing building impact on human health and the environment during the building's lifecycle, through better siting, design, construction, operation, maintenance, and removal. Green Buildings should be designed and operated to reduce the overall impact of the built environment on its surroundings. Besides that, Green buildings are designed to save energy and resources, recycle materials and reduce the emission of toxic substances throughout its life cycle, and also able to sustain and improve the quality of human life whilst maintaining the capacity of the ecosystem at local and global levels. (Green Building Index Malaysia, 2018).

2.2.2 Green retrofit

Tryson states that retrofit is make change of elements or part of a building. Wherein, the change for green retrofit is limited to improve a building environment performance (Lisa Tryson, 2016). The retrofit also refers to other terms in literature as well, such as refurbishment, rehabilitation, renovation, improvements, adaptation, repairs and renewal on existing buildings (Liang, Peng and Shen, 2016). Further, green retrofit is the upgrading of the building fabric, systems or controls to improve the energy performance of the property. Besides that, the U.S. Green Building Council (USGBC) defines green retrofit as any kind of upgrade at an existing building that is wholly or partially occupied to improve energy and environment performance, reduce water use and improve the comfort and quality of the space in terms of natural light, air quality and noise. From these definitions, it can be seen that green retrofit can improve energy performance, satisfactory service level and indoor environmental quality of existing building.

2.3 Green building criteria

Different countries and regions have a variety of characteristics such as distinctive climatic conditions, unique cultures and traditions, diverse building types and ages, or wide-ranging environmental, economic and social priorities. Hence, all of which shape their approach to green building. This is why World Green Building Council (WGBC) supports its member Green Building Councils and their member companies in individual countries and across regions, to pursue green buildings that are best suited to their own markets (WorldGBC, 2018). One of the Malaysia rating tools that are administered by Green Building Councils is Green Building Index (GBI). GBI have list out the Green Building Index (GBI) rating criteria such as Energy Efficiency, Indoor Environment Quality, Materials & Resources, Sustainable Site Planning & Management, Water Efficiency and Innovation.

2.3.1 Green building rating tool

By 2018, 45 green building rating tools over the world are being administered by Green Building Council. On the other hand, most of the nation in the Asia-Pacific region has their own rating tools as shown in **Table 2.1**. This research focuses on the existing academic building in UTeM. Therefore, for each green building rating tool focusing on existing construction is selected for the study. For some tools like GBI, LEED and BREEAM, there are different versions available. Further, in there rating tools, there are different schemes for different types of building such as hotel, resort, industrial, hospital, historic building, non-residential building and residential building. In this case, consider the relevant rating tools associated with non-residential buildings for the research (Illankoon *et al.*, 2017).

Table 2. 1: Green building rating tools.

Region	Assessment tool	Countries which use the assessment tool
America	LEED	Argentina, Brazil, Canada, Chile, Peru, United States of America
Europe	LEED	Poland, Spain, Sweden, Turkey
	BREEAM	Croatia, Germany, Netherlands, Norway, Switzerland, Poland, Spain, Sweden, Turkey, United Kingdom
Asia Pacific	LEED	Taiwan Taipei, India
	BEAM Plus	Hong Kong
	Green Mark	Singapore
	CASBEE	Japan
	GBI	Malaysia
	IGBC	India
	Green Star	Australia, New Zealand
South Africa	Green Star	South Africa
Middle East & North Africa	LEED	Jordan, United Arab Emirates
	BREEAM	United Arab Emirates

Table 2.2: Assessment criteria of selected green building rating tool.

Assessment tool	Assessment criteria	Credit point
LEED	Energy and atmosphere	35
	Location and transport	20
	Indoor environmental quality	18
	Material and resources	14
	Water efficiency	12
	Sustainable sites	10
	Innovation	5
	Regional priority	4
	Integrative process	1
	Accredited professional	1
Green Star	Energy	22
	Indoor environment quality	17
	Management	14
	Material	14
	Water	12
	Innovation	10
	Transport	10
	Land use and ecology	6

	Emissions	5
Green Building Index (GBI)	Energy efficiency	38
	Indoor environmental quality	21
	Water efficiency	12
	Sustainable site planning & Management	10
	Innovation	10
	Material and resources	9
BREEAM	Energy	27
	Management	23
	Health and wellbeing	17
	Pollution	13
	Land use and ecology	12
	Transport	12
	Material	11
	Innovation	10
	Water	9
	Waste	6

2.4 Sustainability rating system description

In this section, the green building rating system is described in detail are briefly illustrated. Assessment criteria of selected green building rating tool are shown in **Table 2.2** above.

2.4.1 LEED

LEED short form of Leadership in Energy and Environment Design developed by the U.S. Green Building Council is the majority used green building rating system in the world for evaluating sustainability for different building phases: the design, construction, maintenance and operation. The new version of LEED (2013) was revised from the previous LEED (2009). The number of criteria was rise and the tools for performance calculation were equalize, in order to adapt the agreement to different backgrounds around the world. The criteria are categorized into ten part that address key aspects of green buildings. These nine parts of criteria have different of credits or point. The highest number of achievable point is 110 but 5 extra points can be achieved in the "Innovation" categories. Based on the number of points attained, it is possible to gain one of the LEED rating levels: LEED Platinum (80 points above), LEED Gold (from 60 to 79 points), LEED Silver (from 50 to 59points) and LEED Certified (from 40 to 49 points) (LEED, 2018).

2.4.2 Green Star

Green Star is one of the majorities followed voluntary rating system for construction and communities, organize by the Green Building Council of Australia (GBCA) in 2003. The latest version was introduced in 2016. The system evaluates the environmental design and achievements of buildings, considering a broad range of issues. The system can be applied to building construction, refurbishment and operation phases. Green Star rating can apply for every type of building, not only new building but also existing building. For each credit, which is allocated into its specific category, a maximum number of points can be achieved. The maximum credit point of achievable is 100. The certification is expressed as a number of stars: 1–3 Stars (from 10 to 44 points) correspond respectively to Minimum Practice, Average Practice and Good Practice; 4 Stars (from 45 to 59 points) correspond to the Best practice score achievement; 5 Stars (from 60 to 75) is the Australian Excellence Level and lastly more than 75 points allows to obtain the 6 stars rating, that is the World Leadership grade. 4 to 6 Star Green Star certification can achieve by Design, As Built, Interiors and Communities project as shown in **Figure 2.1** (Green Star, 2018).

Figure 2.1: The Green Star rating scale. [Source: Green Star: 2016]

2.4.3 GBI

GBI short form of Green Building Index is Malaysia's industry recognised green rating tool for buildings to work for sustainability in the built environment and raise awareness among Developers, Architects, Engineers, Planners, Designers, Contractors and the Public about environmental issues and our responsibility to the future generations. The GBI rating tool supply a change for developers and building owners to design and construct green, sustainable buildings that can provide energy efficiency, water efficiency, a wellness indoor environment, high quality of public transport and the adoption of recycling and greenery for their projects and minimize the impact on the environment. By November 2018, GBI have certified 219 661 334 SQ FT gross floor area of green building. Based on the number of points attained, it is possible to gain one of the GBI rating levels: GBI Platinum (86 points above), GBI Gold (from 76 to 85 points), GBI Silver (from 66 to 75 points) and GBI Certified (from 50 to 65 points) (GBI, 2018).

2.4.4 BREEAM

Building Research Establishment Environmental Assessment Method (BREEAM) is the oldest protocol. The most current version was introduced in 2016. Initially, it was based on the construction phase of individual new buildings, now it is the world's leading sustainability assessment strategy for masterplanning project, infrastructure and building. Nowadays, BREEAM become ad big schemes that applied over seventy nations worldwide on mega of projects. BREEAM standards have been applied across the world by many type of building such as office, retail, industrial, data centers, education, healthcare, residential, mixed use and other building. Starting from the final score achieved, it is possible to earn one of the following rating levels: Unclassified is less than 30 points, Pass is more than 30 points, Good is more than 45 points, Very Good is more than 55 points, Excellent is more than 70 points and Outstanding is more than 85 points (BREEAM, 2018).

2.5 Indoor Environmental Quality Factors

Indoor environmental quality of building depends significantly on the air quality, thermal comfort, lighting, visual & acoustic comfort and verification. Internal environmental quality will impact the health, efficiency and resident calmly. IEQ may able to improve the working and learning efficiency. (Marchetti *et al.*, 2017).

2.5.1 Indoor air temperature

The internal temperature is one of the main steps of a closed environment. It can be controlled to precision rely on the building and HVAC system. Indoor temperature influenced some part of person, including thermal comfort, perceived air quality, sick building syndrome symptoms (Lan et al., 2014). According to a Cornell University research, temperature is obviously a key variable that can make an impression on a person (Lang, 2004). OSHA suggest that indoor air temperature should be between 23-26° C as shown in **Table 2.4**, the optimum temperature is 24.5° C for human comfortable (OSHA, 2016). In sum, indoor temperature affects indoor environment quality.

2.5.2 Indoor air humidity

Air hold some amount of vapor, which is called air humidity. (ASHRAE Standard, 2009) defined the relative humidity as the ratio of the partial pressure or density of water vapor in the air to the saturation pressure or density of water vapor at the same temperature and same total pressure. With regard to humidity, if it is too high this will cause discomfort (excessive perspiration, exacerbation of the effects of high temperature, feelings of 'closeness', etc) and if it's too low it can cause respiratory problems. The optimum humidity level in the range of 40%-65% as shown in **Table 2.3**. Humidity levels below 40% will start to lead the problems for human with conditions such as sinusitis (ASHRAE Standard, 2010).

2.5.3 Indoor Carbon Dioxide

The indoor Carbon Dioxide (CO_2) level is usually used approach which has been referred as an Indoor Air Quality (IAQ) guide for inefficient and ill-functioning air-filtration system (Lin and Deng, 2003). CO_2 within the building is the output of human breathe. The breath out air have about 100 times higher CO_2 than breathe in air. The American Society of

Heating, Refrigerating and Air Conditioning Engineer Inc. (ASHRAE), suggest that indoor air CO_2 levels be below than or equal to 645 ppm above the outdoor air concentration of CO_2 as shown in **Table 2.3** (ASHRAE, 2002). In a past study, Denmark reported the CO_2 as 1092 ppm in working hours in the academic building due to low level of ventilation (Denmark et al., 2013). Another case in Italy, academic building is detected have high concentration of CO_2 due to lack of air movement through window.

Table 2.3: Acceptable range for physical parameters by ASHRAE Standard.

[Source: ASHRAE, 2017]

Parameter	Acceptable range	Reference
Temperature	23 – 28°C	ASHRAE Standard 55-2010 ISO 7730
Relative humidity	40% - 65%	ASHRAE Standard 55-2010
Carbon dioxide (CO_2)	≤ 645 ppm over outdoor ambient	ASHRAE Standard 62.1-2010

Table 2.4: Acceptable range for physical parameters by GBI Standard.

[Source:GBI Malaysia]

Parameter	Acceptable range	Reference
Temperature	23 – 26°C	GBI Standard
Relative humidity	55% - 70%	
Carbon dioxide (CO_2)	≤ 1000 ppm	

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter illustrates the methodology used in this research to collect field data through doing measurement and field study in proposed buildings to gather indoor environmental quality such as air temperature, humidity and carbon dioxide (CO_2) emission to observe the current condition in term of healthy environment to the occupants in the building of Centre for Languages and Human Development (PBPI). Hence, the data was compared by using GBI Standard.

In the process of measuring the physical parameters, all the measuring device are located at the height of 1.1 meter from the floor level, which is parallel to the sitting level (ASHRAE Standard, 2004).

Besides that, Internet of Things (IoT) indoor environment monitoring device was used as backup measuring device of physical parameter in the building.

The data measurement result was analyze and then draught the graphs and tables by using Microsoft Excel software in order to analyze the indoor environment condition with green building condition and determined whether it meets the required design.

A literature study is used to inspect the existing standard (GBI Standard) to verify the acceptable range of indoor environment quality of green building related to these standards and will be a benchmark of this study.

Finally, to develop and propose the design concept with green building element based on the current existing building by refer to literature study.

3.2 Building description

This section will describe about the academic building that conducted in this study.

3.2.1 Centre for Languages and Human Development (PBPI)

Centre for Languages and Human Development also knows as Pusat Bahasa & Pembangunan Insan (PBPI). The PBPI building is located at Universiti Teknikal Malaysia Melaka (UTeM), 76100 Durian Tunggal, Melaka, Malaysia. This building as shown in **Figure 3.1** and **Figure 3.2** consists of Language Laboratories, Self-Access Language Laboratories (SALL), Seminar room, lecture room, Lecturer's room, meeting room and administration office. The building floor area is about 2010-meter square and consist of ground floor, second floor and third floor shown in **Table 3.1**. This building was provided thermal comfort by the central air conditioning system and split units air conditioning system. The normal office hours of this building are from 8 am to 5 pm. **Appendix C** shown the layout of each level of PBPI building.

Figure 3.1: PBPI building from Satellite view [Source: Google Maps]

Figure 3.2: PBPI building

Table 3.1: PBPI building facilities

Floor	Facilities
Ground	Lobby Administration office Self-Access Language Laboratories (SALL) 2 Language laboratories 3 Lecture room (BK1-BK3) 10 Lecturer’s room
First	2 Meeting room 2 Language laboratories 2 Lecture room (BK4-BK5) 14 Lecturer’s room
Second	Seminar room Discussion room 3 Lecture room (BK6-BK8) 34 Lecturer’s room

3.3 Project flow chart

Figure 3.3 shows the project flow chart for achieve the objectives of this project. There are three physical measurement items which are indoor temperature, relative humidity (RH) and carbon dioxide (CO_2). The location in the building of measurement is been identified and divided into few zones before prepare measurement equipment. Criteria for determine indoor air quality may divide into two basic group which is comfort and health. Measurements data were gathered and compared with existing green building benchmarks created by the American Society for Heating, Refrigerating and Air Conditioning Engineers (ASHRAE, 2001, 2007), the Department of Safety and Health (DOSH, 2005) and GBI. In addition, choose the proper building criteria and analyse the data measurements, then solution is proposed based on the analysis. Finally, the design concept of existing building is proposed.

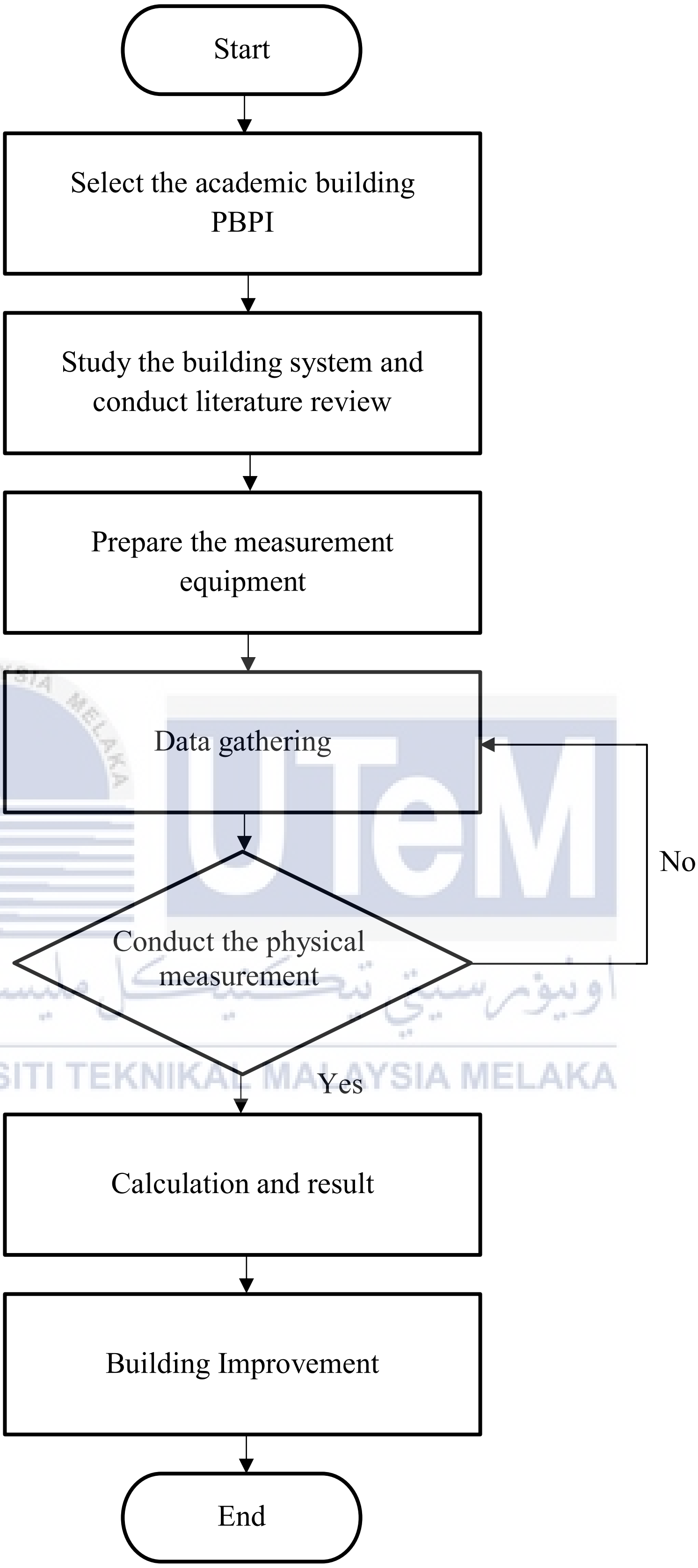

Figure 3.3: Project flow chart.

3.4 Analysis of Indoor Environmental Quality

The following are the procedure for building indoor air quality analysis, which focusing on the temperature, humidity and carbon dioxide. The indoor air quality audit process was started with the physical parameter measurement of the building and descriptive information about the building plant layout for each floor.

3.4.1 Initial walk-through tour

A tour in each floor of the building has been conducted, so that the real situation of indoor air system of that building can visualise. It includes a review of temperature base on the air conditioning thermostat. The selected room is measured to get the area size. Then the room has divided into few zones for physical measurement. The main objective of the tour is to find out common guidance about the case study building such as air conditioning system, ventilation system and any equipment that influence the indoor air quality as shown in **Figure 3.4**. Besides that, to find out the way to improve the indoor air quality. **Appendix C** shown the layout of each level of PBPI building.

Figure 3.4: PBPI corridor

3.4.2 Physical Parameters Measurement

One of the criteria in green building is to have a good indoor air quality. Temperature and relative humidity measurements used to determine thermal comfort in the building. Comfort level is an importance point in term of contribute healthy, efficiency and concentration of occupant. Hence, physical parameters measurement has been carrying out to get the measure of temperature, relative humidity and carbon dioxide. Carbon dioxide is one of the physical parameters in IAQ, because high level of CO_2 in the indoor environment can make occupant headaches and sleepiness. The measurement of physical parameters is to determine whether IAQ in the building is meet the required design of green building as proposed by Malaysia GBI. TSI IAQ-CALC 7545 Indoor Air Quality meter as shown in **Figure 3.5** is an outstanding apparatus for investigating and monitoring IAQ used to measure physical parameter in this project. **Figure 3.6** and **Figure 3.7** shows measurement of CO_2, relative humidity and temperature conducted at PBPI building with occupants and without occupants respectively.

The CO_2 concentrations sensor is placed at 1.1m from the floor level. Pilot measurement is conducted by setting 5 seconds time interval to collect the data for 5 minutes. Interval of time will be adjusted if the data shows negligible changes. After that, the real measurement is conducted by setting 5 seconds time interval to collect data for around 5 minutes in each zone. The measurement is conducted at the same time with the thermal parameters measurement during morning session from 9 am to 12 pm and afternoon session from 2 pm to 5 pm for both cases with occupants and without occupants. The collected data is then being analysed.

TSI IAQ-CALC 7545 Indoor Air Quality meter able to measure CO2, carbon monoxide (CO), temperature, humidity. Besides that, this device also able to calculates dew point, wet bulb temperature and percentage outside air. This IAQ meter has used thermistor sensor for measure temperature within range 0°C to 60°C in 30 seconds response time. Thin-film capacitive sensor has used for measure relative humidity between range of 5% to 95% in 20 second response time. Besides, dual-wavelength NDIR sensor has used to measure CO_2 within range of 0 to 5000ppm in 20 seconds response time. LogDat2 software able to install on the computer for easy transfer the data from the IAQ meter and for easy report creation.

Figure 3.5: TSI IAQ-CALC 7545 Indoor Air Quality meter

Based on Berkeley study (Berkeley, 2014), to get a high accuracy and precision on the physical data, several procedures for measurement should be apply, include:

1. The selected room should be clean and tidy.
2. There should be no occupants when measuring in process.
3. The selected room should have consistent air conditioning system.
4. Measurement should be taken periodically at many zones of the room.

Figure 3.6: Measurement of Temperature, CO_2 and Relative Humidity conducted at MB1, ground floor of PBPI building using a TSI Indoor Air Quality meter.

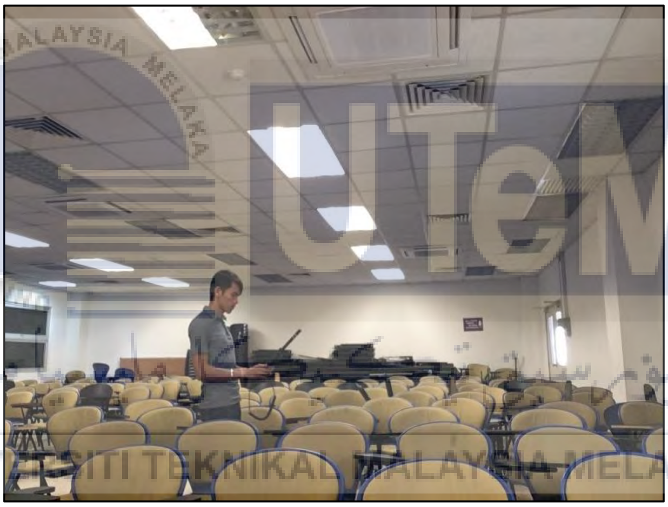

Figure 3.7: Measurement of Temperature, CO_2 and Relative Humidity conducted at MB5, first floor of PBPI building using a TSI Indoor Air Quality meter.

3.4.3 Survey

Besides physical parameters measurement, questionnaire also has been used in this analysis as shown in **Appendix D**. It lends a comprehensive view of how the occupants sensate with the indoor conditions. Then the result of the questionnaire is correlated with the measurements of the physical parameters. The variables consist of the questionnaire are referring to occupant's consciousness on indoor air quality (carbon dioxide) and thermal comfort (indoor temperature and relative humidity).

Questionnaire for the investigate is created according to the ASHRAE scale and categorized into three sections as described below:

i. Occupier's personal information

   This section includes occupant's gender, age and health condition at that time.

ii. Current environment conditions

   This section describes the building outdoor condition such as cloudy, sunny, rainy, windy or overcast.

iii. Occupier's thermal comfort and indoor air quality perception vote

   This section describes the feeling of occupants on the temperature, humidity level inside the class. The overall comfort perception in the class such as comfort, discomfort, slightly discomfort or very discomfort.

The questionnaire form was distributed to the occupants during the lecture session for the selected lecture room. There were two sessions for data collection which is the morning session is from 9 am to 12 pm and the afternoon session is from 2 pm to 5 pm. **Figure 3.8** shows during distributing the questionnaire survey form to occupants. The occupants fill in the questionnaire during the lecture session was shown in **Figure 3.9**.

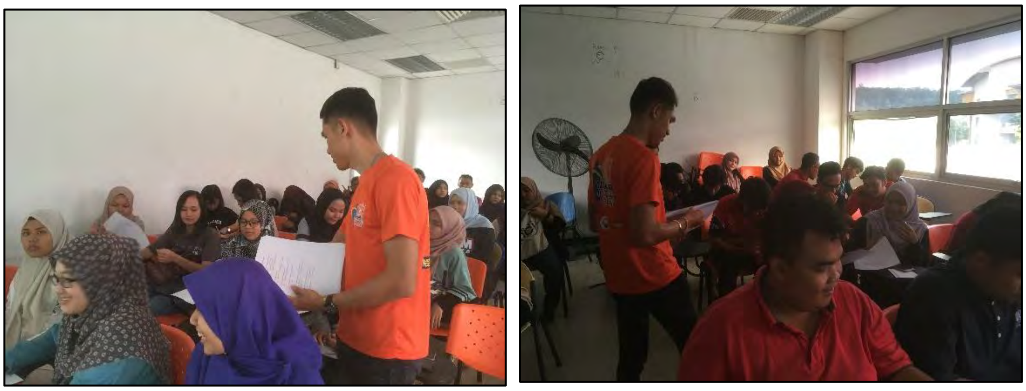

Figure 3.8: During distributing the questionnaire survey form to occupants.

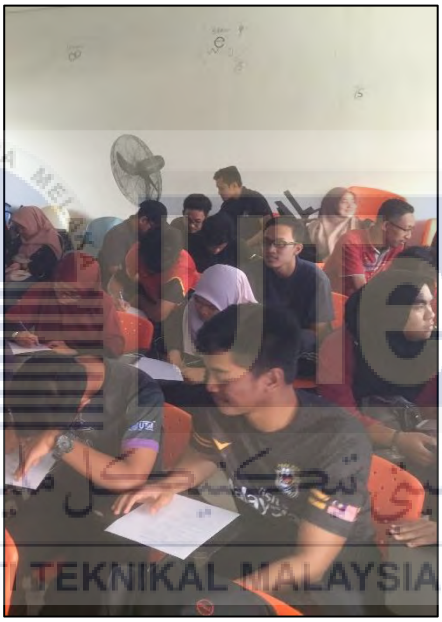

Figure 3.9: Occupants filled questionnaires in lecture room.

3.5 Retrofit Analysis

Retrofit analysis is the method to improve their indoor environmental quality and sustainable performance in the building by propose installing or upgrading existing equipment which supposed able to increase the indoor environmental quality. Furthermore, compare the existing building with green building element, so that lack of green building element on the existing building can be identifies, then propose the design concept.

CHAPTER 4

RESULTS AND ANALYSIS

4.1 Physical Measurement Result

Physical measurements were conducted for the selected lecture room in building of Centre for Languages and Human Development (PBPI). The measurements consist of two conditions with occupants and without occupants.

Measurement for condition with occupants and without occupants were carried out for two sessions which are 9am to 12pm and 2pm to 5pm. Condition without occupants were starting conducted on 21th March 2019. Besides that, condition with occupants were starting conducted on 2nd March 2019.

In this study, two main factors which are thermal comfort and indoor air quality are focused in order to determine the indoor environment quality as one of the criteria of green building design. The physical parameters used to measure human thermal comfort and indoor air quality are air temperature, relative humidity and carbon dioxide level.

The data for the indoor environment quality is recorded for 5 second interval for around 5 minutes in each zone and 60 samples are taken.

4.1.1 Ground floor (With Occupants and Without Occupants)

4.1.1.1 Lecture Room BK1

There are total 4 measurement zones in ground floor lecture room. The room area is about 76 m^2. In this study, the obtained results for both conditions are analysed and compared in order to know how good the indoor environment quality is when there are no occupant or occupants in the room.

The parameter used to analyse indoor environment quality included air temperature, relative humidity and carbon dioxide. The data for the thermal parameters is recorded for 5 second interval for around 5 minutes in each zone.

The air temperature result obtained from each zone in morning session and afternoon session are shown in **Figure 4.1** and **4.2** respectively. Base on the table shows, when there are occupants inside the lecture room, the temperature obviously increased about 1°C in each zone.

According to MS 1525, the recommended range for indoor air temperature in the air-conditioning building is 23°C to 26°C. Compared with this study, it is found that the overall indoor air temperature obtains for both conditions are not complying with the standard range. The indoor air temperature is lower than the minimum recommended temperature by 2.3°C for no occupancy condition while for the occupancy condition is lower by 1.8°C as shown in **Figure 4.1**.

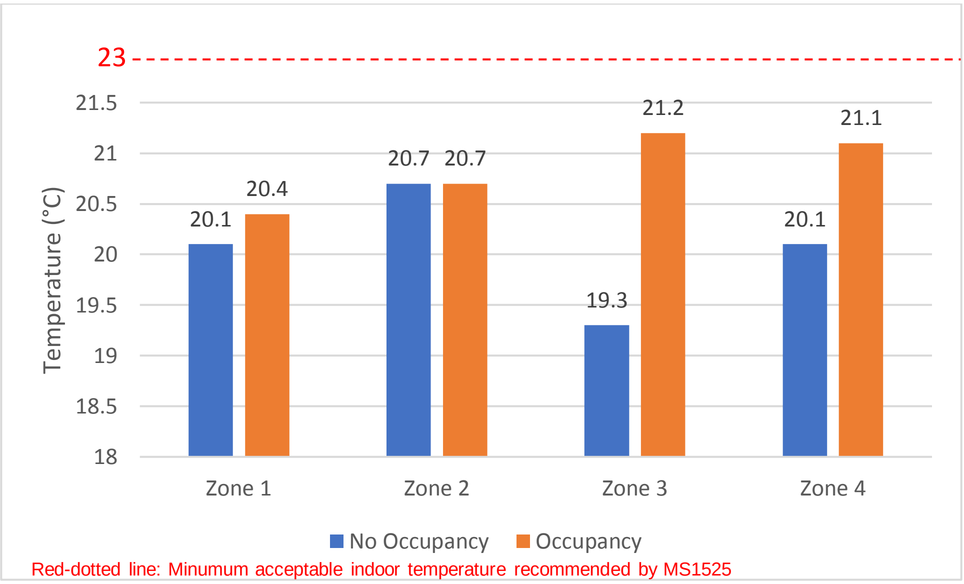

Figure 4.1: Indoor air temperature in lecture room during morning

According to **Figure 4.2**, the air temperature result obtained from each zone in afternoon session is compared with GBI Standard, the recommended range for indoor air temperature in the air-conditioning building is 23°C to 26°C. Compared with this study, it is found that the overall indoor air temperature obtains for both conditions is within standard range except for zone 4 no occupancy condition, the indoor air temperature is lower than the minimum recommended temperature by 1°C.

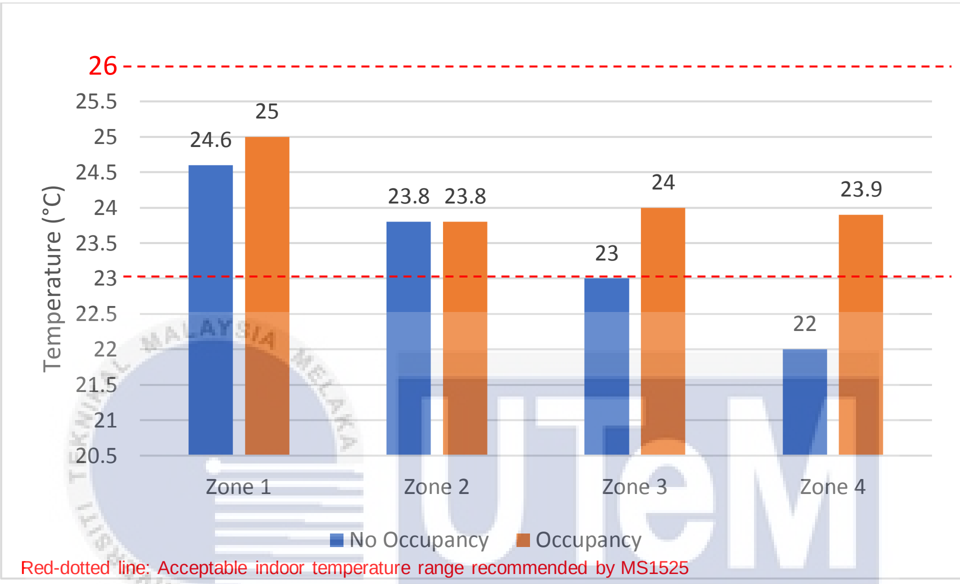

Figure 4.2: Indoor air temperature in lecture room during afternoon

The relative humidity result obtained from each zone in the morning session and afternoon session is shown in **Figure 4.3** and **4.4** respectively. The relative humidity level recommended by GBI Standard is range between 55% to 70%. The result during morning as shown in **Figure 4.3** is compared with the standard, the relative humidity is lower than the standard.

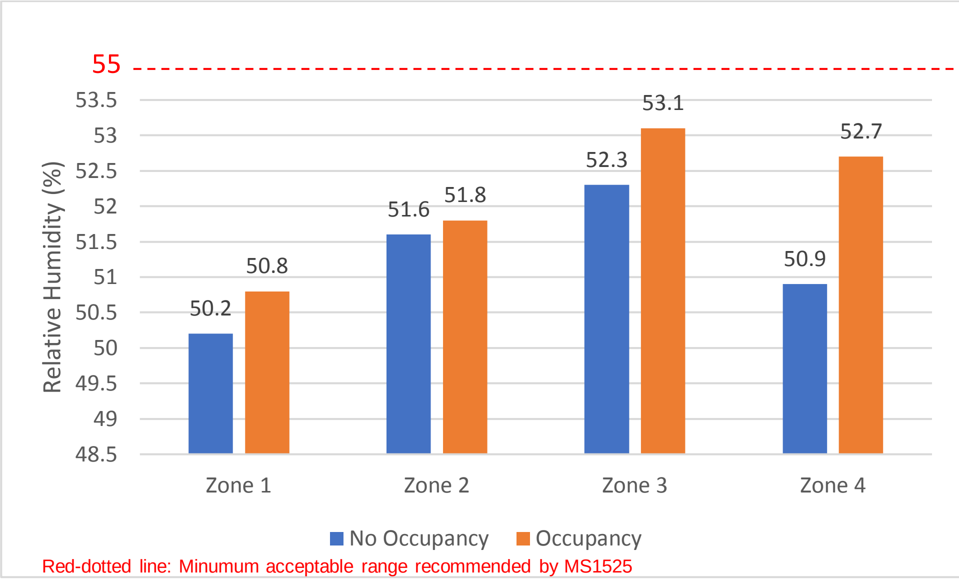

Figure 4.3: Relative humidity in lecture room during morning

Relative humidity during the afternoon session is shown in **Figure 4.4**. The relative humidity slightly increases during the afternoon session compare to the morning session. The average overall relative humidity for no occupancy and occupancy are 52.8 and 59.8 respectively. For no occupancy, the relative humidity is lower than the standard and for occupancy, there is within the standard based on GBI Standard.

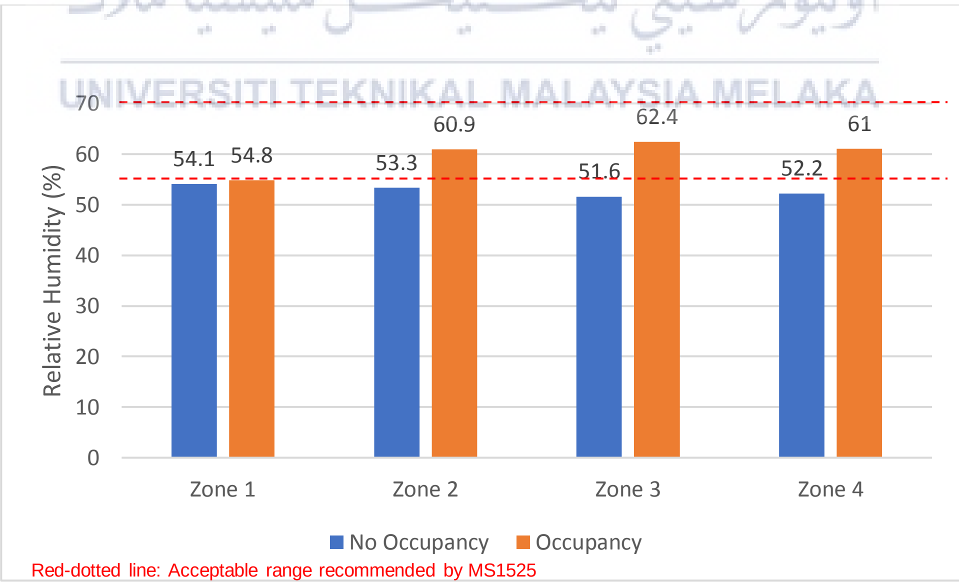

Figure 4.4: Relative humidity in lecture room during afternoon

The carbon dioxide result obtained from each zone in the morning session and afternoon session is shown in **Figure 4.5** and **4.6** respectively. Based on **Figure 4.5**, the average overall CO_2 level of all zones for no occupancy during the morning session is 578 ppm. However, during occupancy, the average level of carbon dioxide increases to 1095 ppm. According to GBI Standard, the maximum level of indoor carbon dioxide should not more than 1000 ppm. Compared to the data result, the level of indoor carbon dioxide is lower than the standard maximum carbon dioxide level during no occupancy, but during occupancy, the level of indoor carbon dioxide is higher than standard by 95 ppm.

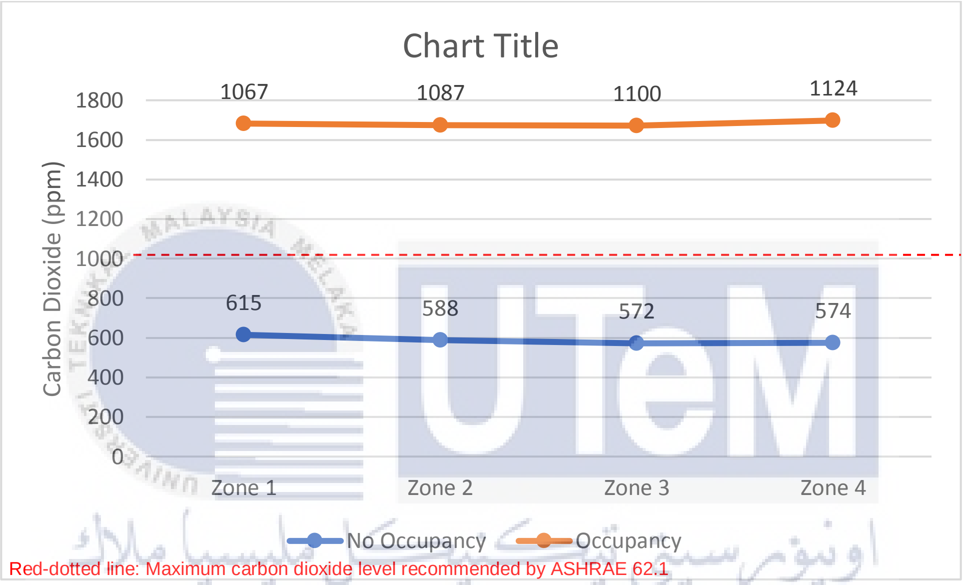

Figure 4.5: Carbon dioxide in lecture room during morning

Based on **Figure 4.6**, the average overall CO_2 level of all zones for no occupancy during the afternoon session is 846 ppm. However, during occupancy, the average level of carbon dioxide increases to 2080 ppm. According to GBI Standard, the maximum level of indoor carbon dioxide should not more than 1000 ppm. Compared to the data result, the level of indoor carbon dioxide is slightly lower than the standard maximum carbon dioxide level during no occupancy, but during occupancy, the level of indoor carbon dioxide is higher than standard by 1080 ppm.

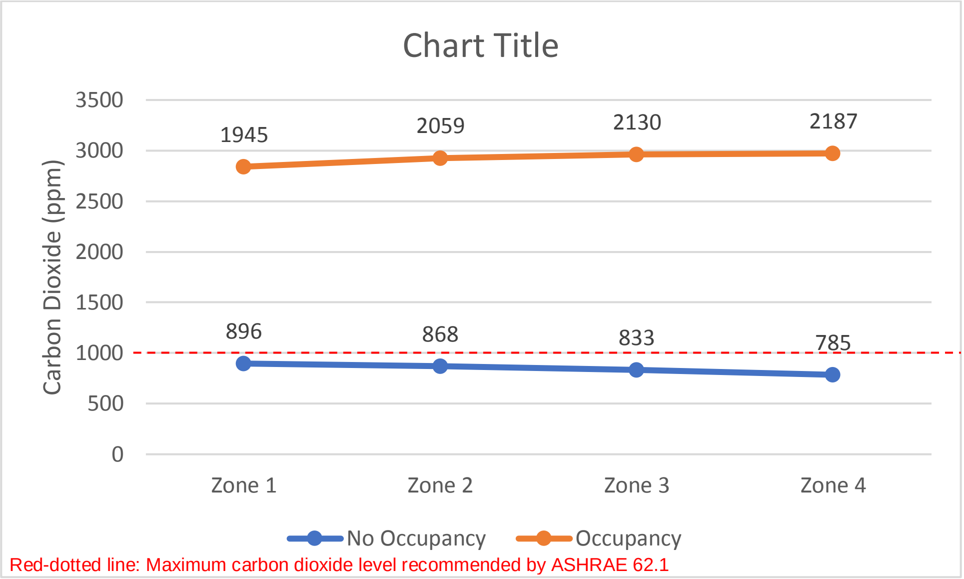

Figure 4.6: Carbon dioxide in lecture room during afternoon

4.1.1.2 Language laboratories MB1

There are total 4 measurement zones in ground floor Language laboratories. The laboratories area is about 152 m^2. In this study, the obtained results for both conditions are analysed and compared in order to know how good the indoor environment quality is when there are no occupant or occupants in the laboratories.

The parameter used to analyse indoor environment quality included air temperature, relative humidity and carbon dioxide. The data for the thermal parameters is recorded for 5 second interval for around 5 minutes in each zone.

The air temperature result obtained from each zone in morning session and afternoon session are shown in **Figure 4.7** and **4.8** respectively. Base on the **Figure 4.7**, the average overall temperature in the laboratories during no occupancy and occupancy is 24°C and 24.5°C respectively.

According to **Figure 4.7**, the air temperature result obtained from each zone in morning session is compared with GBI Standard, the recommended range for indoor air temperature in the air-conditioning building is 23°C to 26°C. Compared with this study, it is found that the overall indoor air temperature obtains for both conditions is within the standard range.

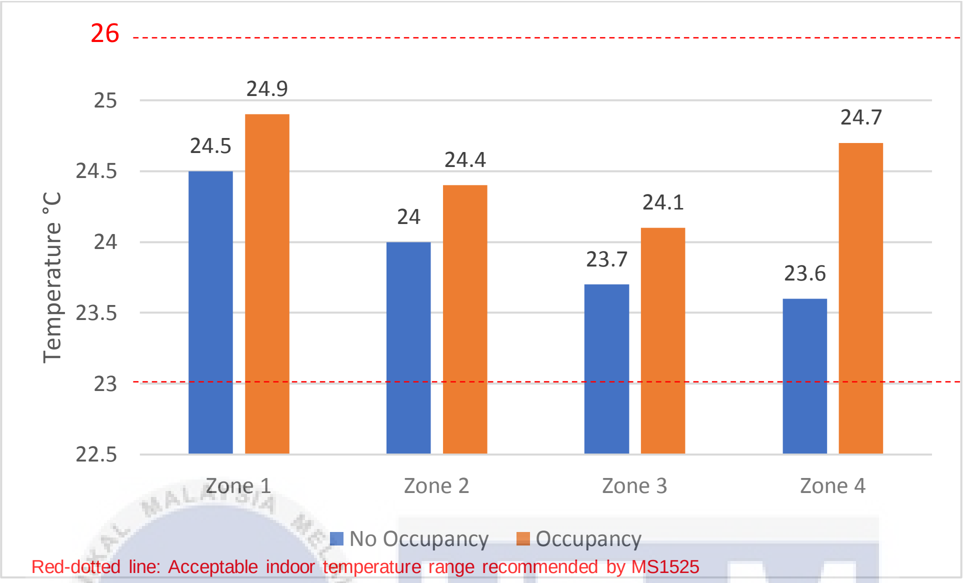

Figure 4.7: Indoor air temperature in lecture room during morning

Figure 4.8 shown the indoor air temperature result obtained from each zone in the afternoon session, the average overall temperature in the laboratories during no occupancy and occupancy is 23.9°C and 25°C respectively. The result is compared with GBI Standard, the recommended range for indoor air temperature in the air-conditioning building is 23°C to 26°C. Compared with this study, it is found that the overall indoor air temperature obtains for both conditions is within the standard range.

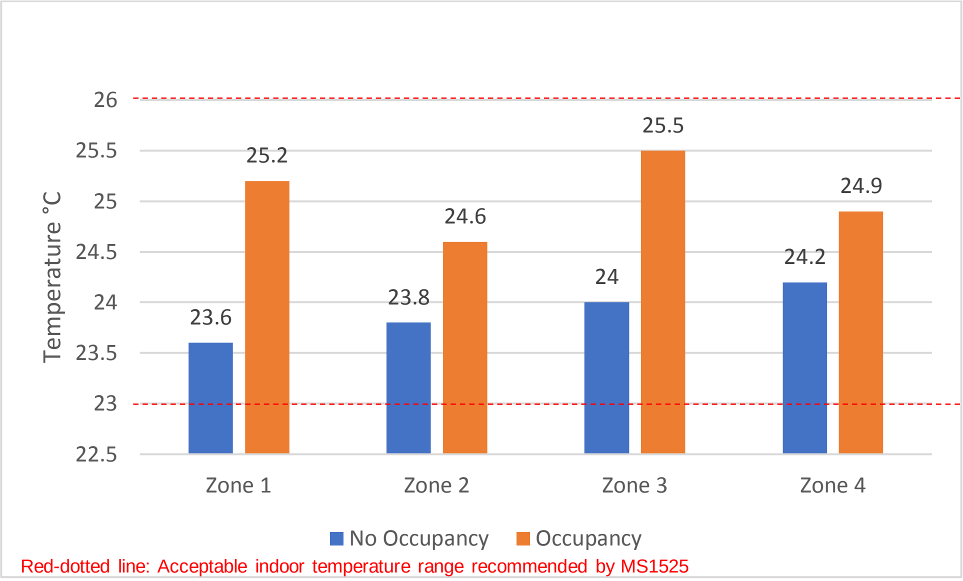

Figure 4.8: Indoor air temperature in lecture room during afternoon

The relative humidity result obtained from each zone in morning session and afternoon session is shown in **Figure 4.9** and **4.10** respectively.

The average overall relative humidity for no occupancy and occupancy are 58.3% and 61.0% respectively as shown in **Figure 4.9.** The relative humidity slightly increases during the no occupancy compare to during occupancy. The relative humidity level recommended by GBI Standard is range between 55% to 70%. The result during morning as shown in **Figure 4.9** is compared with the standard, the relative humidity within the standard.

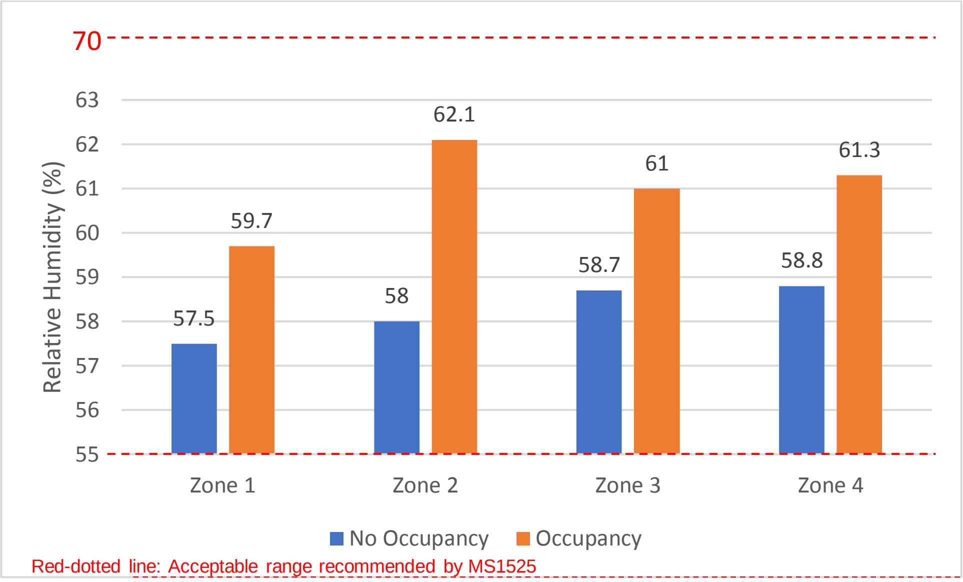

Figure 4.9: Relative humidity in lecture room during morning

The average overall relative humidity for no occupancy and occupancy during afternoon session are 58.5% and 62.4% respectively as shown in **Figure 4.10.** The relative humidity slightly increases during the no occupancy compare to during occupancy. The relative humidity level recommended by GBI Standard is range between 55% to 70%. The result during the afternoon is compared with the standard, the relative humidity within the standard.

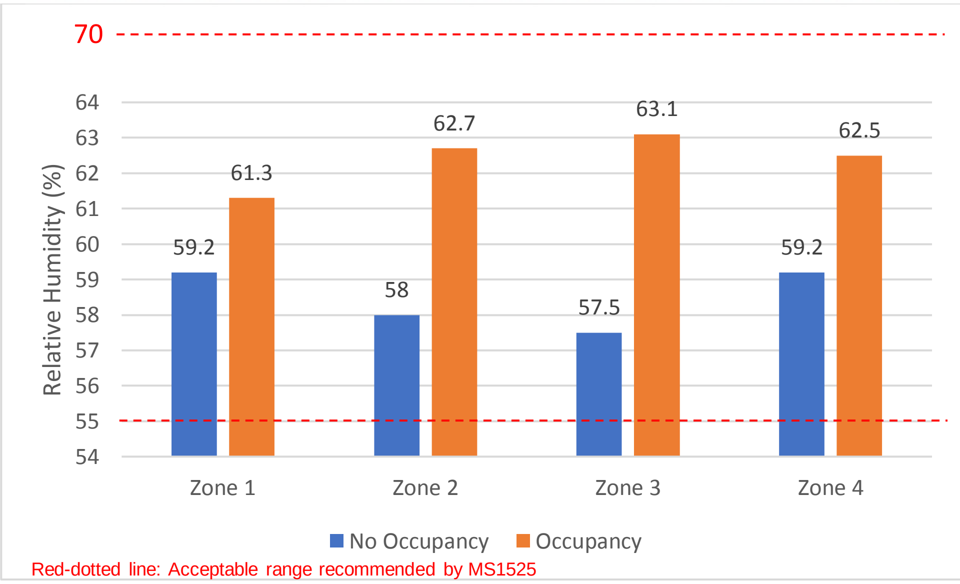

Figure 4.10: Relative humidity in lecture room during afternoon

The carbon dioxide result obtained from each zone in the morning session and afternoon session are shown in **Figure 4.11** and **4.12** respectively.

Based on **Figure 4.11**, the average overall CO_2 level of all zones for no occupancy during the morning session is 647 ppm. However, during occupancy, the average level of carbon dioxide increases to 981 ppm. According to GBI Standard, the maximum level of indoor carbon dioxide should not more than 1000 ppm. Compared to the data result, the level of indoor carbon dioxide is lower than the standard maximum carbon dioxide level during no occupancy and occupancy.

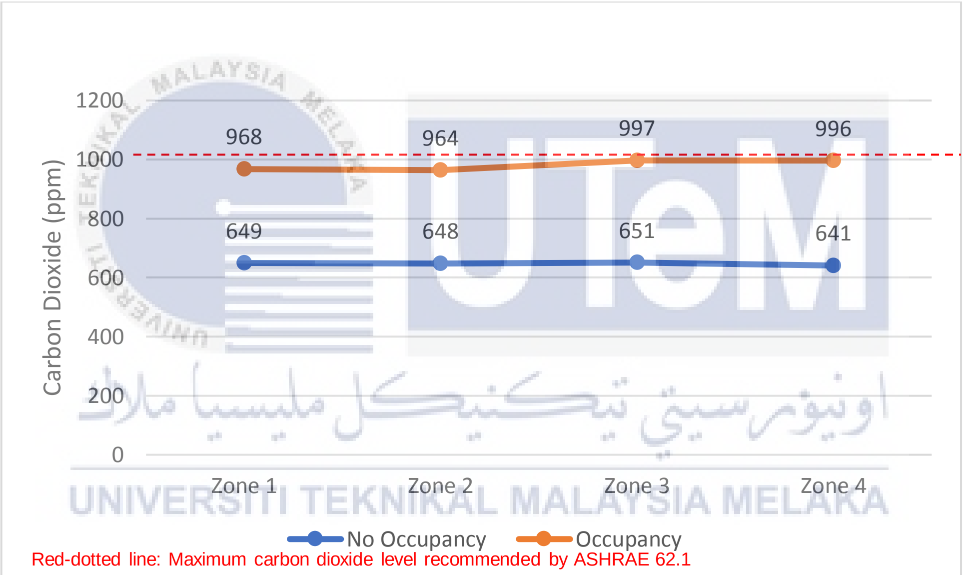

Figure 4.11: Carbon dioxide in lecture room during morning

Based on **Figure 4.12**, the average overall CO_2 level of all zones for no occupancy during the afternoon session is 805 ppm. However, during occupancy, the average level of carbon dioxide increases to 994 ppm. According to GBI Standard, the maximum level of indoor carbon dioxide should not more than 1000 ppm. Compared to the data result, the level of indoor carbon dioxide is lower than the standard maximum carbon dioxide level during no occupancy and occupancy, but nearly to maximum standard.

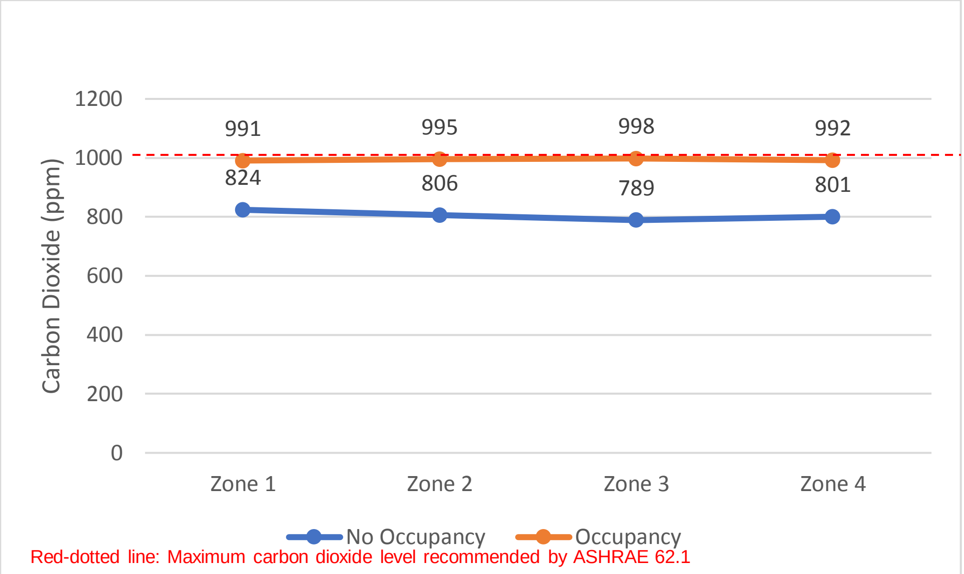

Figure 4.12: Carbon dioxide in lecture room during afternoon

4.1.2 First floor (With Occupants and Without Occupants)

4.1.2.1 Lecture room BK5

There are total 4 measurement zones in ground floor lecture room. The room area is about 153 m^2. In this study, the obtained results for both conditions are analysed and compared in order to know how good the indoor environment quality is when there are no occupant or occupants in the room.

The parameter used to analyse indoor environment quality included air temperature, relative humidity and carbon dioxide. The data for the thermal parameters is recorded for 5 second interval for around 5 minutes in each zone.

The air temperature result obtained from each zone in morning session and afternoon session are shown in **Figure 4.13** and **4.14** respectively. Base on the figure shows, when there are occupants inside the lecture room, the temperature obviously increased about 1°C in each zone.

Figure 4.13 shown the indoor air temperature result obtained from each zone in the morning session, the average overall indoor air temperature in the lecture room BK5 during no occupancy and occupancy is 19.6°C and 20.7°C respectively. The result is compared with GBI Standard, the recommended range for indoor air temperature in the air-conditioning building is 23°C to 26°C. Compared with this study, it is found that the overall indoor air temperature obtains for both conditions are not complying with the standard range. The indoor air temperature is lower than the minimum recommended temperature by 3.1°C for no occupancy condition while for the occupancy condition is lower by 2.1°C

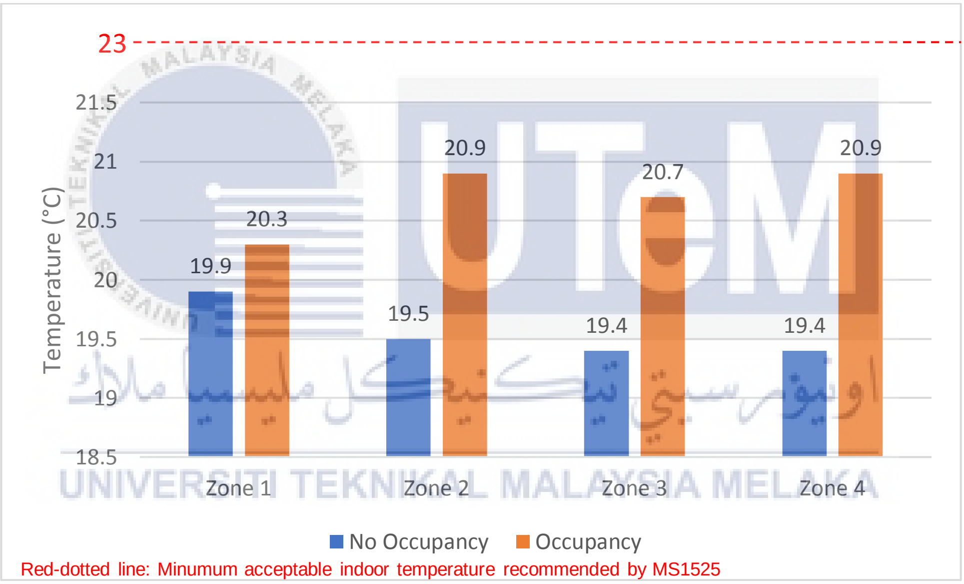

Figure 4.13: Indoor air temperature in lecture room during morning

According to **Figure 4.14**, The average overall air temperature for no occupancy and occupancy are 23°C and 23.7°C respectively. The indoor air temperature slightly increases during the afternoon session compare to the morning session. The air temperature result obtained from each zone in afternoon session is compared with GBI Standard, the recommended range for indoor air temperature in the air-conditioning building is 23°C to 26°C. Compared with this study, it is found that the overall indoor air temperature obtains for both conditions is within the standard range except for zone 1.

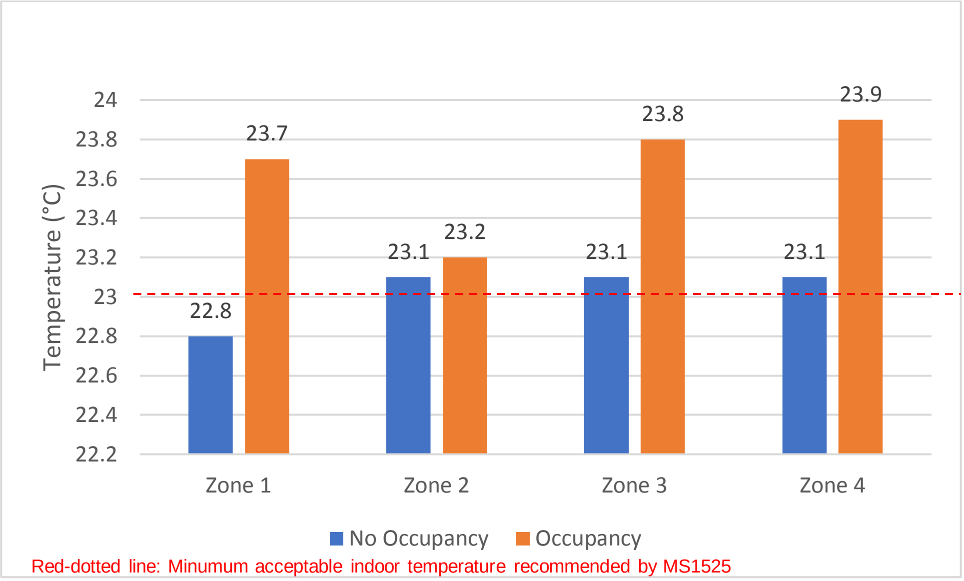

Figure 4.14: Indoor air temperature in lecture room during afternoon

The relative humidity result obtained from each zone in morning session and afternoon session are shown in **Figure 4.15** and **4.16** respectively. The average overall relative humidity for no occupancy and occupancy during morning session are 57.8% and 52.8% respectively as shown in **Figure 4.15.** The relative humidity slightly decreases during the no occupancy compare to during occupancy. The relative humidity level recommended by GBI Standard is range between 55% to 70%. The result during morning as shown in **Figure 4.15** is compared with the standard, the relative humidity for occupancy lower than standard, for no occupancy within the standard.

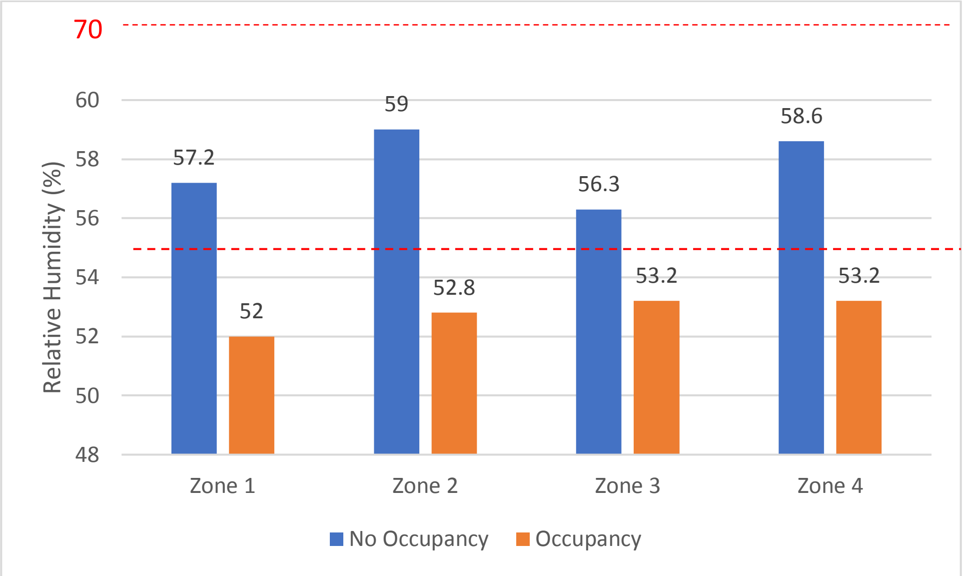

Figure 4.15: Relative humidity in lecture room during morning

The average overall relative humidity for no occupancy and occupancy during afternoon session are 58.5% and 62.4% respectively as shown in **Figure 4.10.** The relative humidity slightly increases during the no occupancy compare to during occupancy. The relative humidity level recommended by GBI Standard is range between 55% to 70%. The result during the afternoon is compared with the standard, the relative humidity within the standard.

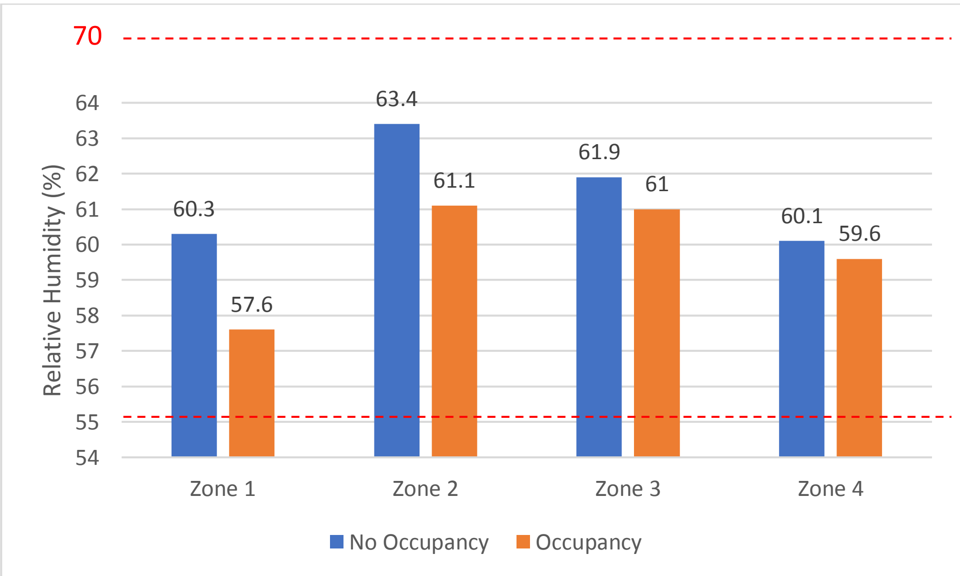

Figure 4.16: Relative humidity in lecture room during afternoon

The carbon dioxide result obtained from each zone in morning session and afternoon session are shown in **Figure 4.17** and **4.18** respectively.

Based on **Figure 4.17**, the average overall CO_2 level of all zones for no occupancy during the morning session is 449 ppm. However, during occupancy, the average level of carbon dioxide increases to 1156 ppm. According to GBI Standard, the maximum level of indoor carbon dioxide should not more than 1000 ppm. Compared to the data result, the level of indoor carbon dioxide is lower than the standard maximum carbon dioxide level during no occupancy, but during occupancy, the level of indoor carbon dioxide is higher than standard by 174 ppm.

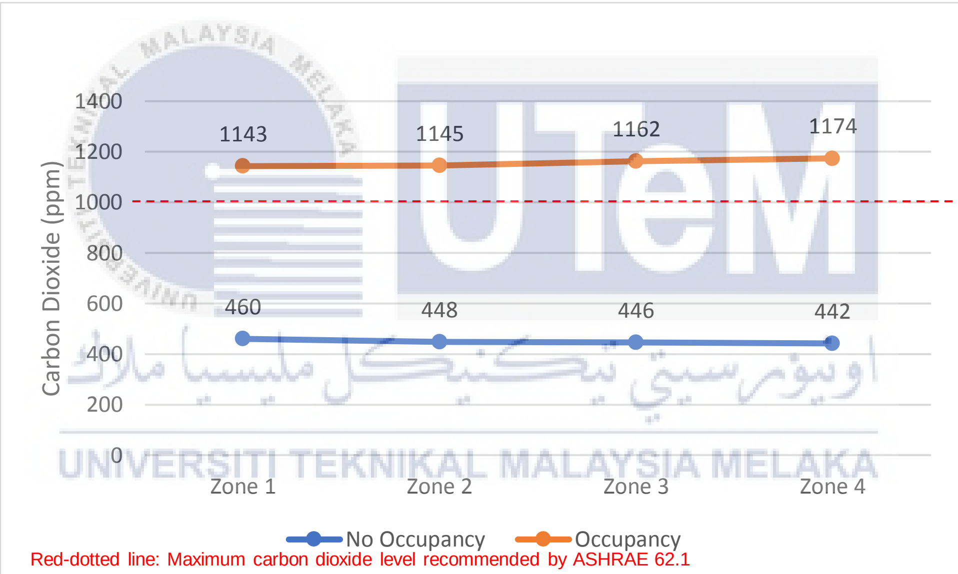

Figure 4.17: Carbon dioxide in lecture room during morning

Based on **Figure 4.18**, the average overall CO_2 level of all zones for no occupancy during the afternoon session is 531 ppm. However, during occupancy, the average level of carbon dioxide increases to 2343 ppm. According to GBI Standard, the maximum level of indoor carbon dioxide should not more than 1000 ppm. Compared to the data result, the level of indoor carbon dioxide is lower than the standard maximum carbon dioxide level during no occupancy but during occupancy, the level of indoor carbon dioxide is higher than standard by 1411 ppm.

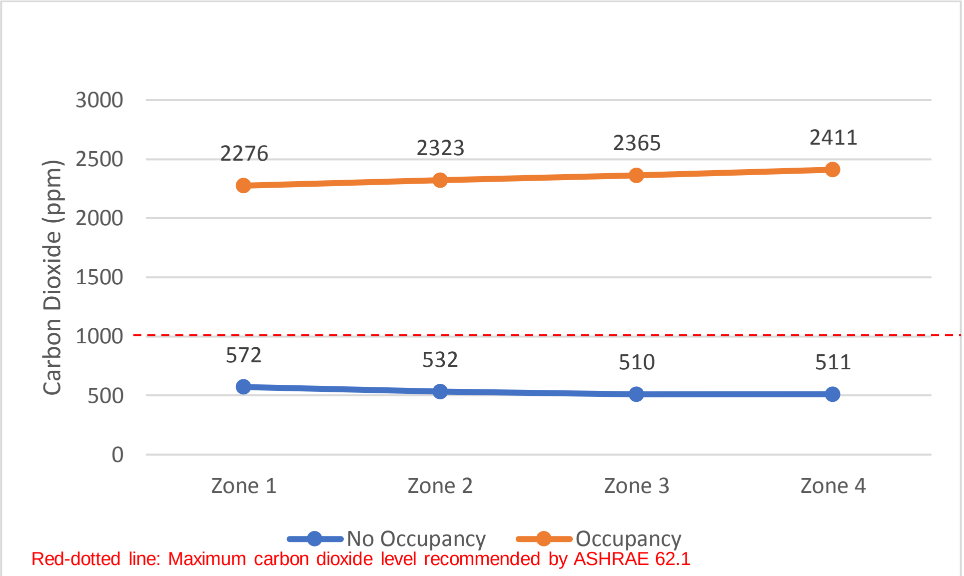

Figure 4.18: Carbon dioxide in lecture room during afternoon

4.1.2.2 Language laboratories MB3

There are total 4 measurement zones in ground floor Language laboratories. The laboratories area is about 154 m^2. In this study, the obtained results for both conditions are analysed and compared in order to know how good the indoor environment quality is when there are no occupant or occupants in the laboratories.

The parameter used to analyse indoor environment quality included air temperature, relative humidity and carbon dioxide. The data for the thermal parameters is recorded for 5 second interval for around 5 minutes in each zone.

The air temperature result obtained from each zone in morning session and afternoon session are shown in **Figure 4.19** and **4.20** respectively.

Figure 4.19 shown the indoor air temperature result obtained from each zone in the morning session, the average overall temperature in the laboratories during no occupancy and occupancy is 24.4°C and 24.8°C respectively. The result is compared with GBI Standard, the recommended range for indoor air temperature in the air-conditioning building is 23°C to 26°C. Compared with this study, it is found that the overall indoor air temperature obtains for both conditions is within the standard range.

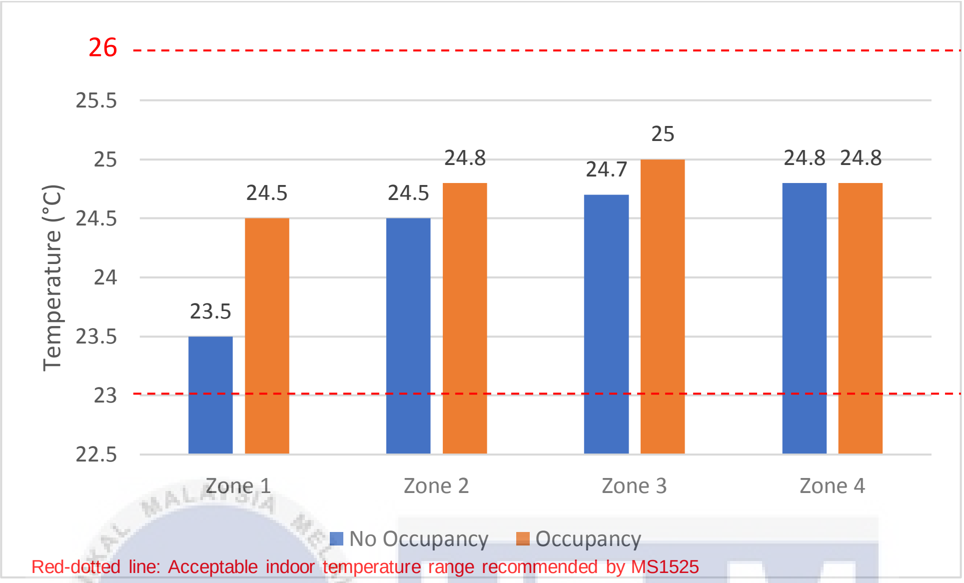

Figure 4.19: Indoor air temperature in lecture room during morning

Figure 4.20 shown the indoor air temperature result obtained from each zone in the afternoon session, the average overall temperature in the laboratories during no occupancy and occupancy is 26.2.9°C and 26.3°C respectively. The result is compared with GBI Standard, the recommended range for indoor air temperature in the air-conditioning building is 23°C to 26°C. Compared with this study, it is found that the overall indoor air temperature obtains for both conditions is not within the standard range, the temperature higher than maximum standard temperature.

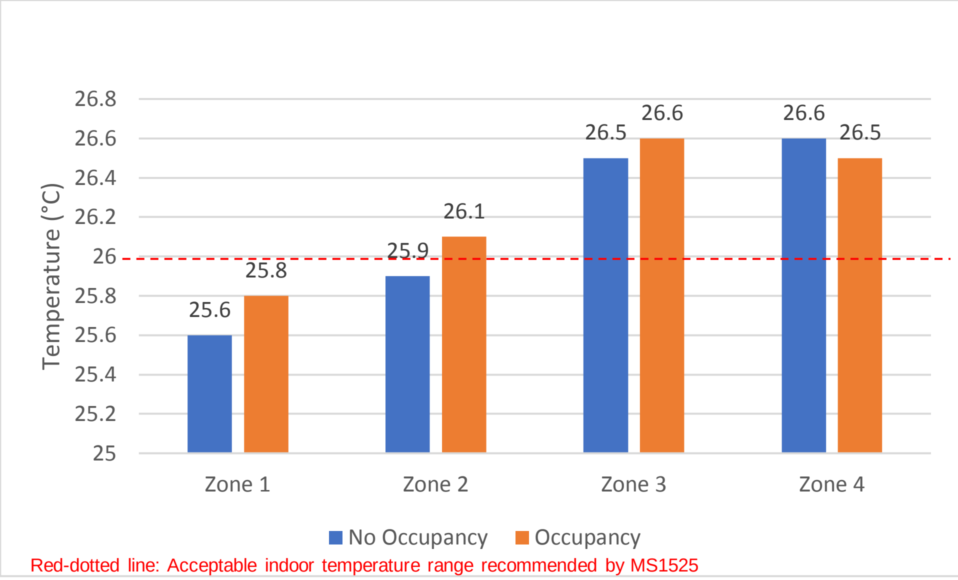

Figure 4.20: Indoor air temperature in lecture room during afternoon

The relative humidity result obtained from each zone in morning session and afternoon session are shown in **Figure 4.21** and **4.22** respectively.

The average overall relative humidity for no occupancy and occupancy during morning session are 65% and 63.9% respectively as shown in **Figure 4.21.** The relative humidity slightly decreases during the occupancy compare to during no occupancy. The relative humidity level recommended by GBI Standard is range between 55% to 70%. The result during morning as shown in **Figure 4.21** is compared with the standard, the relative humidity of the laboratories within the standard.

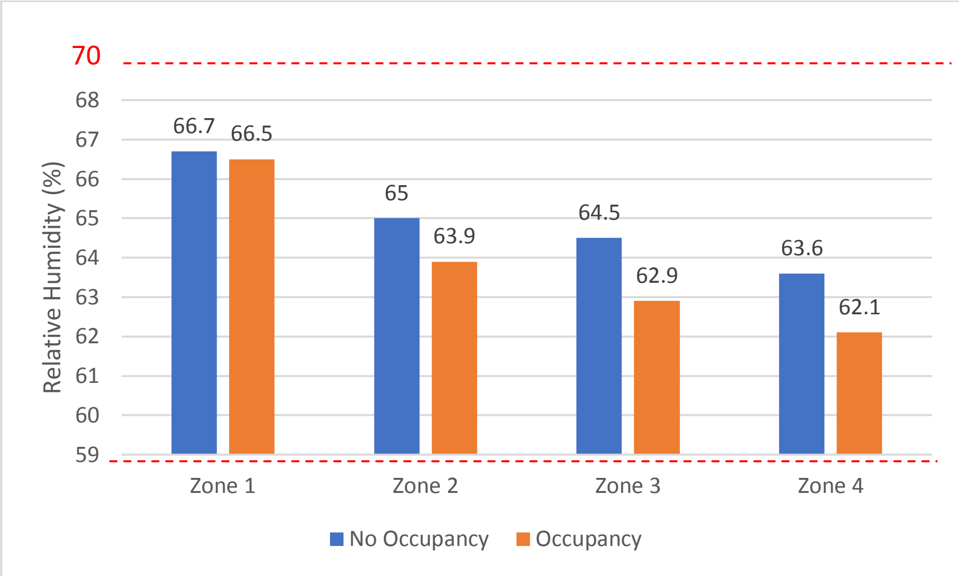

Figure 4.21: Relative humidity in lecture room during morning

The average overall relative humidity for no occupancy and occupancy during afternoon session are 64.7% and 62.9% respectively as shown in **Figure 4.22.** The relative humidity slightly decreases during the occupancy compare to during no occupancy. The relative humidity level recommended by GBI Standard is range between 55% to 70%. The result during the afternoon is compared with the standard, the relative humidity within the standard.

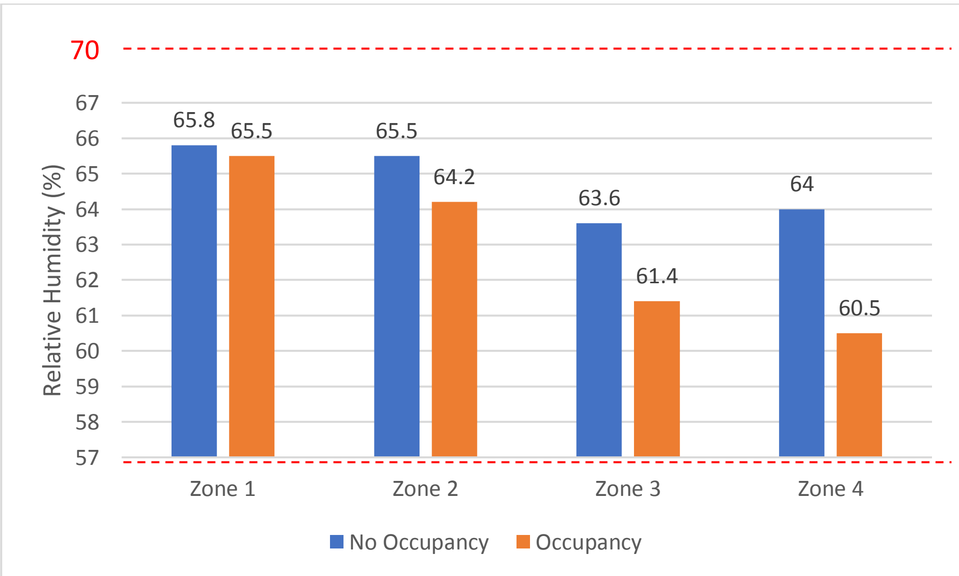

Figure 4.22: Relative humidity in lecture room during afternoon

The carbon dioxide result obtained from each zone in morning session and afternoon session are shown in **Figure 4.23** and **4.24** respectively.

Based on **Figure 4.23**, the average overall CO_2 level of all zones for no occupancy during the morning session is 408 ppm. However, during occupancy, the average level of carbon dioxide increases to 1297 ppm. According to GBI Standard, the maximum level of indoor carbon dioxide should not more than 1000 ppm. Compared to the data result, the level of indoor carbon dioxide is lower than the standard maximum carbon dioxide level during no occupancy, but during occupancy, the level of indoor carbon dioxide is higher than standard by 345 ppm.

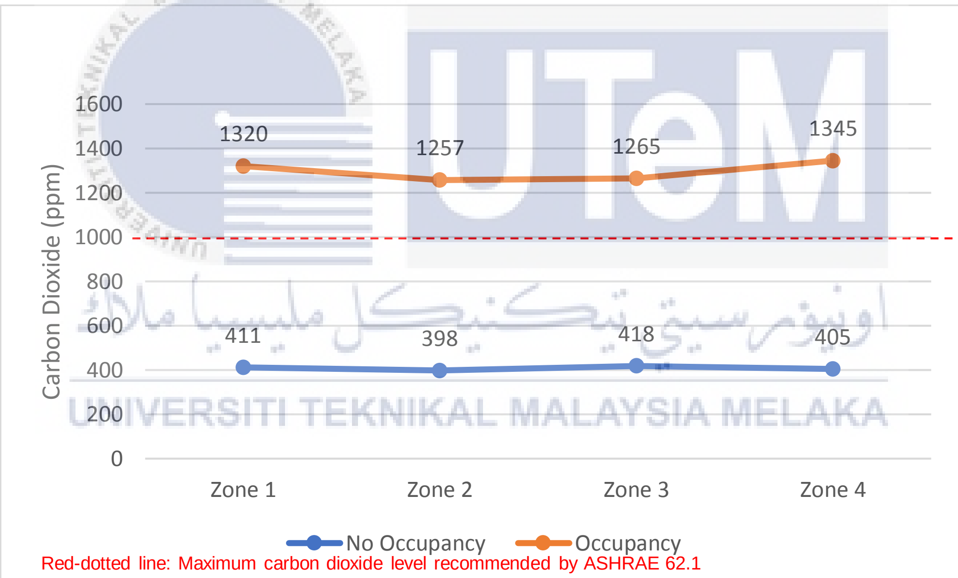

Figure 4.23: Carbon dioxide in lecture room during morning

Based on **Figure 4.24**, the average overall CO_2 level of all zones for no occupancy during the afternoon session is 413 ppm. However, during occupancy, the average level of carbon dioxide increases to 1409 ppm. According to GBI Standard, the maximum level of indoor carbon dioxide should not more than 1000 ppm. Compared to the data result, the level of indoor carbon dioxide is lower than the standard maximum carbon dioxide level during no occupancy but during occupancy, the level of indoor carbon dioxide is higher than standard by 467 ppm.

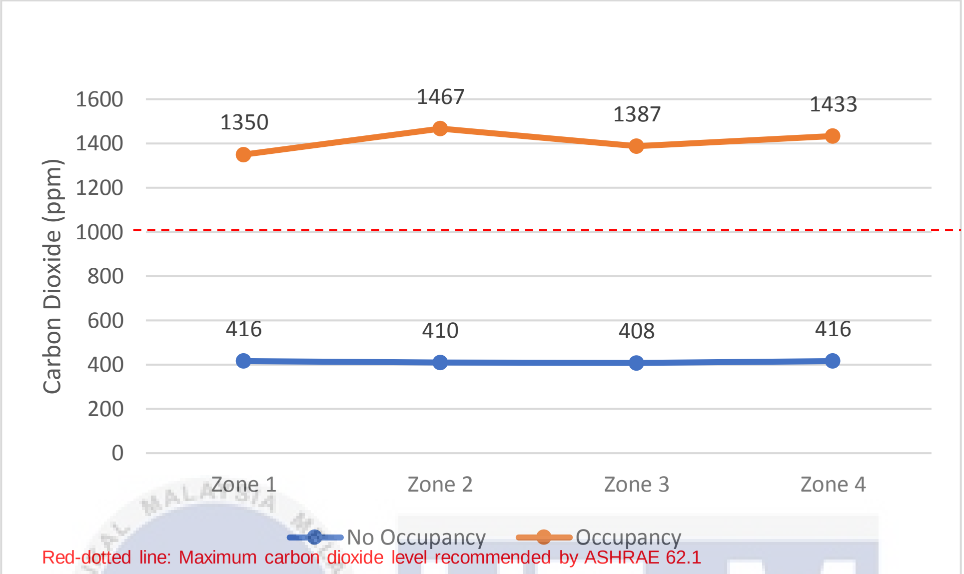

Figure 4.24: Carbon dioxide in lecture room during afternoon

4.1.3 Second floor (With Occupants and Without Occupants)

4.1.3.1 Lecture room BK8

There are total 4 measurement zones in ground floor lecture room. The room area is about 60 m^2. In this study, the obtained results for both conditions are analysed and compared in order to know how good the indoor environment quality is when there are no occupant or occupants in the room.

The parameter used to analyse indoor environment quality included air temperature, relative humidity and carbon dioxide. The data for the thermal parameters is recorded for 5 second interval for around 5 minutes in each zone.

The air temperature result obtained from each zone in morning session and afternoon session are shown in **Figure 4.25** and **4.26** respectively.

Figure 4.25 shown the indoor air temperature result obtained from each zone in the morning session, the average overall indoor air temperature in the lecture room BK8 during no occupancy and occupancy is 21.5°C and 23.3°C respectively. The result is compared with GBI Standard, the recommended range for indoor air temperature in the air-conditioning building is 23°C to 26°C. Compared with this study, it is found that the overall indoor air temperature obtains for both conditions are not complying with the standard range. The indoor air temperature is lower than the minimum recommended temperature by 1.2°C for no occupancy condition while for the occupancy condition is within the standard range.

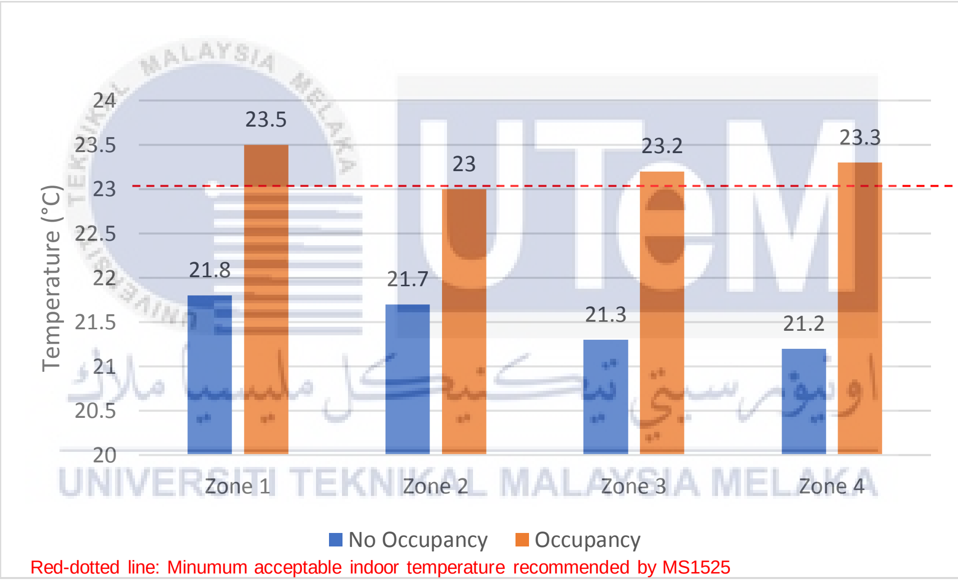

Figure 4.25: Indoor air temperature in lecture room during morning

According to **Figure 4.26**, The average overall air temperature for no occupancy and occupancy are 20.3°C and 23.6°C respectively. The indoor air temperature slightly increases during the afternoon session compare to the morning session. The air temperature result obtained from each zone in afternoon session is compared with GBI Standard, the recommended range for indoor air temperature in the air-conditioning building is 23°C to 26°C. Compared with this study, the indoor air temperature is lower than the minimum recommended temperature by 1.9°C for no occupancy condition while for the occupancy condition is within the standard range.

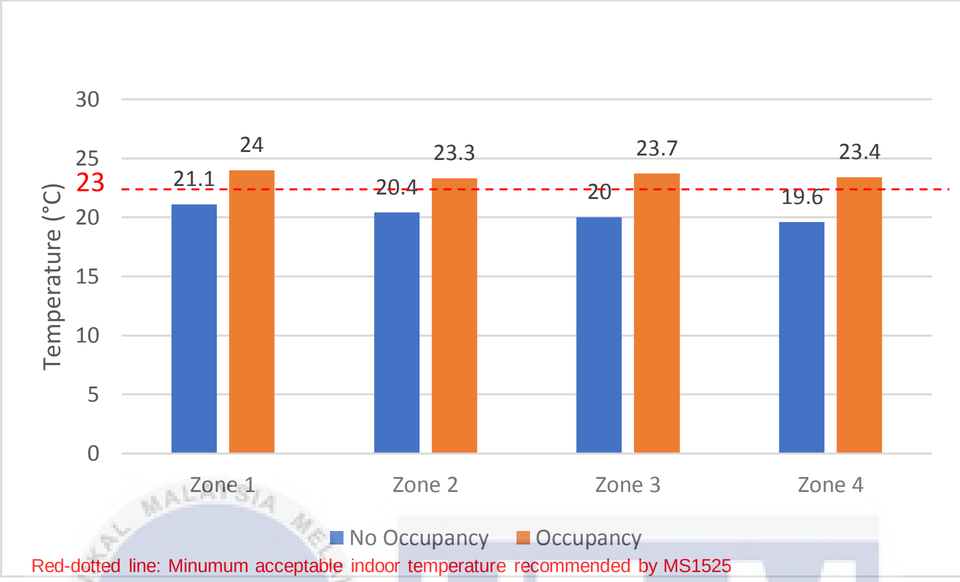

Figure 4.26: Indoor air temperature in lecture room during afternoon

The relative humidity result obtained from each zone in morning session and afternoon session are shown in **Figure 4.27** and **4.28** respectively.

The average overall relative humidity for no occupancy and occupancy during morning session are 56% and 53.4% respectively as shown in **Figure 4.27.** The relative humidity slightly decreases during the occupancy compare to during no occupancy. The relative humidity level recommended by GBI Standard is range between 55% to 70%. The result during the morning as shown in **Figure 4.27** is compared with the standard, the relative humidity for occupancy at zone 1 and zone 2 within the standard, but zone 3 and zone 4 lower than standard followed by no occupancy.

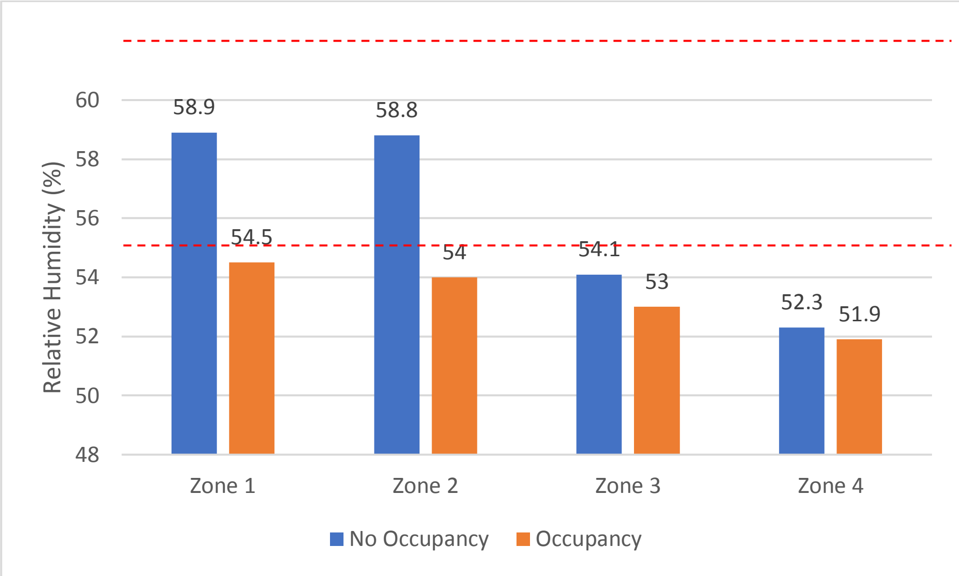

Figure 4.27: Relative humidity in lecture room during morning

The average overall relative humidity for no occupancy and occupancy during afternoon session are 60% and 53.8% respectively as shown in **Figure 4.28.** The relative humidity slightly increases during the no occupancy compare to during occupancy. The relative humidity level recommended by GBI Standard is range between 55% to 70%. The result during the afternoon is compared with the standard, the relative humidity within the standard except for zone 1 during occupancy.

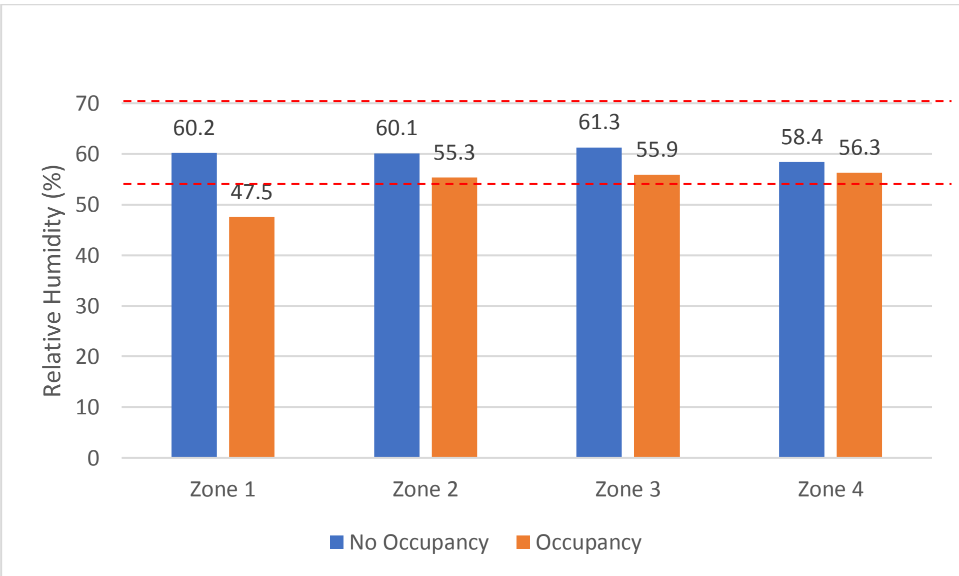

Figure 4.28: Relative humidity in lecture room during afternoon

The carbon dioxide result obtained from each zone in morning session and afternoon session are shown in **Figure 4.29** and **4.30** respectively.

Based on **Figure 4.29**, the average overall CO_2 level of all zones for no occupancy during the morning session is 435 ppm. However, during occupancy, the average level of carbon dioxide increases to 1107 ppm. According to GBI Standard, the maximum level of indoor carbon dioxide should not more than 1000 ppm. Compared to the data result, the level of indoor carbon dioxide is lower than the standard maximum carbon dioxide level during no occupancy, but during occupancy, the level of indoor carbon dioxide is higher than standard by 181 ppm.

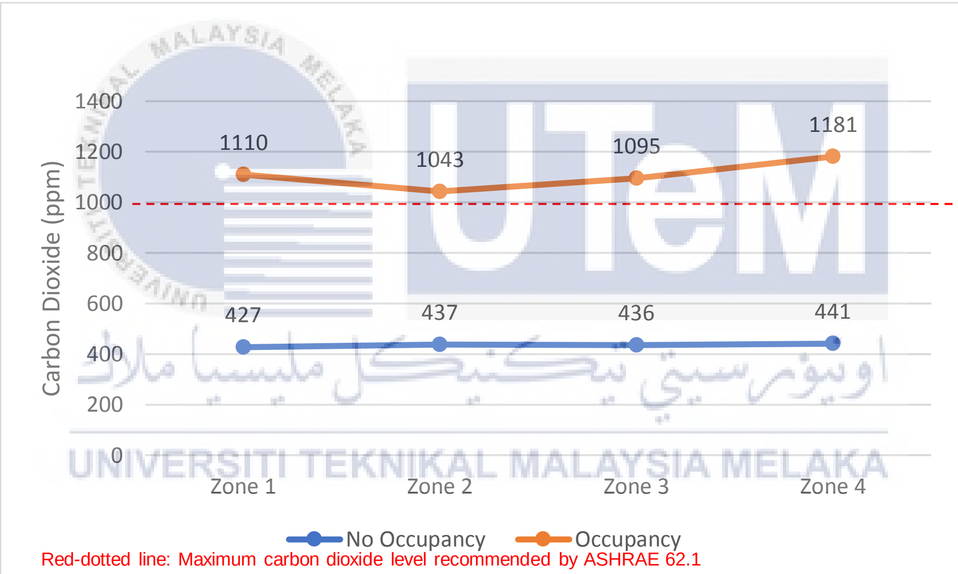

Figure 4.29: Carbon dioxide in lecture room during morning

Based on **Figure 4.30**, the average overall CO_2 level of all zones for no occupancy during the afternoon session is 409 ppm. However, during occupancy, the average level of carbon dioxide increases to 2673 ppm. According to GBI Standard, the maximum level of indoor carbon dioxide should not more than 1000 ppm. Compared to the data result, the level of indoor carbon dioxide is lower than the standard maximum carbon dioxide level during no occupancy but during occupancy, the level of indoor carbon dioxide is higher than standard by 1837 ppm.

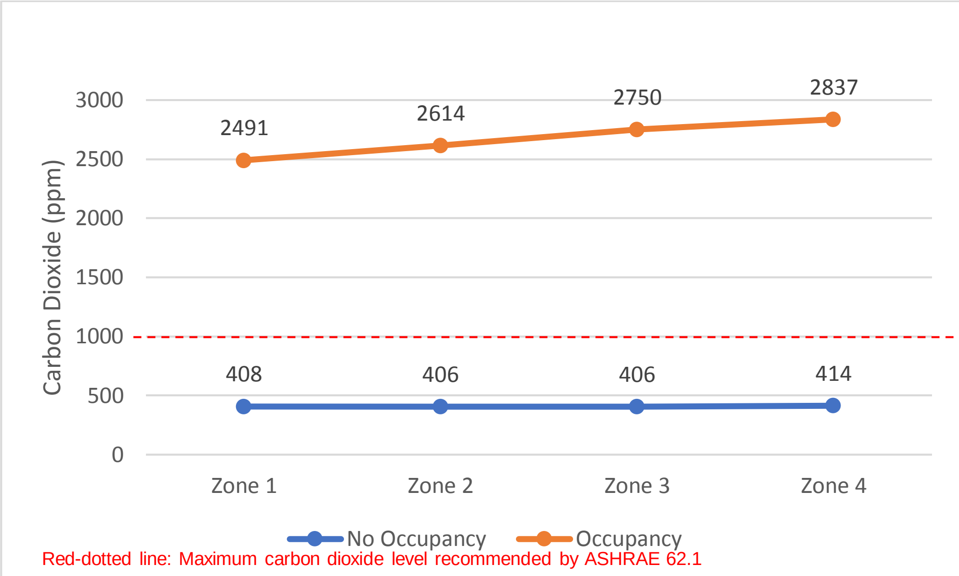

Figure 4.30: Carbon dioxide in lecture room during afternoon

4.1.4 Overall physical measurement result

In general, the average readings for each of the parameters for both conditions in ground floor, first floor and second floor are list in **Table 4.1**, **4.2** and **4.3** respectively.

Table 4.1: Physical measurement results at ground floor

	Ground floor			
	Without occupants	Comment	With occupants	Comment
	Lecture room BK1			
Temperature (°C)	AM: 20.4 PM: 23.35	- Lower - Within standard	AM: 20.9 PM: 24.2	- Lower - Within standard
Relative Humidity (%)	AM: 52 PM: 52.9	Slightly low	AM: 50.6 PM: 59.8	- Lower - Within standard
Carbon Dioxide (ppm)	AM: 587 PM: 846	Within standard	AM: 1095 PM: 2080	- Slightly high - Higher than standard
	Language laboratories MB 1			
Temperature (°C)	AM: 24 PM: 23.9	Within standard	AM: 24.5 PM: 25.1	Within standard
Relative Humidity (%)	AM: 58.3 PM: 58.5	Within standard	AM: 61 PM: 62.4	Within standard
Carbon Dioxide (ppm)	AM: 647 PM: 805	Within standard	AM: 981 PM: 994	Within standard

*AM=Morning session, PM=Afternoon session

Table 4.2: Physical measurement results at first floor

	First floor			
	Without occupants	Comment	With occupants	Comment
	Lecture room BK5			
Temperature (°C)	AM: 19.6 PM: 23.5	- Lower - Within standard	AM: 20.7 PM: 23.7	- Lower - Within standard
Relative Humidity (%)	AM: 57.8 PM: 61.4	Within standard	AM: 52.8 PM: 59.8	- Lower - Within standard
Carbon Dioxide (ppm)	AM: 449 PM: 531	Within standard	AM: 1156 PM: 2344	Higher than standard
	Language laboratories MB 3			
Temperature (°C)	AM: 24.4 PM: 26.2	Within standard	AM: 24.8 PM: 26.3	Within standard
Relative Humidity (%)	AM: 65.0 PM: 64.7	Within standard	AM: 63.9 PM: 62.9	Within standard
Carbon Dioxide (ppm)	AM: 408 PM: 413	Within standard	AM: 1297 PM: 1409	Higher than standard

*AM=Morning session, PM=Afternoon session

Table 4.3: Physical measurement results at second floor

	Second floor			
	Without occupants	Comment	With occupants	Comment
	Lecture room BK8			
Temperature (°C)	AM: 21.5 PM: 20.3	Lower than standard	AM: 23.3 PM: 23.6	Within standard
Relative Humidity (%)	AM: 56.0 PM: 60	Within standard	AM: 53.4 PM: 53.75	Slightly low
Carbon Dioxide (ppm)	AM: 435 PM: 409	Within standard	AM: 1107 PM: 2673	Higher than standard

*AM=Morning session, PM=Afternoon session

Based on **Table 4.1**, the indoor air temperature for lecture room BK1 during the morning is lower than the minimum recommended air temperature and hence not comply with the GBI Standard. The air temperature increase when occupants are present is because of additional heat gains from occupant body. The carbon dioxide exceeds maximum GBI Standard when increase the number of occupants. The physical parameter results inside Language laboratories at ground floor of the building is comply with standard.

Relative humidity can be defined as the ratio of the amount of moisture present to the maximum amount of moisture that the air able to hold at its current temperature. Indoor humidity is important to be concerned as it highly affects human health. High humidity enhances the fungal growth and influences the number of indoor allergens which could lead to Sick Building Syndrome (J. Wang et al., 2013). **Table 4.1** and **Table 4.3** shows that the relative humidity in lecture room without occupants is higher than occupancy conditions is slightly lower than recommended range by GBI Standard.

Based on **Table 4.2**, the relative humidity in lecture room and language laboratories for both conditions are within the recommended range by GBI Standard except the morning session for occupancy condition 53% of relative humidity is lower than the minimum allowable relative humidity by standard. However, most of the natural ventilated buildings in tropics have relative humidity higher than 70% due to the hot and humid climates. The indoor condition of natural ventilated building is highly influenced by outdoor weather conditions as it relies on air movement through openings. Study showed that there is a strong correlation between air temperatures with relative humidity. As air temperature increases, the relative humidity decreases. lower the temperature will rise relative humidity. (Nguyen & Schwartz, 2014). Hence, the increase in relative humidity during the morning can be explained by the low air temperature and cause the relative humidity increases.

Most of the studies mentioned that carbon dioxide level commonly used as a parameter to determine the indoor air quality of a building. Carbon dioxide level can be used to evaluate the adequacy of the room ventilation (Telejko, 2017). Based on **Table 4.1**, the carbon dioxide level for without occupants in the lecture room is within the recommended standard by GBI Standard. But, the carbon dioxide level during occupants in the lecture room is slightly higher than the recommended standard by GBI Standard. Based on **Table 4.2** and **Table 4.3** the carbon dioxide level for both conditions in the lecture room is also within the recommended level by GBI Standard during morning session. The carbon dioxide level increases when occupants are present. CO_2 within the building is the output of human breathe. Most of the studies showed that the carbon dioxide level increases when the rooms start to be occupied. Academic building is detected have high concentration of CO_2 due to lack of air movement through window (Denmark et al., 2013).

4.2 Subjective Assessment

In this study, questionnaire surveys are conducted during the objective measurement session in the lecture room. The subjective assessment is carried out starting on 2nd March 2019 in lecture room and language laboratories. There are total 30 respondents in each room for each session.

In this study, ASHRAE seven-point scales are used to investigate occupants' perception towards the indoor environment of the lecture room and language laboratories. According to ASHRAE Standard 55, the indoor environment is considered acceptable if 80% of the occupants voted for interval (-1, +1). Moreover, Fanger's theory mentioned that votes for interval (-1, +1) means that the thermal environment is acceptable while votes for intervals (-3, -2) and (+2, +3) describe the environment is not acceptable.

4.2.1 Survey analysis at ground floor

Thermal sensation votes in ground floor lecture room BK1 and language laboratories MB1 are shown in **Table 4.4**.

Based on **Table 4.4**, in lecture room BK1, 10% of respondents voted for hot while 22% of respondents voted for warm and 12% of respondents voted for slightly warm. 18% of respondents voted for neutral, 28% of respondents voted for slightly cool. 7% of respondents voted for cool and only 3% % of respondents voted for cold. Besides that, in Language Laboratories MB1, 27% of respondents voted for hot while 33% of respondents voted for warm and 17% of respondents voted for slightly warm. 23% of respondents voted for neutral. There is no respondent voted for slightly cool, cool and cold in Language Laboratories. The results indicate that less than 80% of the respondents in lecture room and language laboratories voted for the central three categories (slightly cool, neutral, and slightly warm). This finding shows that ground floor was not in thermal acceptable conditions.

Table 4.4: Occupants thermal sensation vote for ground floor

ASHRAE Scale		Lecture Room BK1			Language Laboratories MB1		
		Morning	Afternoon	Total	Morning	Afternoon	Total
Hot	+3	0	6	6	4	12	16
Warm	+2	0	13	13	8	12	20
Slightly warm	+1	0	7	7	4	6	10
Neutral	0	9	2	11	14	0	14

Slightly cool	-1	15	2	17	0	0	0
Cool	-2	4	0	4	0	0	0
Cold	-3	2	0	2	0	0	0
Total		30	30	60	30	30	60

Table 4.5 shows shown the relative humidity sensation scale in ground floor lecture room BK1 and language laboratories MB1. Based on table, 63% of the BK1 respondents voted for neutral and 12% respondents voted for slightly dry. 20% respondents voted for slightly humid. 5% respondents voted for Moderately humid. At language laboratories MB1, majority of 67% of respondents voted for neutral. There are only 5% of the respondents voted for moderately humid while 8% of respondents voted for slightly dry. On the other hand, 20% of the respondents voted for slightly humid. Majority of the respondents expressed their votes (-1, 0 and +1) in BK1 and MB1 at 95%.

Table 4.5: Occupants relative humidity sensation vote for Ground floor

ASHRAE Scale		Lecture Room BK1			Language Laboratories MB1		
		Morning	Afternoon	Total	Morning	Afternoon	Total
Very dry	+3	0	0	0	0	0	0
Dry	+2	0	0	0	0	0	0
Slightly dry	+1	3	4	7	3	2	5
Neutral	0	22	16	38	17	23	40

Slightly humid	-1	8	4	12	7	5	12
Moderately humid	-2	1	2	3	3	0	3
Humid	-3	0	0	0	0	0	0
Total		30	30	60	30	30	60

4.2.2 Survey analysis at first floor

Based on **Table 4.6**, in lecture room BK5 at first floor, 10% of respondents voted for slightly while 18% of respondents voted for neutral and 40% of respondents voted for slightly cool. 20% of respondents voted for cool, 12% of respondents voted for cold. There is no respondent voted for warm and hot in lecture room BK5. Besides that, in Language Laboratories MB3 at first floor, 37% of respondents voted for hot while 27% of respondents voted for warm and 25% of respondents voted for slightly warm. Only 12 of respondents voted for neutral. There is no respondent voted for slightly cool, cool and cold in Language Laboratories MB3. The results indicate that less than 80% of the respondents in lecture room and language laboratories voted for the central three categories (slightly cool, neutral, and slightly warm). This finding shows that first floor was not in thermal acceptable conditions.

Table 4.6: Occupants thermal sensation vote for first floor

ASHRAE Scale		Lecture Room BK5			Language Laboratories MB3		
		Morning	Afternoon	Total	Morning	Afternoon	Total
Hot	+3	0	0	0	4	18	22
Warm	+2	0	0	0	10	6	16
Slightly warm	+1	0	6	6	9	6	15
Neutral	0	2	9	11	7	0	7
Slightly cool	-1	9	15	24	0	0	0
Cool	-2	12	0	12	0	0	0
Cold	-3	7	0	7	0	0	0
Total		30	30	60	30	30	60

Based on **Table 4.7**, 32% of the respondents voted for neutral and 28% of respondents voted for slightly dry. 22% of the respondents voted for slightly humid. There are only 2% of the respondents voted for humid while 18% of respondents voted for moderately humid in lecture room BK5. On the other hand, there are only 2% of the respondents voted for very dry. While 38% of respondents voted for Slightly humid. 33% of respondents voted for neutral and 12% of respondents voted for slightly dry. 15% of respondents voted for moderately humid in language laboratories MB3. Results shown that majority of the respondents expressed their votes (-1, 0 and +1) for lecture room BK5 and language laboratories MB3 is 82% and 60% respectively.

Table 4.7: Occupants relative humidity sensation vote for first floor

ASHRAE Scale		Lecture Room BK5			Language Laboratories MB3		
		Morning	Afternoon	Total	Morning	Afternoon	Total
Very dry	+3	0	0	0	0	1	1
Dry	+2	0	0	0	0	0	0
Slightly dry	+1	3	14	17	1	6	7
Neutral	0	7	12	19	10	10	20
Slightly humid	-1	11	2	13	14	9	23
Moderately humid	-2	9	2	11	5	4	9
Humid	-3	0	1	1	0	0	0
Total		30	30	60	30	30	60

4.2.3 Survey analysis at second floor

Based on **Table 4.8**, in lecture room BK8, 37% of respondents voted for slightly warm. 25% of respondents voted for neutral and slightly cool respectively. Only 13% of respondents voted for cool. There is no respondent voted for cold, hot and warm in lecture room BK8. The results indicate that more than 80% of the respondents in lecture room and language laboratories voted for the central three categories (slightly cool, neutral, and slightly warm). This finding shows that second floor room was in thermal acceptable conditions.

Table 4.8: Occupants thermal sensation vote for Second floor

ASHRAE Scale		Lecture Room BK8		
		Morning	Afternoon	Total
Hot	+3	0	0	0
Warm	+2	0	0	0
Slightly warm	+1	15	7	22
Neutral	0	5	10	15
Slightly cool	-1	7	8	15
Cool	-2	3	5	8
Cold	-3	0	0	0
Total		30	30	60

Based on **Table 4.9** Occupants relative humidity sensation vote for second floor, 63% of the respondents voted for neutral. 20% respondents voted for slightly humid. There are only 5% of the respondents voted for moderately humid. 12% of respondents voted for slightly dry in lecture room BK8. Results in Table 4.9 indicates that majority of the respondents expressed their votes (-1, 0 and +1) in lecture room BK8 by 95%.

Table 4.9: Occupants relative humidity sensation vote for second floor

ASHRAE Scale		Lecture Room BK8		
		Morning	Afternoon	Total
Very dry	+3	0	0	0
Dry	+2	0	0	0
Slightly dry	+1	3	4	7
Neutral	0	22	16	38
Slightly humid	-1	8	4	12
Moderately humid	-2	1	2	3
Humid	-3	0	0	0
Total		30	30	60

4.3 Comparison between objective measurement and questionnaire

Based on measurement results shown in Table 4.1, the air temperature in at ground floor is around 20.9°C when occupants are present. From the subjective measurement results shown in Table 4.4, the thermal condition in ground floor is not acceptable due to less than 80% of the respondents voted for the central three categories which include slightly cool, neutral, and slightly warm. This mean the physical measurement and the survey is related. So, air temperature in ground floor need to be improve.

From the measurement results shown in Table 4.2, the air temperature in at first floor is around 20.7°C when occupants are present. From the subjective measurement results shown in Table 4.6, the thermal condition at first floor is not acceptable due to less than 80% of the respondents voted for the central three categories which include slightly cool, neutral, and slightly warm. This mean the physical measurement and the survey is related. So, air temperature at first floor also need to be improve.

Based on measurement results shown in Table 4.3, the air temperature in at second floor is around 23.2°C when occupants are present. From the subjective measurement results shown in Table 4.8, the thermal condition in second floor is acceptable due to more than 80% of the respondents voted for the central three categories which include slightly cool, neutral, and slightly warm. This mean the physical measurement and the survey is in good related.

4.4 Regression Analysis

Many of the studies on thermal comfort analysis used regression method to investigate the relationship between operative temperature and TSV/PMV as the air temperature is considered the deterministic factor of thermal sensation. Regression analysis is applied to determine the neutral temperature from the thermal sensation data. Based on previous studies, it proved that a strong linear relationship between TSV/PMV and operative temperature. The classification of R-squared value to interpret the strength of relationship between dependent variable and independent variable is shown in **Table 4.10**.

Table 4.10: Classification of R-squared value (Moore et al., 2013)

Range of R-squared value	**Strength of relationship**
$R_2 < 0.3$	Very weak
$0.3 < R_2 < 0.5$	Weak
$0.5 < R_2 < 0.7$	Moderate
$R_2 > 0.7$	Strong

4.4.1 Regression analysis at ground floor

According to ASHRAE 55, PMV index relates the thermal comfort factors and predicts the mean value of votes from occupants on the seven point scale. The regression of PMV and operative temperature in machine workshop is shown in **Figure 4.31**. Based on the figure, the R_2 is 78.2% or 0.782. This indicated that the relationship between PMV and operative temperature is strong. The predicted neutral temperature from PMV regression is 22.3°C.

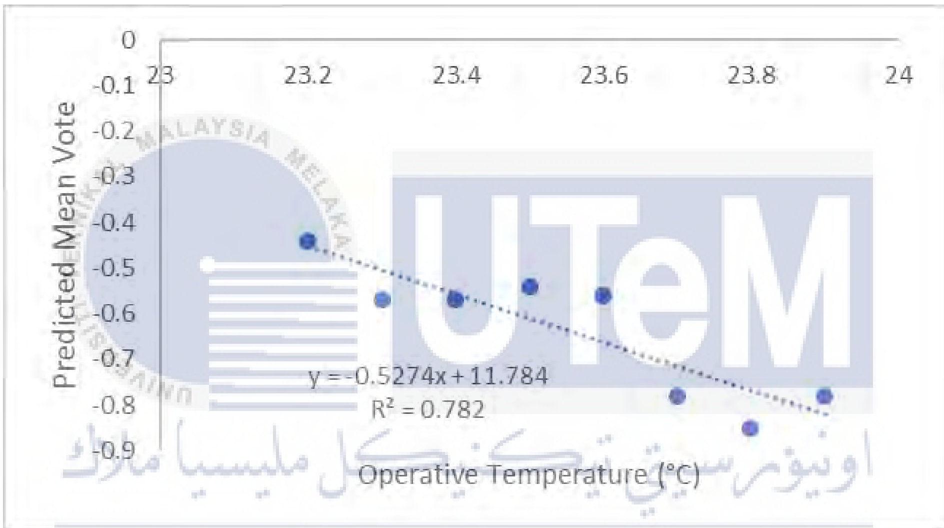

Figure 4.31: Graph of PMV versus operative temperature at ground floor

4.4.2 Regression analysis at first floor

According to ASHRAE 55, PMV index relates the thermal comfort factors and predicts the mean value of votes from occupants on the seven-point scale. The regression of PMV and operative temperature in machine workshop is shown in **Figure 4.32**. Based on the figure, the R_2 is 72.48% or 0.7248. This indicated that the relationship between PMV and operative temperature is strong. The predicted neutral temperature from PMV regression is 26.1°C.

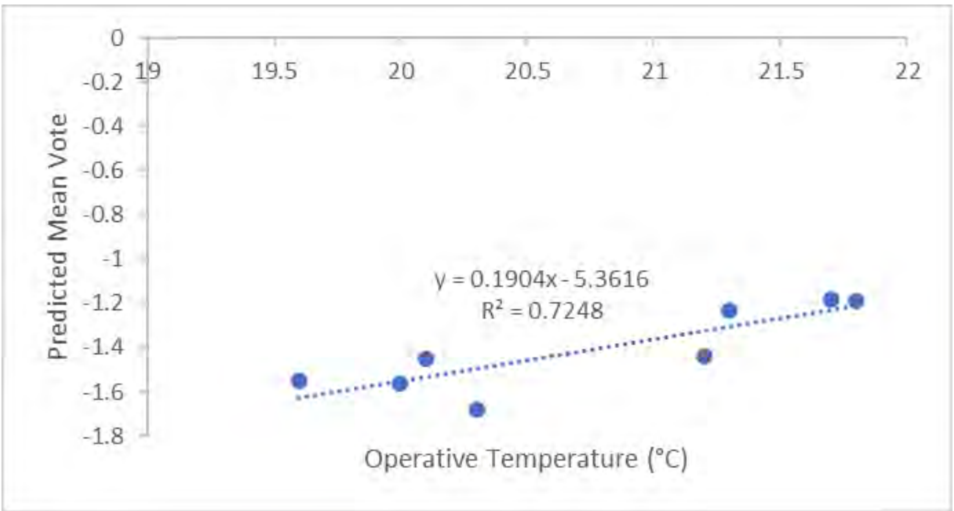

Figure 4.32: Graph of PMV versus operative temperature at first floor

4.4.3 Regression analysis at second floor

According to ASHRAE 55, PMV index relates the thermal comfort factors and predicts the mean value of votes from occupants on the seven-point scale. The regression of PMV and operative temperature in machine workshop is shown in **Figure 4.33**. Based on the figure, the R_2 is 83.93% or 0.8393. This indicated that the relationship between PMV and operative temperature is strong. The predicted neutral temperature from PMV regression is 26.0°C.

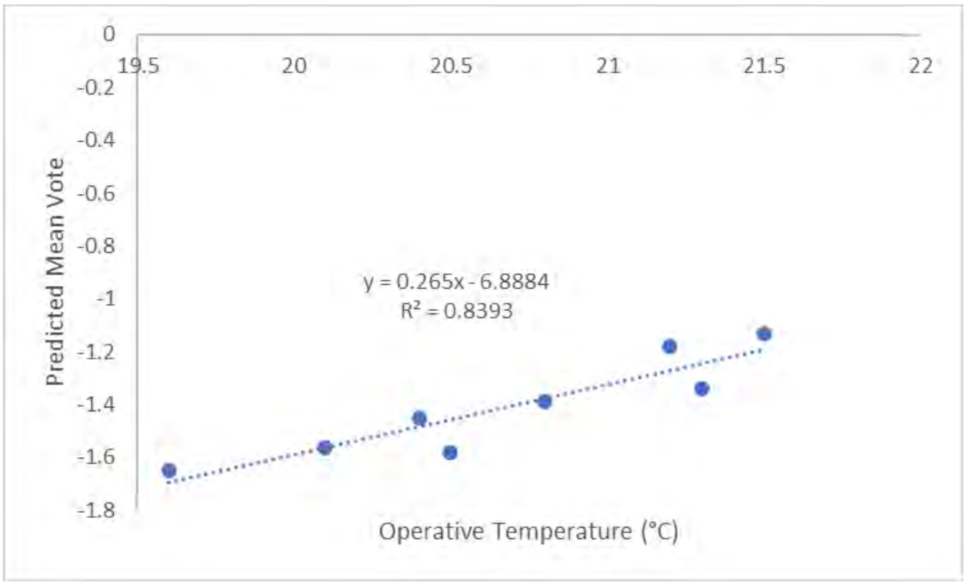

Figure 4.33: Graph of PMV versus operative temperature at second floor

4.5 Recommendations for retrofit design base of the green building element

Indoor environment quality is one of the important elements should be achieve in green building index rating system include achieve good quality performance in indoor air quality and thermal comfort. These will involve the use of low volatile organic compound materials, application of quality air filtration, proper control of air temperature and humidity. In this study, further improvement measures are suggested after thermal comfort analysis and indoor air quality analysis are done in the building.

4.5.1 Carbon dioxide monitoring and control

Use carbon dioxide monitoring and control system to deliver the required outdoor air to the occupants to suit variation in occupancy.

Install carbon dioxide (CO_2) monitoring and control system with at least one CO_2 sensor at main return air points on each floor to facilitate continuous monitoring and adjustment of outside air ventilation rates to each floor, and ensure independent control of ventilation rates to maintain CO_2 level less than 1,000 ppm as shown in **Figure 4.34**.

Use of carbon dioxide monitoring system is a typical energy conservation measure to ensure different spaces receive adequate outdoor air for their current occupancy and the ventilation system can adjust the ventilation rate to meet changing requirements. This helps ensure occupants will receive adequate outdoor air at all times. The specifications of HDH transmitters are shown in **Table 4.8.**

By provide the carbon dioxide monitoring and control system, will get maximum of one point in GBI assessment criteria.

Table 4.11: Specifications of HDH transmitters ("PRODUAL", n.d.)

Product Name	HDH transmitters 
Range	0 – 2000 ppm
Accuracy	typ. ±40 ppm ±3 % of value
Dimensions	87 x 86 x 30 mm

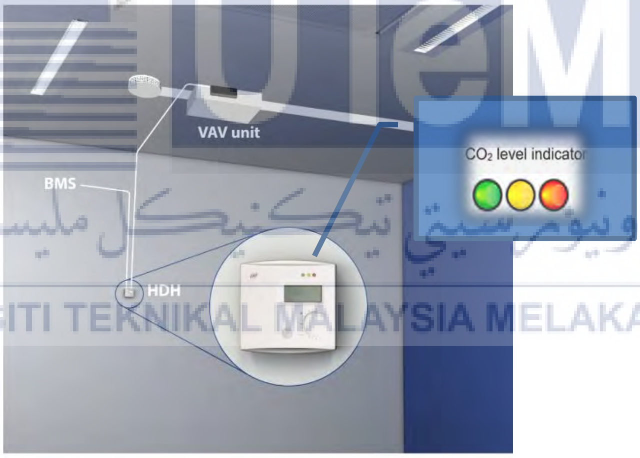

Figure 4.34: HDH transmitters operating diagram (Retrieved from http://www.produal.com/news/new-co2-transmitter-hdh-pir-pir-functionality-room-occupancy-detection/)

4.5.2 Replace existing Air Conditioner to Green Air Conditioner

Energy conservation, indoor air quality and comfort are among the core green building issues encompassed by air-conditioning and ventilation design.

The current air conditioner (AC) is non-inverter. So, recommendation is to change to inverter air conditioner. The inverter air conditioners are more effective and utilize less power when compared with the normal air conditioners. An Inverter AC adapts its speed depending on the heat load in the room. Unlike the regular Split AC, The Inverter Air conditioners have shifting speed motors that adjust their speed according to the requirement. So, Obviously, they consume 30- 40% less electricity.

The existing air conditioner are using R410A Refrigerant which has GWP (Global warming potential) of 2090 and R32 refrigerant which has GWP of 675. The R32 Refrigerant has three times lower GWP than R410A and also more energy efficient than R410A. Hydrofluorocarbons R-410A and R-32 are better than Hydrochlorofluorocarbons and do not deplete the ozone layer. But they also have the potential for global warming. R-32 is better than R-410A regarding Global warming.

The Inverter technology is the latest evolution of technology concerning the electro motors of the compressors. Inverter technology good in energy saving and precise temperature control. Inverter technology reduces power consumption by varying the speed of the compressor according to temperature changes with the aim of minimising the temperature fluctuations so you can enjoy consistent cooling comfort.

Intelligent eco sensors ECONAVI is a high-precision sensor technology that detects where energy is usually wasted and adjusts cooling power according to room conditions and activity levels. ECONAVI has two sensors which is human activity sensor and sunlight sensor. Together, they monitor human location, movement, absence, and sunlight intensity to use energy more efficiently.

Panasonic's Nanoe™ is nano-sized electrostatic atomised water particle that are rich in hydroxyl radicals. This technology is a revolutionary air purification system that deodorises, inhibits the growth of bacteria and viruses; and is effective in dust removal to create a fresher and cleaner living environment. The dust sensor automatically switches on nanoe to purify the air whenever a high level of particle concentration is detected and also constantly monitors particle concentration levels in the room. Nanoe releases negative ions which attach to particles as small as PM2.5, the measuring benchmark of air quality monitoring agencies. These particles are then brought back to the positively-charged filter and removed from the air.

The existing air conditioner are using R410A Refrigerant which has GWP (Global warming potential) of 2090 and R32 refrigerant which has GWP of 675.

This air conditioning has achieved five-star energy rating energy certified by Malaysia Energy Commission. **Table 4.12** shown the comparison of two different types of air conditioner.

Table 4.12: Specifications of different type Air Conditioner

	Current Air Conditioner	Recommendations Air Conditioner
Product Name	ACSON Ceiling Cassette EcoCool F Series	PANASONIC Premium Inverter Aero Series
Model	A5CK 30F	CS-U28VKH-1
Refrigerant Type	R410A	R32
Power Source	240V / 1 Ph / 50 Hz	
Nominal Cooling Capacity	30,000 Btu/h	29,000 Btu/h
EER	3.00 W/W	3.55 W/W
Power Input (Cooling)	2930 W	2000 W

Cooling Capacity calculation: (for BK8)

Volume = width x length x height = 31ft x 21ft x 9ft = 5859 cubic feet

C1 = volume x 6 = 5859 x 6 = 35154 Btu/hr

Each person produces about 500 BTU/hr of heat for normal office-related activity.

C2 = number of people x 500 Btu/hr = 50 x 500 = 25,000 Btu/hr

Estimated Cooling Capacity needed = C1 + C2 = 60,154 Btu/hr

So, BK8 need install 2 units of recommendations air conditioner to fulfil the capacity.

Installation unit cost for Panasonic Premium Inverter Aero Series: RM4665

Operating hours: 9hr/day x 5 day a week

Electricity tariff: RM0.355/kWh

Saving for one unit = (2930 – 2000) x 9 hr / 1000 = 8.37 kWh /day

Annual saving = (8.37 kWh /day) x (5dayx52week) x RM0.355/kWh = RM772.55

Payback Period = 4665 / 772.55 = 6 year

4.5.3 Use low VOC paint and coating throughout the building

Volatile organic compounds (VOC) are carbon-containing substances that easily become vaporise or gases. Paints labelled "low-VOC" should contain fewer than 50 grams per litter of volatile compounds. High VOC can cause respiratory and other health problems for occupants, when used indoors. Their release into the indoor atmosphere is called off-gassing, and it occurs over time, not just during paint application or drying.

By using low VOC paint will improve air quality in the area. The building used low VOC paints and coatings comply with requirements specified in international labelling schemes recognized by GBI will get maximum of one point in GBI assessment criteria.

4.5.4 Air Condition Control Setting

After the thermal comfort analysis and indoor air quality analysis are conducted, it resulted that the indoor air temperature in lecture room is not within the recommended range by GBI Standard. The indoor air temperature is much lower than standard temperature. This will contribute to uncomfortable for occupants and also will contribute to higher energy consumption. Further improvement on thermal comfort level can be done by increasing the air temperature around 2°C to achieve indoor temperature in acceptable range between 23°C to 26°C through setting on thermostat.

4.5.5 Installation of air grilles

Air grille is able to promote air circulation by continuously supplying and returning the air. It can provide required air flow with suitable size in an occupied zone. Study mentioned that air grille increases the air change effectiveness as well as the pollutant removal efficiency (Fisk et al., 1997). In this study, the purpose of installing transfer air grilles is to provide proper circulation for lecture room to reduce the carbon dioxide during occupants. The specifications of transfer grille are shown in **Table 4.13**.

Due to the limited space in machine workshop, the air grilles are designed at top of the entrance door and at the entrance door. The total volume flow rate is 0.52m3/s or 1102cfm. Although it is not fulfilling the recommended ventilation rate of 3178.3 cfm, it is still considered higher than the breathing zone outdoor airflow, V_{bz}.

Table 4.13: Specifications of transfer air grille ("TROX ", n.d.)

Air grille type	Transfer air grille 
Air grille size	For wall grille: 2 x 625mm (width) x 325mm (height) For door grille: 2 x 325mm (width) x 225mm (height)
Maximum volume flow rate	For wall grille: 2 x 0.2m3/s= 0.4m3/s For door grille: 2 x 0.06m3/s= 0.12m3/s

4.5.6 Ventilation Effectiveness

Ensure that the stoppers of windows are working properly. Trimming of trees timely so that it does not interfere with the circulation. Due to dampness in most of the classes, the inside air is humid. The awning window in the lecture room should not be fully closed. It should be an open angle of 1 degree to 10 degrees. This will allow air flow in and out through the window openings thus will reduce the carbon dioxide during occupants.

Figure 4.35: Awning window in lecture room

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

In conclusion, indoor environment quality analysis as part of green building criteria are conducted in this study to evaluate the thermal comfort and indoor air quality of lecture class in PBPI building. The data measurement result of the building is been recorded and compare with the standard to get the analysis result. Results obtained from thermal comfort analysis showed that the average indoor air temperature in the lecture room during without occupants is not within the comfort zone range recommended by GBI Standard. Besides, the relative humidity of the ground floor lecture room is not satisfied with GBI Standard. Furthermore, results obtained from indoor air quality analysis showed that the concentration of carbon dioxide in lecture class during occupant is higher than the maximum standard allowed by GBI Standard.

After analysis, building retrofit design based on green building criteria for existing building is proposed to improve the indoor environment quality in the lecture room. Based on the current condition for lecture room in PBPI building, the measure is more to meet the minimum requirements of ventilation rate of carbon dioxide in GBI Standard. Higher concentrations can affect respiratory function and lead to excitation followed by depression of the central nervous system.

5.2 Recommendation

This study will be a benchmark study for future implementation of green building design in university buildings. This physical parameter measurement study is not considered the number of occupants in the lecture room. For future research, the physical parameter measurement may consider the number of occupants during conduct the measurement to obtain a more accurate analysis result.

To apply for GBI certified building, indoor environmental quality is one of the assessment criteria for GBI certified. Perhaps, in further research, other criteria should be considered such as internal noise level and electric lighting levels as outline by GBI.

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APPENDIX A

Project Gantt Chart for

PSM 1

Task	Academic Week of Semester														
	September 2018				October 2018				November 2018				December 2018		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Project title selection															
Problem statement															
Identify the objective and scope															
Progress Report 1 submission															
Literature Review															
Methodology															
PSM 1 Report preparations															
PSM 1 Report submission															
PSM 1 Seminar															

APPENDIX B

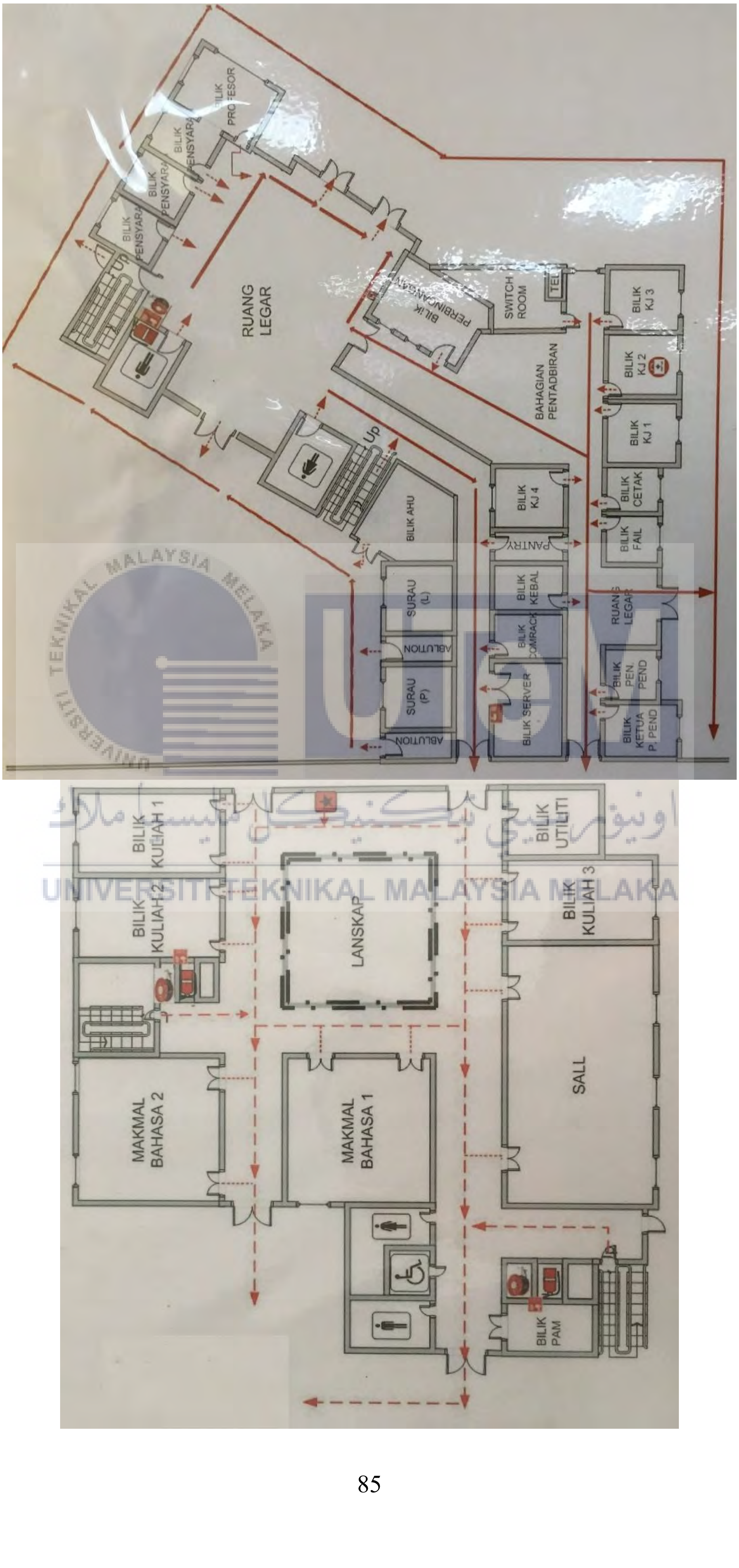
Project Gantt Chart for

PSM 2

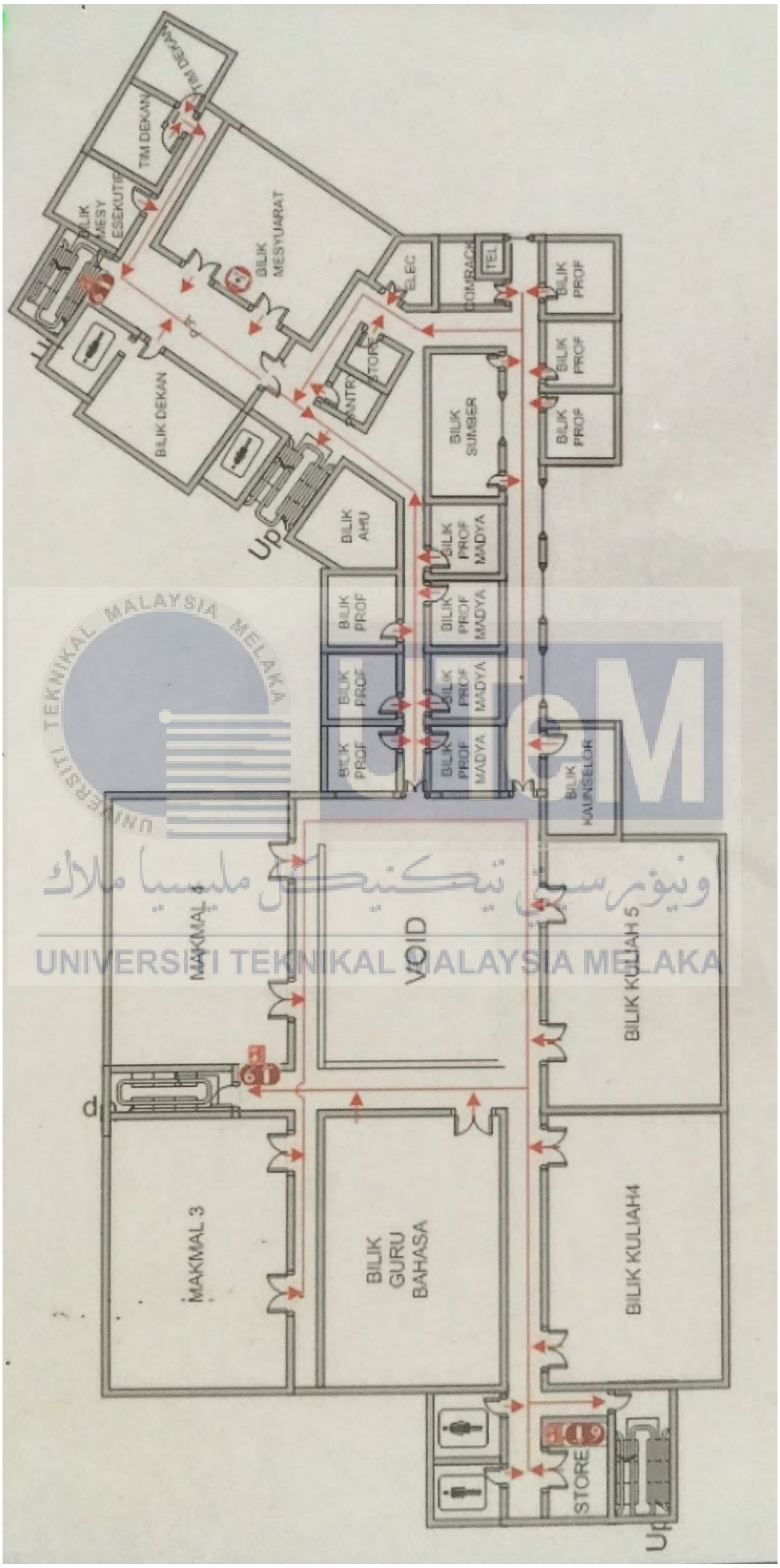
Task	Academic Week of Semester														
	February 2019		March 2019				April 2019				May 2019				June 2019
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Data Measurement															
Questionnaire Distribution															
Analysis of Objective Measurement															
Analysis of Subjective Measurement															
Progress Report 2 submission															
Propose Retrofit Design															
PSM 2 Report submission															
PSM 2 Seminar															
Hardbound Final Report															

APPENDIX C

PBPI Building Layout



Ground Floor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PANTRY
BILIK SUMBER
BILIK AHU
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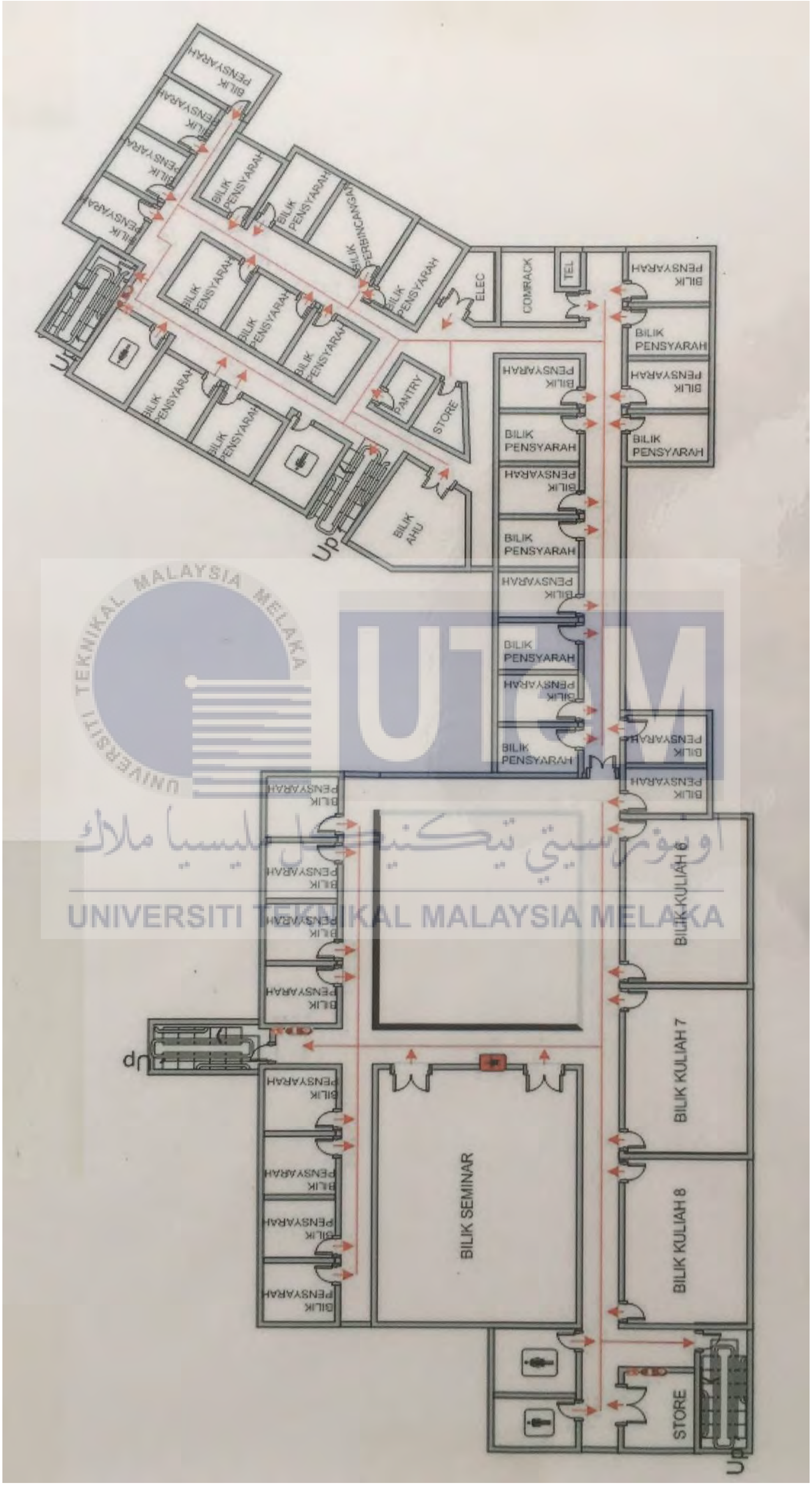
BILIK PROF MADYA
BILIK PROF MADYA
BILIK PROF MADYA
BILIK PROF
BILIK PROF
BILIK PROF
BILIK KAUNSELOR
MAKMAL 4
VOID
BILIK KULIAH 5
MAKMAL 3
BILIK GURU BAHASA
BILIK KULIAH4
STORE
Up

First Floor



Second Floor

APPENDIX D

Questionnaire Form

QUESTIONNAIRE FORM

Indoor Air Quality for PBPI building.

*Please tick your answer provided carefully. Thanks for you cooperation.

Date: ____________ Time: ___________ (a.m/ p.m)

Age: ___________ Gender: Male ☐ Female ☐

Health Condition: ☐ Good ☐ Normal ☐ Not well ☐ Sick

1. How is the outdoor condition?

☐ Sunny ☐ Cloudy ☐ Overcast ☐ Rainy ☐ Windy

2. How do you feel about the class temperature?

☐ Hot ☐ Slightly warm ☐ Slightly cool ☐ Cold

☐ Warm ☐ Neutral ☐ Cool

3. Are you satisfied with the temperature inside the class?

☐ Yes ☐ No

4. How do you feel about the humidity level inside the class?

☐ Very dry ☐ Slightly dry ☐ Slightly humid ☐ Humid

☐ Dry ☐ Neutral ☐ Moderately Humid

5. In overall, how do you feel while inside the class?

☐ Comfort ☐ Discomfort

☐ Slightly discomfort ☐ Very discomfort

APPENDIX E

Permission Letter

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Rujukan Kami (Our Ref): UTeM.23.01/600-1/7/3 Jilid 10 (80)
Rujukan Tuan (Your Ref):
Tarikh (Date): 6 Mac 2019 29 Jamadilakhir 1440H

Dr. Zawiah binti Mat
Dekan
Pusat Bahasa & Pembangunan Insan (PBPI)
Universiti Teknikal Malaysia Melaka

20/3/19.
Tiada halangan

Assalamualaikum wrt. wbt. dan Salam Sejahtera,

DR. ZAWIAH BINTI MAT
Dekan
Pusat Bahasa dan Pembangunan Insan
Universiti Teknikal Malaysia Melaka

Tuan,

PERMOHONAN PENGUKURAN DATA UNTUK MENYIAPKAN PROJEK SARJANA MUDA

2. Adalah dimaklumkan bahawa, penama berikut adalah Pelajar Ijazah Sarjana Muda Kejuruteraan Mekanikal. Beliau sedang dalam proses pengambilan data untuk analisis Projek Sarjana Muda yang bertajuk "*Conceptual Retrofit Design Of A Green Building Office From An Existing Building*".

Bil.	Nama	No. Matrik	Nama Penyelia
1	Lua Yong Weng	B041510277	Prof. Madya Dr. Tee Boon Tuan Tel : 019-9389469 Emel : tee@utem.edu.my

3. Pelajar ini juga akan menjalankan pengukuran data di beberapa bahagian dalam bangunan PBPI yang dibenarkan. Bagi tujuan pemantauan aktiviti pengukuran, pelajar ini akan dibantu oleh Encik Asjufri bin Muhajir, Penolong Jurutera, Fakulti Kejuruteraan Mekanikal. Selain itu, pelajar juga perlu mendapatkan data seperti berikut:

(a) Pelan lantai bangunan universiti yang terlibat dalam kajian kes ini (termasuk keluasan dan binaan bangunan)

(b) Maklumat berkenaan unit penghawa dingin dan penyelenggaraan

4. Sehubungan dengan ini, saya sangat berbesar hati sekiranya pihak tuan dapat memberi peluang kepada pelajar ini untuk menjalankan kajian kes beliau. Sebarang pertanyaan, pihak tuan boleh terus berhubung dengan Penyelia pelajar seperti di atas.

...2/-

Perkara	:	Permohonan Pengukuran Data Untuk Menyiapkan Projek Sarjana Muda
Muka surat	:	2/2
No. Rujukan	:	UTeM.23.01/600-1/7/3 Jilid 10 (80)

Kerjasama dan perhatian pihak tuan dalam hal ini amatlah dihargai dan didahului dengan ucapan terima kasih.

Sekian.

"BERKHIDMAT UNTUK NEGARA"
"KOMPETENSI TERAS KEGEMILANGAN"

Saya yang menjalankan amanah,

DR. RUZTAMREEN BIN JENAL
Dekan
Fakulti Kejuruteraan Mekanikal

tbt/fkm/akuan pelajar