# THERMAL COMFORT PERFORMANCE OF BUS STOPS AT IIUM GOMBAK CAMPUS

BY

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# ABSTRACT

In an effort to ensure a sustainable campus environment, IIUM embarked on the Green campus mission by encouraging an increase in the use of bicycles and public buses as a means to reduce pollution and ensure a friendlier and safer campus and its environs. In line with this noble cause that the university is championing, this study seeks to augment this effort by conducting research on the thermal comfort of the university concentrating on the bus stops encircling the IIUM Gombak campus. These bus stops host public buses and passengers (staffs, students and visitors) who wait for the bus to get to their destinations. For this purpose, the thermal comfort condition of bus stop encircling IIUM Gombak campus was evaluated. The research is divided into two segments; firstly, field measurements of thermal environments to calculate the human thermal comfort indices from the environmental data obtained from the bus stops, and secondly the subjective method namely field survey questionnaire, to assess the relationships between the thermal environment and the evolved subjective human reactions. The measurements were done at selected bus stops within IIUM Gombak. Then, by cross-tabulating the data using SPSS, these values were summed up in a table to indicate minimum and maximum measures. They were then compared with the current users' perceptions of environmental values from questionnaire survey. The findings revealed that some bus stops are thermally more comfortable than the other.

# البحث

يتم تعديل المناخ في المناطق الحضرية مما أدى إلى درجة الحرارة أكثر دفئا وجفافا من المناطق المحيطة شبه المناطق الحضرية والريفية. واحد من الأسباب الرئيسية للتعديل هو أنه في عملية التحضر حيث يتم تحويل السطوح مزروعة على أسطح الأسفلت والخرسانة المعروفة باسم البيئة المبنية. وتتأثر للغاية توزيع درجة الحرارة في طبقة المظلة الحضرية عن طريق التوازن الإشعاعي في المناطق الحضرية. ويتم امتصاص الطاقة الشمسية الحادث الإشعاع على السطوح في المناطق الحضرية وتحول بعد ذلك إلى حرارة معقولة. معظم الاشعاع الشمسي اعتداء على أسطح المباني، وجدران عمودية من المباني، وعلى مستوى الأرض. كوالا لمبور، مثل غيرها من المدن في بيئة استوائية تواجه تدهور بيئي خطير من جزيرة الحرارة الحضرية، وتلوث الغلاف الجوي، والاختناقات المرورية، وارتفاع استهلاك الطاقة نظرا لتطورها السريع والتحضر. وأجريت التجارب في الهواء الطلق للتحقيق في الآثار المترتبة على حركة مختلفة من المواد على البيئة الحرارية في المناطق الحضرية. وسجلت الأحوال الجوية مثل درجة حرارة الهواء، الرصيف لدرجة الحرارة السطحية والرطوبة النسبية وسرعة الرياح لتحديد الاختلافات في درجات الحرارة بين، الأسفلت الطوب والخرسانة المتشابكة والأسطح العشب. الرصيد الصافي بين المكاسب الشمسية وفقدان الحرارة عن طريق الإشعاع المنبعث موجة طويلة يحدد التوازن الحراري من المناطق الحضرية. لأن فقدان الحرارة الإشعاعية أبطأ في المناطق الحضرية الرصيد الصافي هو اكثر ايجابية مما كان عليه في المناطق الريفية المحيطة بها، وبالتالي يتم تقديم ارتفاع درجات الحرارة.

# APPROVAL PAGE

I certify that I have supervised and read this study and that in my opinion, it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a thesis for the degree of Master of Science (Built Environment).

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I certify that I have read this study and that in my opinion, it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a thesis for the degree of Master of Science (Built Environment).

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Alias Abdullah
Dean, Kulliyyah of Architecture
and Environmental Design

# DECLARATION

I hereby declare that the findings of this dissertation are the product of my research efforts. I also declare that it has not been previously or concurrently submitted as a whole for any other degrees at IIUM or other institutions.

Adebayo-Aminu Sarat Iyabode

Signature …….. Date ……...

INTERNATIONAL ISLAMIC UNIVERSITY MALAYSIA

# DECLARATION OF COPYRIGHT AND AFFIRMATION OF FAIR USE OF UNPUBLISHED RESEARCH



## AN EVALUATION OF THERMAL COMFORT OF IIUM GOMBAK CAMPUS BUS STOP



Affirmed by Adebayo-Aminu Sarat Iyabode.

…….. ……

Signature Date

To my dearest ones

My husband,

Mr. Aminu Olanrewaju Sikiru

My children, Ikhlas-Abdul Sattar

and Hafeezoh Olaide Aminu.

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# CHAPTER ONE

# INTRODUCTION

## 1.0 BACKGROUND OF STUDY

There has been rapid increase in road transport usage due to surge in population growth and technological development. Apart from privately owned vehicles, public bus is one of the major transportation means responsible for the mobility of passengers. Many people used the bus service to reach their various destinations, since it is cheaper and has a wider coverage than other modes of transport.

In hot and humid climatic environment such as Malaysia, individuals consider the use of bus stops which make use of only natural ventilation as better transitional places, (Ghaddar, Ghali and Chehaitly 2011). This is consistent with other researcher (Ely, de Oliveira and Logsdon (2012) which reported that certain features of bus stops may improve or worsen passengers' experiences.

According to Lin, Matzarakis and Huang, (2006); Goshayeshi, Jaafar, Shahidan and Khafi, (2013) bus stops can be considered as a semi-outdoor space with shelter provided in the form of a roof. They offer passengers a temporary environment to wait in. It also represents the first stage of a bus journey (Lin et al., 2006). Apart from being a designated place where buses stop for passengers to board or alight from, McPherson and Biedenbender, (1991) and Axarli and Teli (2008) added that it should provide physical and psychological comfort. Ely et al., (2012) explained that the psychological comfort relates to the users' own safety perception, to a good visibility of the traffic that will enable users to easily sight the buses when they approach.

With respect to the above explanation, it is therefore important to know the meaning of human thermal comfort. According to ASHRAE, Standard 55, (2010), Human thermal comfort is defined as "that condition of mind which expresses satisfaction within the thermal environment". Heat conduction, convection, radiation, and evaporative heat loss affect human thermal comfort.

Similarly, the outdoor thermal environment is impacted by the built environment, through anthropogenic heat (Ichinose et al. 1999), ground surface covering (Lin et al. 2007), evaporation and evapotranspiration of plants (Robitu et al. 2006), and shading by trees or constructed objects (Lin et al. 2006). Sangkertadi, (2012) stated that construction materials such as roofing and wall play vital role in determining the convective and radiant temperature of an environment. Thus, outdoor thermal comfort depends on the utilization of surface material.

Thus, thermal comfort is maintained when the heat generated by human metabolism is allowed to dissipate, thus maintaining thermal equilibrium with the surroundings. Any heat gain or loss beyond this generates a sensation of discomfort.

This study examines the thermal comfort of the bus stops as well as the perception of users at International Islamic University Malaysia (IIUM) Gombak campus with a view to ascertaining whether the surface materials are adequate enough to provide the necessary comfort to its users. This is taking into consideration the various developments of both human and material that have taken place in the University. The relevance and paramount importance of this study is the fact that IIUM hosts students from across the world with diverse weather experiences.

## 1.1 PROBLEM STATEMENT

The microclimate of buses stops in IIUM Gombak campus can be harsh for the staffs and students as a result of the intense heat from solar radiation, less wind and thermal variations at certain time of the day, which have adverse effect on the comfort level of the university community especially the bus stop users. This is because the outdoor environment of IIUM Gombak campus experiences emission of pollution from increased number of vehicles plying its road, and due to the high temperature and degradation in air quality caused by the purchase of more equipment to cater for the expansion of the university's projects.

Thus, a noticeable trend in the IIUM Gombak is that people within the campus are inclined towards the habit of staying indoor, in air-conditioned offices and classrooms leading to reduced out-door activities. At the bus stops, people are seen preferring to be under the available shelter and seat areas while others are scattered around the buses trying to get some comforts.

Thus, the purpose of the study is to examine the thermal comfort of bus stops and the perception of users in IIUM Gombak campus.

## 1.2 AIM AND OBJECTIVES OF THE RESEARCH

The research aims to examine the thermal comfort of bus stop as well as the perception of users in IIUM Gombak campus by taking the environmental data through objective and subjective means, while the objectives include:

1. To take the inventory the bus stop at IIUM Gombak campus
2. To determine the basic environmental parameters at the bus stop for thermal comfort analysis.

3. To evaluate the users' perception of the bus stop in IIUM Gombak campus.
4. To examine the correlation between thermal comfort and bus stop users' perception.

## 1.3 RESEARCH QUESTIONS

Considering the identified challenges in the problem statement, the research proposes to answer the following questions;

1. What are the typologies of IIUM bus stop?
2. What are the basic environmental parameters at the bus stop for thermal comfort analysis?
3. What are the users' perceptions of the bus stop?
4. What are the correlation between thermal comfort and users' perception of the bus stop?

## 1.4 SIGNIFICANCE OF THE STUDY

The study examines the thermal comfort of the shelters of bus stop circulating IIUM Gombak campus. The IIUM Gombak campus is selected as a case study area because the university authority recently launched the policy of Green campus and a mission to reduce pollution within the campus, thereby encouraging the use of bicycles and public bus transportation.

Additionally, the study is more relevant because IIUM is the only university in Malaysia with the largest number of students and staff from different nationalities. Also, reviews of literature show that the study on outdoor human thermal comfort of bus stops within university campus is still very emerging. Thus, field measurement of environmental parameters and a questionnaire survey of human thermal comfort perception seemed

essential to evaluate the thermal comfort of IIUM Gombak Campus bus stop. Therefore, thermal comfort of passengers waiting in the bus stop is very crucial because usually, passengers spend quite some time waiting for buses; therefore an appropriate thermal environment is vital for their overall well-being.

## 1.5 SCOPE OF THE STUDY

The thesis focuses mainly on the thermal comfort of bus stops circulating IIUM Gombak campus through the observation of environmental parameters related with air, relative humidity, air velocity and surface temperature of the fabrics. Additionally, evaluation of users' perception through the means of questionnaire field survey is carried out. The study is however, limited to bus stops catchment only and not the entire campus. The conclusions of this study could not be generalized for Gombak Kuala Lumpur.

## 1.6 RESEARCH METHODOLOGY

The methodologies employed in this study include the use of field experiment, and questionnaire survey. The measurement and the questionnaire survey are administered based on American Society of Heating, Refrigeration, and Air-Conditioning Engineers, (ASHRAE) and the 7-points Fanger scale (Fanger, 1970) is employed. Measurement and questionnaire survey were done simultaneously in the selected bus stops in IIUM.

The micro-climate parameters used in this study include air temperature, relative humidity and air velocity, and surface temperature. The equipment to be used include; thermometer, hygrometer, radiation meter and anemometer respectively. The field raw data are analyzed through statistical method using SPSS such as regression and correlation analyses

## 1.7 RESEARCH FRAMEWORK

In order to answer the research questions and achieve research aim and objectives, the subsequent tasks are recognized and carried out accordingly. The framework of this study is divided into four phases (Figure 1.1). Phase 1 consists of thermal comfort of IIUM bus stops. The methodologies employed and data collection methods are explained in phase 2. In the phase 3, data gathered from field measurement and questionnaire survey are analyzed and discussed adequately. Lastly, based on the data obtained and the analysis, conclusions are made with appropriate recommendations.

## 1.8 STRUCTURE OF THE THESIS

The thesis consists of five chapters as shown in figure 1.2. The first chapter is the Introduction which gives the main idea of the whole study. The second chapter is the literature review; it presents the work done by previous researchers as they are relevant to this study. The chapter develops a sound research background; it discussed the factors and parameters related to thermal comfort. Chapter three is the research methodology; it discusses the methodology employed in the study. Chapter four relates the data acquisition, analysis and discussions. The chapter shows the result obtained from the field experiment and the questionnaire survey conducted. Chapter five comprises findings, conclusion and recommendation. It brings together the completion of the whole thesis.

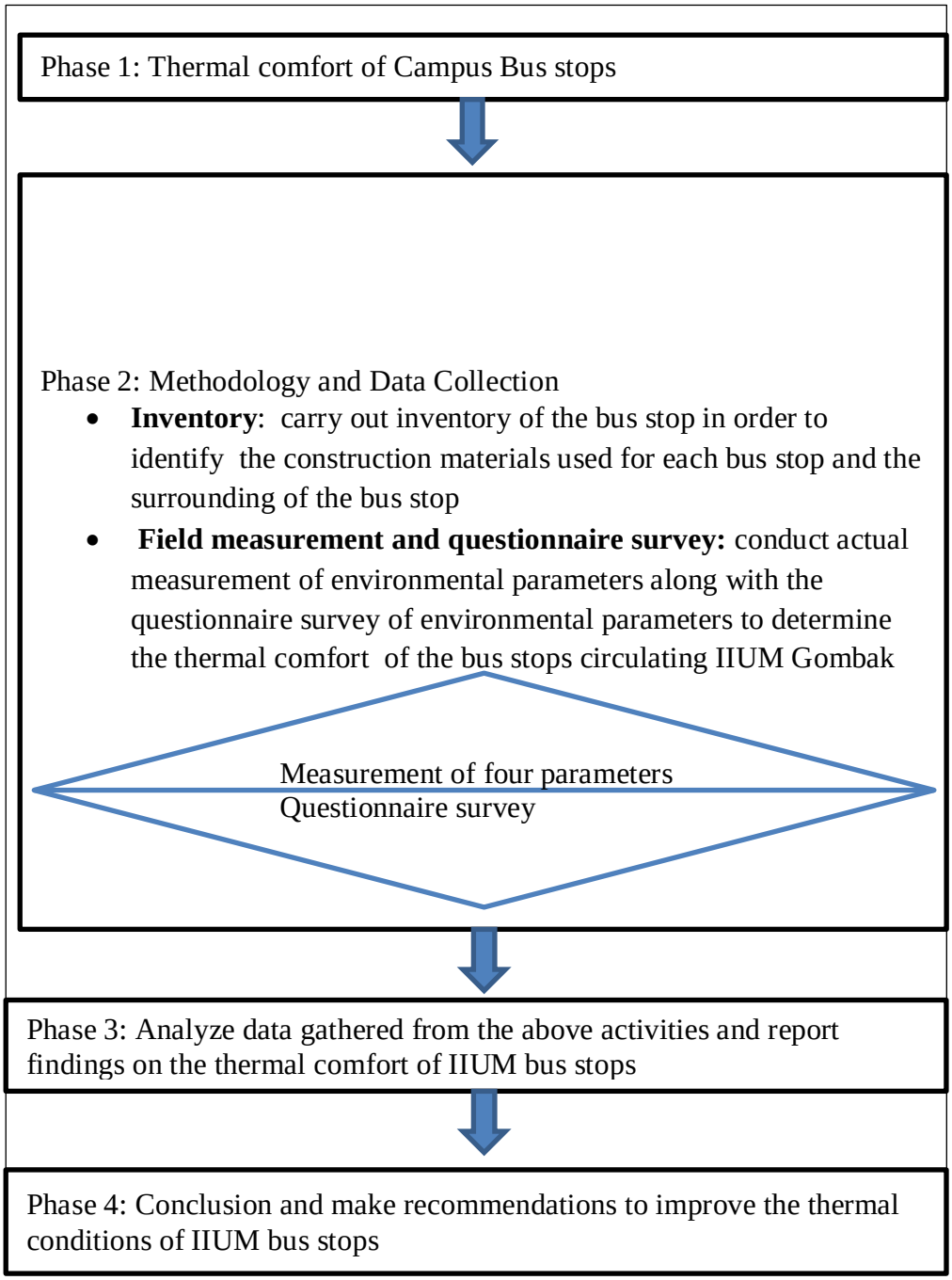


Figure 1.1 Research framework

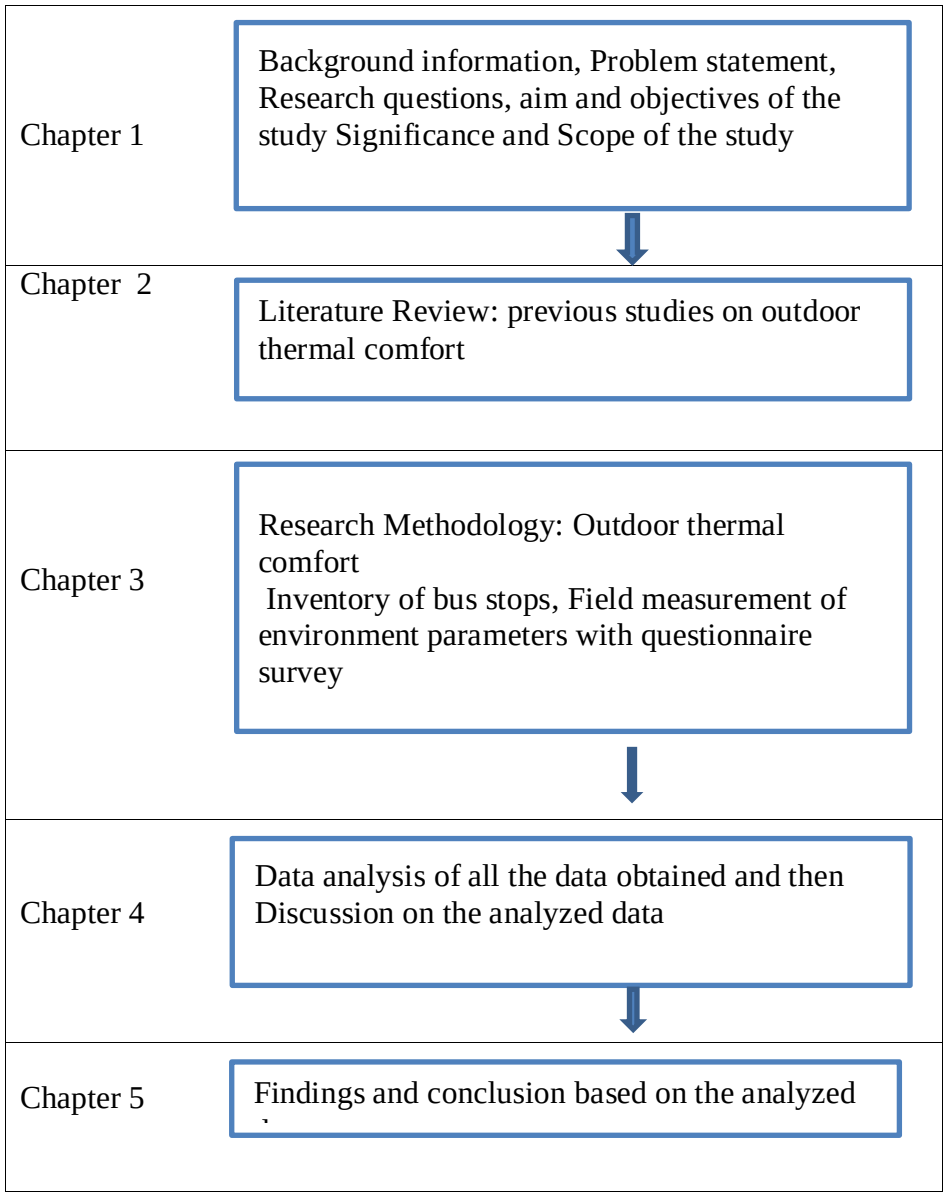


Figure 1.2 structure of the thesis

# CHAPTER TWO

# LITERATURE REVIEW

## 2.0 INTRODUCTION

This chapter contains a review from previous studies on thermal comfort, heat balance, microclimate parameters affecting thermal comfort, thermal indices and adaptation and effect of vegetation and construction materials on outdoor thermal comfort in order to establish the gap for this study.

## 2.1 THERMAL COMFORT

There are many definitions of thermal comfort, which depends on the aims and expectations of those who defined it (Chappells, and Shove, 2004). Jiao (2010) stated that, the rate at which human body gain and lose energy, and also the state of comfort is satisfactory once all heat flow in and out of the body are in equilibrium. Also, (ASHRAE 2004), described it as "the state of mind that expresses satisfaction with the surrounding environment." This definition highlights subjective and psychological dimension of thermal comfort.

### 2.1.1 The heat balance

In order to maintain a constant internal human body temperature, the heat which is continuously produced by the body must be dissipated to the environment (Jiao, 2010). From the energy exchange perspective, Fanger (1970), explained that thermal comfort state is reached when metabolic heat production and heat dissipation from the body to the

environment are balanced, and when skin temperature and sweat rate are consequently within a defined comfort range (Hoppe, 2002). From this explanation, the person is viewed as a passive recipient of thermal stimuli, and presumes that the effects of a given thermal environment are mediated exclusively by the physics of heat and mass exchanges between body the human body and environment (Gail and Brager 1998). According to Hoppe (1999), the heat balance for the human body can be expressed mathematically as:

$$M + W + R + C + E_D + E_{Re} + E_{Sw} + S = 0 \quad (2.1)$$

Where:

M = metabolic heat generated by the human body,

W = physical work output,

R = net radiation

C= convection heat losses from the body

$E_D$ = latent heat loss by evaporation of moisture diffused through the skin (imperceptible perspiration),

$E_{Re}$ = sum of heat flows for heating and humidifying the inspired air,

$E_{Sw}$ = heat loss due to the evaporation of sweat,

S = storage heat for heating and cooling the body mass.

It should be noted here that each term of the equation (2.1) has positive sign especially when they result in an energy gain for the body and for energy loss, M is always positive; W, $E_D$ and $E_{Sw}$ are always negative. The whole-body equation is expressed in terms of the rate of change in an energy flux, thus, the heat flows are calculated in watts (W).

### 2.1.2 Microclimate Parameters Affecting Thermal Comfort

Basically, a single factor cannot be used to express the impact of thermal environment on human body. Thus, thermal index combined various factors into a single variable, these factors according to ASHRAE (2001), the instantaneous effects on the sensory and physiological responses of the body are added up. Local micro climate greatly influence thermal comfort sensation of people. Therefore, people's decision to use a particular outdoor space depends on the microclimate of that space (Chen and Ng, 2012).

Essentially, microclimatic conditions are critical parameter for the use of outdoor spaces. There are four basic environmental parameters influencing the overall thermal comfort (refer to figure 2.1). It include: air temperature, radiation, relative humidity and wind velocity, (Johansson, and Emmanuel, 2006; Huang, 2007 and Makaremi, *et al.*, 2012). These parameters affect human response to thermal environments (Parsons, 2003; Noor Hanita, 2004). The tolerance of outdoor thermal environments varies for people in different climates, and they have different thermal perception given by the same thermal environment (Nikolopoulou and Lykoudis, 2006; Thorsson et al. 2007; Lin and Matzarakis; 2008; Didel and Dilshan 2009; Noémi and János 2010).

At the same time, people's various level of activity and their clothing play a major role in the thermal sensation process (Fanger, 1970; Nikolopoulou et al. 2001). These two factors, vary with people, even though they are exposed to the same environmental conditions noted (Bessoudo, 2008).