View metadata, citation and similar papers at core.ac.uk

brought to you by CORE

provided by Universiti Teknologi Malaysia Institutional Repository

IMPACT OF THERMAL BEHAVIOUR ON OUTDOOR HUMAN THERMAL COMFORT IN TROPICAL CLIMATE

LEE YEE YONG

A thesis submitted in fulfilment of the
requirements for the award of the degree of
Doctor of Philosophy (Civil Engineering)

Faculty of Civil Engineering
Universiti Teknologi Malaysia

JUNE 2016

DEDICATION

Dedicated to my beloved family members and husband, *Yeong Huei*

ACKNOWLEDGEMENT

The author would like to express her utmost gratitude to her supervisor, Assoc. Prof. Ir. Dr. Mohd Fadhil Md Din for his guidance and assistance throughput the study. The author also would like to thank Assoc. Prof. Dr. Zainura Zainon Noor and Prof. Dr. Kenzo Iwao for their continuity of supervision.

Special thanks to Ministry of Higher Education Malaysia (MOHE) for providing scholarship to author by the channel of MyBrain15-MyPhD. All the expenses in this project was funded by several university's grants which were led by author's supervisor. External funding also given by ASSET Construction Inc., Tajimi General Constructors Association (TGCA) and Heat Island Solutions Global Asia Sdn Bhd. All the supports are gratefully acknowledged.

The author sincere gratitude extend to Assoc Prof. Dr. Shamsuddin Shahid who had provided assistance and knowledge on statistical analysis in her research study. The author is fortunate to have her colleagues, Dr. Nickholas Anting Anak Guntor, Dr. Eeydzah Binti Aminudin and Dr. Low Wen Pei in sharing knowledge and the help in laboratory as well as field works. Last but not least, deepest appreciation to the author’s parents and friends for their moral supports throughout the ups and downs in completing this thesis.

ABSTRACT

In recent years, the challenges of the urban environment have been identified as urban heat island phenomenon due to the impacts of thermal behaviour from the surrounding built-up environment, with a low surface albedo. Their impacts on individuals are getting worse due to improper urban building designs with albedo modification that changed thermal behaviour in cities which in turn affects the quality of thermal comfort, especially in tropical countries. Therefore, this research aims to evaluate human thermal comfort by developing a preferable range of Discomfort Index (DI) interpretation for tropical climate. Next, the study integrates the application of a Surrogate Human Sensor (SHS) with measurements of climatic variables. Following this, Heat Stress Index (HSI) and Thermal Comfort Index (TCI) are established, using the correlation of the thermal perception with SHS and climatic variables measurement for evaluating thermal comfort in outdoor spaces. In-situ field measurements were carried out to analyse the impacts of thermal behaviour and its relationship to human discomfort. Human discomfort levels were evaluated using Thom's DI and a new extended DI range of 20°C to 28.9°C for “partially comfortable”. It was proposed in association with local climate as a result of thermal adaptability. Outdoor thermal sensations for the outdoor environment can be assessed using questionnaire surveys and a SHS model that was initially developed as a sensor to receive data on the impacts of thermal behaviour. SHS significantly reflects the impacts of thermal behaviour from the surrounding ambient environment towards human skin surface and found to be useful as a simple sensor, or indicator, for pre-assessing thermal conditions and comfort. In this study, two factors, i.e. climatic and psychological factors, are taken into consideration. Within this combination, SHS acts like a sensor to predict the thermal responses of people with respect to the influence from climatic variables. Thermal perception regression models, which represent the HSI, and SHS temperature regression models were developed based on the local microclimate environment. With this correlation, TCI was established where it enhances the understanding of the relationship between human psychologies and the climatic environment using SHS. Then, the SHS can be used to identify the perception level of the people as the SHS correlated with the thermal perception and surrounding climate measurements. All the regressions established were verified through execution in the real case scenarios by comparing the observed and predicted outputs. These verifications have shown that the regressions may be suitably applied in all tropical climate locations, especially in Malaysia, to evaluate correctly outdoor thermal comfort.

ABSTRAK

Sejak kebelakangan ini, persekitaran bandar telah mengalami cabaran besar yang dikenal pasti sebagai fenomena pulau haba bandar yang disebabkan oleh kesan haba daripada permukaan pembinaan yang mempunyai albedo rendah. Kesannya semakin teruk disebabkan oleh rekabentuk bangunan bandar yang tidak mesra dengan pengubahsuaian albedo yang akan mempengaruhi kesan haba di bandar, seterusnya akan menjejaskan kualiti keselesaan haba terutama di negara-negara tropika. Oleh itu, kajian ini bertujuan untuk menilai keselesaan haba dengan membangunkan satu julat baru yang lebih sesuai untuk penentuan Indeks Ketidakselesaan (DI) pada iklim tropika. Seterusnya, kajian ini mengintegrasikan penggunaan "*Surrogate Human Sensor*" (SHS) dengan mengunakan nilai pembolehubah iklim. Di samping itu, Indeks Haba Tekanan (HSI) dan Indeks Keselesaan Haba (TCI) juga dirangka dengan menggunakan korelasi di antara persepsi haba dengan pengukuran pembolehubah iklim dan SHS untuk menilai keselesaan haba di persekitaran luar. Pengukuran di tapak telah dijalankan untuk menganalisis kesan haba dan kaitannya dengan ketidakselesaan manusia. Tahap ketidakselesaan manusia dinilai menggunakan *Thom's* DI dan DI lanjutan baru dengan julat di antara 20°C hingga 28.9°C untuk "separa selesa". Ini adalah julat yang dicadangkan bagi iklim tempatan sebagai hasil penyesuaian haba. Selain itu, kepekaan haba untuk persekitaran luar boleh dinilai dengan menggunakan soal selidik dan SHS telah dibangunkan sebagai sensor untuk menerima data daripada kesan haba. SHS boleh mencerminkan kesan haba dari persekitaran ke permukaan kulit manusia dan didapati sangat relevan digunakan sebagai sensor mudah atau penunjuk untuk pra-penilaian keselesaan haba. Dalam kajian ini, dua faktor iaitu iklim dan psikologi juga diambil kira. Dengan gabungan ini, SHS bertindak sebagai sensor untuk meramalkan tindak balas haba terhadap pengaruh dari pembolehubah iklim. Regresi persepsi haba, yang juga diwakili oleh HSI, dan regresi SHS telah dibangunkan berdasarkan persekitaran kajicuaca tempatan. Menerusi korelasi ini, TCI akan dihasilkan serta ia dapat meningkatkan pemahaman antara hubungan psikologi manusia dengan persekitaran iklim menggunakan SHS. Dengan itu, SHS boleh digunakan untuk mengenalpasti tahap persepsi manusia kerana SHS menunjukkan korelasi yang nyata dengan persepsi dan pengukuran cuaca persekitaran. Semua regresi yang dijana disahkan melalui pelaksanaan senario kes sebenar dengan perbandingan output pemerhatian dan ramalan. Pengesahan ini telah menunjukkan regresi yang dijana boleh digunakan pada semua lokasi beriklim tropika, terutamanya di Malaysia, untuk penilaian keselesaan di persekitaran luar.

TABLE OF CONTENTS

4 ANALYSIS ON OUTDOOR THERMAL COMFORT 76

5 SURROGATE HUMAN SENSOR ANALYSIS 103

6 OUTDOOR THERMAL SENSATION ANALYSIS 143

LIST OF TABLES

LIST OF FIGURES

LIST OF EQUATIONS

LIST OF SYMBOLS

clo - Clothing Insulation Unit
mtoe - Million Tons of Oil Equivalent
RH - Relative humidity
v - Wind speed
β - Slope (hypothesis test)
s - Standard error
H_A - Alternative hypothesis
T_a - Ambient temperature
$SHS_{average}$ - Average temperature at Surrogate Human Sensor
H_o - Null hypothesis
R_0 - Solar radiation intensity
ΔT_{u-r} - Temperature difference between urban and rural
T_h - Temperature of human skin surface
T_{SHS} - Temperature of Surrogate Human Sensor

LIST OF ABBREVIATIONS

ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
UHI	Urban Heat Island
SPSS	Statistical Package for the Social Sciences
DI	Thom's Discomfort Index
PET	Physiological Equivalent Temperature
PMV	Predicted Mean Vote
PPT	Predicted Percentage of Dissatisfied
CFD	Computational Fluid Dynamics
H/W	Height to Width ratio
W/L	Width to Length ratio
G	Green area
CS	City street at crowed town area
FB	In front of buildings
IB	Buildings located inward from the main road
BB	Between the buildings
SB	Surrounded by buildings
OSG	Open space with vegetation ground
OSC	Open space with concrete ground
BO1S	Building orientations with building at one side
BO2SO	Building orientations with buildings at two sides
BO3SU	Building orientations with buildings surrounded but open at the front of the measurement equipment
BO4SS	Building orientations with buildings surrounded at all sides
QSOS	Location questionnaire survey at open space
QSPW	Location questionnaire survey at pedestrian walk nearby roadside between the buildings

QSRA - Location questionnaire survey at student resting area
QSSB - Location questionnaire survey at parking lot with buildings surrounded and trees at the left side
QSPL - Location questionnaire survey at parking lot
UTM - Universiti Teknologi Malaysia
SET - Standard Effective Temperature
ET - Effective Temperature
SHS - Surrogate Human Sensor
BS EN ISO 7730 - British Standard EN ISO 7730 (2005)
HSI - Heat Stress Index
TCI - Thermal Comfort Index
TP - Thermal Perception regression
TP - SHS - Perception - Manikin regression

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Background of the Study

The world is experiencing high rates of urbanisation and it has slowly become an alarming social process, especially in developing countries. Many cities are gradually transformed into urban metropolitans. The outdoor thermal environment of urban spaces plays a great role on the quality of life in a city. It directly affects people's comfort and/ or behaviour and usage of outdoor spaces. In the path of investigation, the thermal behaviour of urban environments has been documented by various researchers, in anthropogenic factors (Sailor, 2011; Shahmohamadi *et al.*, 2011; Zhou *et al.*, 2011) and 'albedo' effects of surface material (Bougiatioti *et al*., 2009; MD Din *et al*., 2012; Shashua-Bar *et al.*, 2011) as well as the urban arrangement (Amirtham *et al*., 2014 Sharmin *et al*., 2012). According to Kolokotroni and Giridharan (2008), the most critical variables during the day time and nocturnal air temperature is the surface thermal behaviour that influences the absorption and reflection of the incoming solar radiation. This effect highly contributes to the increasing temperature in urban environments. Hence, the thermal behaviour of surface material with high surface albedo and the albedo modification of construction materials are recommended for implementation in the urban built environment as it reduces the urban heat island (UHI) effects (Susca, 2011; Taha, 1988).

The efforts of reducing UHI are becoming significantly important as it negatively effects human thermal comfort. Hence, any approach to assess the consequences of surface thermal behaviour on human comfort should be incorporated into the climatic variables such as ambient temperature, relative humidity, solar radiation and wind velocity. Ann environmentally conscious urban design solution should give high priority to the impacts on outdoor thermal comfort from urban microclimate.

In fact, the increasing of thermal heat, especially in urban areas, could cause discomfort and heat stress. Discomfort and inconvenience that arise from the urban population due to higher temperatures will place the urban population at a greater risk in terms of increased morbidity and mortality rates (Shahmohamadi *et al.*, 2011). The conceptual requisites for the determination of one's thermal comfort are the average body core temperature of 36.5 - 37°C, skin temperature of 30°C at the extremities and 35°C at the body stem and head. At core temperatures beyond 38 − 39°C, there is an increased risk of heat stress and beyond these temperatures, heat stroke can occur with an eventual failure of the central nervous thermoregulatory system (Lundgren *et al.*, 2013). There are six main factors that affect human thermal comfort, namely ambient temperature, relative humidity, mean radiant heat, wind velocity, personal activity level and clothing. Thermal comfort indices are indicators that assess the relationship between the climatic variables that could affect human health and activities. In response to the consequences of heat stress, thermal manikins were developed to enhance the understanding of the relationship between the human body and surrounding environment (Gao and Niu, 2005).

As a city grows, the developed area will expand and the natural ground surface is slowly being replaced by an artificial surface. As a consequence, this increases the amount of heat accumulation during sunny days. This hot city phenomenon is far-reaching the consequences for environmental sustainability and is believed to have significant impacts on human health. The high urban city temperatures, as compared to surrounding rural or suburban areas (green area), is recognized as Urban Heat Island (UHI) phenomenon (Che-Ani *et al.*, 2009; Livingstone, 2006; Voogt, 2004). The significant difference in heat concentration created between cities and neighbouring areas is caused by the anthropogenic modifications of land surfaces, urban expansion, population growth, lack of green spaces, thermal admittance of building fabric and its consequent generation of waste heat that causes alarming effects in many metropolitan areas (Ghazanfari *et al.*, 2009; Kololotsa *et al.*, 2009; Kolokotroni and Giridharan, 2008; Shahmohamadi *et al.*, 2011). Since high UHI indicates the increment of heat stress, worse air quality, and higher energy usage especially during hotter days (Kolokotroni and Giridharan, 2008) awareness of this situation has risen in many cities. Additionally, its impact on the cooling load of buildings, as well as the peak electricity demand for cooling, is also becoming an issue for sustainability.

In the 10th Malaysia plan (2011-2015), two major national policies: National Green Technology Policy 2009 and National Climate Change Policy 2009, were outlined on environmental protection and conservation. These policies place emphasis on sustainable development and the application of green technologies, as well as help stream line and coordinate the policy and legislation to facilitate implementation (Ho *et al.*, 2013). Hence, it is essential for the evaluation of thermal comfort, especially in urban cities in parallel with developmental activities, to achieve sustainability. The UHI effect is one of the main factors that contribute to the rise in temperature and eventually induces climate change and thermal discomfort. By introducing this research in Malaysia, it will support a sustainable environment for better living and become one of the solutions for the National Climate Change Policy 2009.

In tandem with the Malaysia Plan and other national policies, the Ministry of Housing and Local Government of Malaysia, through its Department of Town and Country Planning, had translated these into spatial form through the National Physical Plan and the National Urbanisation Policy. Green urbanism has been introduced in the Malaysia’s National Urbanisation Policy (NUP) and approved by the Cabinet on August 8th, 2006. The NUP guides and coordinates the planning and urban development in Malaysia where it encourages development that reduces the impact of UHI by proper land use planning and integrates the development of green areas in urban centres (Rosly *et al.*, 2010). The UHI factors that contribute higher heat impacts on the environment and its effects toward human thermal comfort have been reported (Rosly *et al.*, 2010). This encourages the implementation of mitigation strategies for UHI and heat stress reduction that the NUP must fulfil. Furthermore, this study is important in benefiting the consumer by reducing their electricity consumption, for example, the usage of an air-conditioner can be reduced in order to meet the sustainable low-energy building. By reducing the temperature and energy usage, this can also reduce the effect of global warming which has a major impact on human life and the built environment, according to governmental policies.

1.2 Problem Background

Due to the increasing rate of urbanisation and population, the consequences resulting from heat impacts should be vital in order to obtain sustainable living. Climate change on outdoor thermal environment and UHI dominantly effect human health and well-being in a city. The increment in outdoor air temperatures also creates economic consequence, where UHI has clearly exemplified the environmental and economic impacts associated with a rise of ambient temperature. Apart from that, climate effects are negatively impacted by the UHI phenomenon, especially for people working outdoors. The outdoor environment is the most extreme and critical condition in investigating human thermal comfort as it is exposed to the "double sun" phenomena, exposure from both direct sunlight and heat reflecting off the surrounding buildings. These issues can lead to social impacts if there is still lack of awareness and attention given to the thermal condition. The current study focused on the determination of thermal comfort in selected areas, with several urban environmental parameters, i.e. street geometry, orientation, surface albedo and vegetation, and concentrated on using conventional methods for accessing heat stress. However, a knowledge gap still exists, which can be related to the impacts of thermal behaviour on outdoor human thermal comfort and heat stress in tropical climate, in terms of the effect of the built environment, land use and artificial construction materials. Little research can be found on the relationship between the impact of urban surface thermal behaviour and outdoor thermal comfort in Johor Bahru a city in Malaysia.

The interest shown in thermal manikin studies has gradually increased. However, previous thermal manikin studies are mainly focused on indoor environments, where it is installed in a climatic chamber and connected to a power supply with a computer-controlled system or using computational fluid dynamic methods (CFD) to investigate the necessary parameters. Among the parameters investigated, there is thermal radiation, resistance and evaporative resistance of the clothing; distribution of local and overall body segment's surface temperature; heat transfer coefficient, sweating mechanism, etc. These parameters are mostly used to investigate the thermal radiation or comfort and simulate human parameters in a controlled environmental condition rather than for predicting the impacts of thermal behaviour of outdoor space or hard surfaces on thermal comfort. Previous manikin using complex mechanism and set up tools in computer or numerical based system for simulation. Besides that, there is a lack of exposure on the prediction of the impacts of thermal behaviour by using a thermal manikin in an outdoor environment.

There are a series of thermal comfort indices for evaluating thermal comfort. Among the thermal comfort indices, Discomfort Index (DI) has been used in this study where a combination of ambient temperature and relative humidity are involved in a simple and quick evaluation of thermal comfort. With regards to this, Thom (1959) proposed a series of range for the classification of DI. However, when compared to a seasonal climate, people in tropical climates like Malaysia may have a wider range of thermal perception (Makaremi et al., 2012). With this in mind, Thom's DI may exhibit inadequacies in the classification of DI when adopted into a tropical climate. Outdoor thermal comfort is directly affected by thermal environment, especially due to the climatic data of ambient temperature, relative humidity, wind speed and solar radiation (Lin, et al, 2010). In hot and humid tropical climates, a state of discomfort is often caused by ambient atmosphere that is too hot and very humid, with greater solar radiation intensity. Wind speed, on the other hand, plays an important role in increasing comfort through evaporative cooling (Sangkertadi, 2012). Each of these parameters provides various impacts on human psychology. It is clearly stated that climatic data is inter-related with thermal comfort, as people are directly exposed and influenced by different meteorological conditions. Traditional studies using thermal indices try to take all climatic variables into account and consequently provide a comprehensive picture of the thermal environment. However, the subjective thermal sensation is difficult to explain with conventional methods. In addition, there are no indicators suitable for evaluating thermal perception in Malaysia, a location with climatic data of ambient temperature, relative humidity, wind speed and solar radiation.

Based on previous research, there were a large number of theoretical and empirical indices used to assess human thermal comfort. Most of these indices were originally developed for enclosed indoor spaces and their validity under outdoor conditions has been increasingly questioned. These indices might face a number of methodological problems such as variability of meteorological parameter measurement, and difficult interpretation, with respect to actual human perceptual and physiological factors in achieving human thermal balance (Tseliou *et al.*, 2010). There is flaw in the existing indices for describing thermal comfort with a combination of parameters of psychological (thermal perception) and meteorological variables, with the assistance of Surrogate Human Sensor (SHS) usage. Less attention is given to the evaluation of outdoor thermal comfort with the use of a sensor or indicator, also known as a “SHS”, which is used to evaluate behavioural or psychological aspects based on local climate conditions. In order to obtain a better assessment of human thermal comfort, sufficient data with these three aspects are needed to be developed with a series of indices to accurately evaluate thermal comfort, especially in a tropical climate. It is expected to facilitate better planning exercises for a more sustainable and comfortable environment.

1.3 Objectives of the Study

In order to answer the problems statements, this research aims:

i. To evaluate human thermal comfort by developing a new range of DI in tropical climate based on the impacts of thermal behaviour.
ii. To integrate the application of SHS with climatic variables for establishing a correlation and predicting the impacts of thermal behaviour.
iii. To establish a Heat Stress Index using the correlation of thermal perception and climatic variables in evaluating thermal comfort.
iv. To identify the human thermal perception using SHS with newly established thermal comfort index in outdoor spaces of tropical climate.

1.4 Scope of Study

This study covers in-situ measurements in outdoor spaces at the Universiti Teknologi Malaysia (UTM) and several other locations within the town centre of Johor Bahru. The impacts of artificial urban structure, albedo effect, surface materials and building orientation toward human thermal comfort are investigated. The selected locations for the in-situ measurements are proposed at the urban city of Johor Bahru town centre and suburban area of UTM.

In-situ measurements consist of analytical parameters of ambient temperature, solar radiation, relative humidity and wind velocity in order to observe the thermal condition due to the impact of thermal behaviour between the hard and soft surfaces at the selected built-up areas. The criteria for the locations selection of in-situ measurements include consideration of urban-rural environment based on different albedo effects, building orientation, open spaces and different land use environment. The built-up areas are qualitatively different from non-urban terrains in terms of their surface geometry and materials. These physical characteristics can decisively influence the absorption and reflection of solar radiation, the capacity for heat storage as well as the absorption and emission of long-wave radiation. In addition, anthropogenic heat from traffic and the heating and cooling of buildings also affects the urban climate, though such effects are beyond the scope of the present study.

Thermal manikins can act as human simulating devices or indicators. In this study, a Surrogate Human Sensor (SHS) is a more suitable term that is developed at the starting point and preliminary stage of the study for establishing a link between human skin surface and devise. It was fabricated to examine the impact of thermal behaviour on human thermal comfort by simulating only the sensible heat process. The SHS used in this study is considered as a simplified model of manikin that uses simple, low cost and easily handled materials for fabrication. SHS is placed in outdoor spaces; areas surrounded by buildings, pedestrian footpaths, carparks and recreational parks, where there is a high risk of exposure to heated environments. This sensor does not consists of a complete physiological model of the human body as it is only limited to human skin surface, but it is used to serve as a useful tool for an evaluation of thermal load due to the impact of thermal behaviour at the surrounding environment. An experiment was designed to determine a linkage between the SHS and the human skin surface and then further expand to establish correlation between SHS and climatic variables

Subjective measurements using questionnaire surveys were carried out to identify the thermal response of occupants in a real thermal environment with at least 10 selected respondents in UTM. Ten healthy female university students were selected and the subjects were, on average, 1.6m in height. The experiment took placed at all daytime where the thermal responses on the environment was recorded at every 1 hour for each of the respondents. A pilot test on the questionnaire survey was carried out on these 10 selected respondents for the pre-screening process on the questionnaire. This was to ensure the reliability of the questionnaire and make sure the respondents understood the questions about certain critical aspects, i.e. temperature and humidity sense, perception and their opinions about the selected heat areas. The respondents were placed at the investigated locations 5 minutes prior to the survey. ASHRAE thermal sensation scale was selected and used to evaluate the thermal response of occupants within the selected environments (ASHRAE Standard 55P, 2004). The obtained data collected from the in-situ measurement such as climatic data, temperature variation from SHS as well as thermal perception from questionnaire survey were correlated to establish a heat stress and thermal comfort index that was incorporated with local microclimate. Both meteorological and psychological, were taken into consideration in this index to then be adapted in the Malaysian tropical climate for the evaluation of human thermal comfort. The results were analysed using Statistical Package for the Social Sciences (SPSS) version 16.0. Appropriate tests such as multiple linear regressions, assumption test, significant test, correlation and two sample hypothesis tests were conducted to establish an equation and determine the relationship, significance, reliability and consistency.

1.5 Significance of the Study

Several thermal environment factors such as the albedo effect, land use, surface materials and building orientations that lead to the occurrence of UHI phenomenon were investigated to discover the most uncomfortable outdoor spaces or urban designs in the cities. This investigation can be enhanced by combining human thermal sensation study in order to obtain true responses in different environmental conditions. The investigation on the impacts of thermal behaviour based on different built up areas is relevant, especially in urban environments, to place stress on the thermal environmental conditions that contribute to the higher heat impact so that people can avoid the thermal condition and stay in healthy and comfortable conditions. Nonetheless, it can also be used by relevant authorities in order to strive towards the best precautionary practice in public health and mitigation for heat stress reduction.

In this study, the Discomfort Index (DI) used to determine the human discomfort level was modified by incorporating psychological factors (thermal sensation) in order to precisely evaluate thermal comfort, especially in the tropical climate of Malaysia. This modified DI that replaced the existing DI classification can be very useful as an indicator for identifying human thermal comfort, which is also correlated to heat related illnesses and health.

Nevertheless, thermal perception of the occupants can be identified by using the established Heat Stress Index (HSI) due to its relation with the climatic variables. Thus, the relationship between thermal perception with the climatic variables and SHS can be developed to establish an index readily useable by practicing engineers or public health. This index is simple when compared to previous heat stress indices and is an informative interpretation of thermal comfort by taken into account the two important factors: climatic and psychological (perception) with the assistance of developed SHS. In addition, the SHS can also act as the sensor or indicator to investigate the impact of the thermal behaviour from the surrounding built-up environment conditions as well as thermal perception or the heat stress of people by integrating the established indices. In the future, the SHS can be used and improved for planning and managing township in order to achieve better human thermal comfort.

1.6 Thesis Outline

This thesis is divided into seven chapters, Chapter 1 presents the introduction; Chapter 2 consists of the literature review; Chapter 3 contains the research methodology on experimental sampling and analytical procedure; Chapter 4 discusses the analysis on climatic measurement and outdoor thermal comfort; Chapter 5 presents the analysis on Surrogate Human Sensor (SHS) measurement; Chapter 6 consists of the analysis of outdoor thermal sensation, with respect to the SHS; and Chapter 7 presents the conclusion and recommendation. Throughout Chapter 1, the background of thermal behaviour and thermal comfort, problem statement, objectives of the study, significance and scope of the study are included in this section. Introduction to the urban environment is presented in the initial part of Chapter 2 where the thermal behaviour of the built environment, and its effect towards human thermal comfort, are reviewed. Human thermal comfort due to heat environment and its relation to heat related illnesses and the assessment of thermal comfort using thermal comfort indices are also included in this chapter. It is then followed by a critical review on the history and related research on SHS as a simplified version of thermal manikins to demonstrate their relevance to the thermal comfort analysis. In addition, a detailed and comprehensive literature review of previous research is carried out to identify the lack of investigation in the field. Lastly, UHI phenomenon was reviewed and it was demonstrated that the impact of the thermal behaviour from the surrounding built-up environment should be discussed instead of elaborating on the concept or the UHI phenomenon. Chapter 3 discusses the research methodology and framework of this research. The procedure, method and experiment design for fabrication of SHS are discussed. Analytical parameters and instrumentations that provide great response to the environment are studied. Experiments, samplings and analytical procedures are discussed in this chapter. For Chapter 4, analysis on climatic measurement and its relation to human discomfort level is discussed. In-situ field measurements had been carried out based on several criteria i.e., green and open space versus urban building, building orientations are also included in this chapter. Also, evaluation of human discomfort level by using Thom's Discomfort Index (DI) and modification of DI based on tropical climate criteria is also analysed in Chapter 4. In Chapter 5, analysis on SHS measurement and its advantage on the investigation of thermal conditions due to the impact of thermal behaviour are discussed. An equation has been determined to measure the temperature at SHS based on climatic variables. In Chapter 6, outdoor thermal sensation based on the questionnaire and its relationship to the climatic variables and SHS are highlighted. A regression model has been developed to integrate the relationship between thermal perception and climatic variables. The advantages of SHS as a sensor and indicator for evaluating thermal perception are discussed and analysed in this chapter. The verification of the regression models established on the four selected field studies are also examined. Lastly, the conclusions and recommendations for future works are highlighted in Chapter 7.

REFERENCES

Abdul Majid N. H. (2004). Thermal Comfort of Urban Spaces in the Hot Humid Climate. *The 21th Conference on Passive and Low Energy Architecture*. 19 - 22 September. Eindhoven, The Netherlands. 1 - 3.

Abdulshukor, (1993). Human Thermal Comfort in the Tropical Climate. PhD thesis. University of London, United Kingdom.

Abreu, M.J. (2008). An investigation of the thermal comfort behaviour for active wear using a thermal manikin. *7th International Thermal Manikin and Modelling Meeting.* September 2008. University of Coimbra.

Ahmed, K.S. (2003). Comfort in urban spaces: defining the boundaries of outdoor thermal comfort for the tropical urban environments. *Energy and Buildings*. 35(1), 103 - 110.

Akbari, H., Menon, S., Rosenfeld, A. (2009). Global cooling: increasing world-wide urban albedos to offset CO_2. *Climatic Change.* 94(3 - 4), 275 - 286.

Akbari, H., Pomerantz, M., Taha, H. (2001). Cool surface and shade trees to reduce energy use and improve air quality in urban areas. *Solar Energy*. 70(3), 295 - 310.

Al-Aqil A., Zulkifli I., Sazili A.Q., Omar A.R., Rajion M.A. (2009). The effects of the hot, humid tropical climate and early age feed restriction on stress and fear responses and performance in broiler chicken. *Asian-Australasian Journal of Animal Sciences*. 22(11), 1581 - 1586.

Alonso J. G. (2012). Human thermoregulation and the cardiovascular system. *Experimental Physiology*. 97(3), 340 - 346.

Al-Tamimi, N.A.M., Syed Fadzil, A.F., Wan Harun, W.M. (2011). The effects of orientation, ventilation and varied WWR on the thermal performance of residential rooms in the tropics. *Journal of Sustainable Development*. 4(2), 142 - 149.

American Society of Civil Engineers ASCE. Task Committe on Outdoor Human Comfort. (2004). Outdoor Human Comfort and Its Assessment: State of the Art. Virginia, USA: ASCE publication.

Amirtham, L.R., Devadas, M.D. (2007). Impact of built environment on outdoor thermal conditions in the hot humid city of Chennai. *Conference on Sustainable Building South East Asia*. 5 - 7 November, Malaysia.

Amirtham, L.R., Horrison, E., Rajkumar, S. (2014). Study on the microclimate conditions and thermal comfort in an institutional campus in hot humid climate. *30th Internaltional PLEA Conference*. 16 – 18 December, CEPT University, Ahmedabad.

Andreou, E. (2013). Thermal comfort in outdoor spaces and urban canyon microclimate. *Renewable Energy*. 55, 182 - 188.

Asaeda, T., Ca, V.T. (1996). Heat storage of pavement and its effect on the lower atmosphere. *Atmosphere Environment*. 30(3), 413 - 427.

ASHRAE Standard 55P, (2004), *Thermal Environmental Conditions for Human Occupancy*. Third Public Review. American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc.

Asseal, M.J., Kakosimos, K.E., Antoniadis, K.D., Assael, J.A.M., (2010). Appliying thermal comfort indices to investigate aspects of the climate in Greece. *International Review of Chemical Engineering (I.RE.CH.E)*. 2(2), 204 – 209.

Beggs, C. (2002). *Energy: Management, Supply and Conservation*, Butterworth-Heinemann.

Berglund, L.G. (1979). Thermal acceptability. *ASHRAE Transactions*. 85(2), 825 - 834.

Bernama. (2014a, march 1). Malaysians must be alert to heat stroke. *The Star Online*. Retrieved March 1, 2014, from http://www.thestar.com.my/news/nation/2014/03/01/health-heat-stroke/

Bernama. (2014b, February 23). Hot weather: People advised to avoid outdoor activities. Retrieved at 20 August 2014, from http://news.abnxcess.com/2014/02/hot-weather-people-advised-to-avoid-outdoor-activities/.

Bogdan, A. and Zwolinska, M. (2012). Future trends in the development of thermal manikins applied for the design of clothing thermal insulation. *FIBRES & TEXTILES in Eastern Europe*. 20, 4(93), 89-95.

Borges C.M., Gaspar A.R. and Quintela D.A. (2008). Analysis of the interaction of thermal plumes within office environment using a thermal manikin. *7th International Thermal Manikin and Modelling Meeting*. September 2008. University of Coimbra.

Bougiatioti, F., Evangelinos, E., Poulakos, G., Zacharopoulos, E. (2009). The Summer Thermal Behaviour of "Skin" Materials in Greek Cities as a Decisive Parameter for Their Selection. *Solar Energy*. 83(4), 582 – 598.

BS EN ISO 7730, (2005). *Ergonomics of the thermal environment. Analytical determination and interpretation of thermal comfort using calculation of the PMV and PPD indices and local thermal comfort criteria*. British standards Institute, Brussels.

Buyantuyev, A., and Wu, J. (2009). Urban heat islands and landscape heterogeneity: Linking spatiotemporal variations in surface temperatures to land-cover and socioeconomic patterns. *Landscape Ecology*, 25(1), 17-33.

CCOHS. (2008). Hot environments - Health effect: What are the Effects of Hot Environments on the Body?. *Canadian Centre for Occupational Health and Safety*. Retrieved from http://www.ccohs.ca/oshanswers/phys_agents/heat_health.html.

Cengiz, C. (2013). Urban Ecology. In Ozyavuz, M. *Advances in Landscape Architecture* (pp. 677 - 696). Rijeka, Croatia: InTech.

Che-Ani, A.I., Shahmohamadi, P., Sairi, A., Mohd-Nor, M.F.I., Zain, M.F.M., Surat, M. (2009). Mitigating the Urban Heat Island Effect: Some Points without Altering Existing City Planning. *European Journal of Scientific Research.* 35(2), 204 - 216.

Cheng Y.D., Niu J.L., Gao N.P. (2012). Thermal comfort models: A review and numerical investigation. *Building and Environment.* 47, 13 - 22.

Cheong, K.W.D., Yu, W.J., Kosonen, R., Tham, K.W., Sekhar, S.C. (2006). Assessment of thermal environment using a thermal manikin in a field environment chamber served by displacement ventilation system. *Building and Environment*. 41(12), 1661 - 1670.

Chia, S.L., Mohd Hamdan, A., Ossen, D.R. (2007). The effect of geometric shape and building orientation on minimizing solar insolation on high-rise buildings in hot humid climate. *Jounal of Construction in Developing Countries*. 12(1), 27 - 38.

Chirag, D., Ramachandraiah, A. (2010). The significance of Physiological Equivalent Temperature (PET) in outdoor thermal comfort studies. *International Journal of Engineering Science and Technology*. 2(7), 2825 – 2828.

Chow, W.T.L. and Roth, M. (2006). Temporal dynamics of the urban heat island of Singapore. *International Journal of Climatology*. 26, 2243 - 2260.

Chudnovsky, A., Ben-Dor, E., Saaroni, H. (2004). Diurnal thermal behaviour of selected urban objects using remote sensing measurement. *Energy and buildings*. 36(11), 1063-1074.

Conceicao, E.Z.E., Lopes, M.C., Lucio, M.M.J.R. (2009). Energy and Thermal Comfort Evaluation for Different Passive Solutions in a Kindergarten in Summer Conditions. *Eleventh International IBPSA Conference*. 27 - 30 July, Glasgow, Scotland.

Dasimah, O., Ahmad, P., Sarimin, M. (2009). Urban Living Condition of Low Income Single Mathers in Malaysia. *European Journal of Social Sciences*. 9, 193 - 201.

Dear, R.J., Leow, K.G. (1990). Indoor climate and thermal comfort in high-rise public housing in an equatorial climate: A field-study in Singapore. *Atmospheric Environment. Part B. Urban Atmosphere.* 24(2), 313 - 320.

Den Hartog, E.A. and Hevenith, G. (2010). Analytical study of the heat loss attenuation by clothing on thermal manikins under radiative heat loads. *International Journal of Occupational safety and Ergonomics (JOSE)*. 16(2). 245 - 261.

Devadas, M.D., Lilly, R.A. (2009) Urban Factors and The Intensity of Heat Island in the city of Chennai. *The seventh International Conference on Urban Climate*. 29 June - 3 July. Yokohama, Japan.

Dobrovolny, P., Reznickova, L., Krahula, L. (2012). Spatial and temporal variability of urban heat island intensity in Brno (Czech Republic). *Geophysical Research Abstracts.* 14, EGU2012 - 4165.

Doulos, L., Santamouris, M., Livada, I. (2004). Passive Cooling of Outdoor Urban Spaces: The Role of Materials. *Solar Energy*. 77(2), 231-249.

Emissivity Table, (2015). Emissivity Table. Retrieved on 14 September 2015, from http://www.thermoworks.com/emissivity_table.html. ThermoWorks.

Epstein, Y., Moran D.S., (2006). Thermal Comfort and the Heat Stress Indices. *Industrial Health*. 44. 388 - 398.

Erell, E. and Williamson, T., (2007). Intra-urban differences in canopy layer air temperature at a mid-latitude city. *International Journal of Climatology*. 27, 1243 – 1255.

Fan J. (2006). Thermal Manikins and Modeling. *Sixth International Thermal Manikin and Modeling Meeting*. 16 - 18October. The Hong Kong Polytechnic University, Hong Kong. 303 - 343.

Fanger, P. O. (1970). *Thermal Comfort*. Danish Technical Press. Copenhagen.

Farrington R. B., Rugh J. P., Bharathan D., Burke R. (2004). *Use of Thermal Manikin to Evaluate Human Thermoregulatory Responses in Transient, Non-uniform, Thermal Environments*. SAE paper no. 2004 - 01- 2345, Warrendale, PA: Society of Automotive Engineers.

Foda E. and Siren K. (2012). A thermal manikin with human thermoregulatory control: Implementation and validation. *International Journal of Biometeorology*. 56(5), 959 - 971.

Fujibe, F. (2009). Relation between long-term temperature and wind speed trends at surface observation stations in .Japan. *SOLA*. 5, 81-84.

Gagge, A.P., Stolwijk, J.A.J., Nishi, Y. (1971). An effective temperature scale, based on a simple model of human physiological regulatory response. ASHRAE Trans. 74, 247-262.

Gagge, A.P., Fobelets, A.P., Berglund, L.G. (1986). .A standard predictive index of human response to the thermal environment. ASHRAE Transactions. 92, 709-731.

Gao, N.P.and Niu, J.L. (2005). CFD Study of the Thermal Environment around a Human Body: A Review. *Indoor Built Environment.* 14(1), 5 -16.

Gao C., Kuklane K., Holmer I. (2010). Thermoregulatory Manikins are Desirable for Evaluations of Intelligent Clothing and Smart Textiles. *8th International Meeting for Manikins and Modeling*. 22 - 26 August, Victoria, British Columbia, Canada.

Gao, N.P., Zhang, H., Niu, J.L. (2007). Investigating indoor air quality and thermal comfort using a numerical thermal manikin. *Indoor and Built Environment*. 16(1), 7 - 17.

Gartland, L. (2008). Heat Islands: understanding and mitigating heat in urban areas. London, UK and Sterling, VA, USA: Earthscan.

Ghazanfari, S., Naseri, M., Faridani, F., Aboutorabi, H. and Farid, A. (2009). Evaluating the effects of UHI on climate parameters (A case study for Mashhad, Khorrasan). *International Journal of Energy and Environment.* 3(2), 94 - 101.

Giridharan, R., Lau S.S.Y., Ganesan, S. (2005). Nocturnal heat island effect in urban residential developments of Hong Kong. *Energy and building.* 37(9), 964 - 971.

Givoni, B., Noguchi, M., Saaroni, H., Pochter, O., Yaacov, Y., Feller, N., Becker, S. (2003). Outdoor comfort research issues. *Energy and buildings*. 35, 77 – 86.

Golden jay S. (2004). The Built Environment Induced Urban Heat Island Effect in rapidly Urbanizing Arid Region - A Sustainable Urban Engineering Complexity. *Environmental Science.* 1, 321 - 349.

Gowrishankar, T. R., Stewart, D. A., Martin, G. T., and Weaver, J. C. (2004). Transport lattice models of heat transport in skin with spatially heterogeneous, temperature-dependent perfusion. *BioMedical Engineering Online*. 3(42), 1 - 17.

Grebowicz, J., Lau, S. F., Wunderlich, B. (1984). The thermal properties of polypropylene. *Journal of Polymer Science: Polymer Symposium*. 71(1), 19 - 37.

Green, H., Gilbert, J., James, R., Byard, R.W. (2001). An analysis of factors contributing to a series of deaths caused by exposure to high environemntal temperatures. *The American Journal of Forensic Medicine and Pathology*. 22(2), 196 – 199.

Grubenhoff, J.A., Kelly du Ford, and Roosevelt, G.E. (2007). Heat Related Illness. *Clinical Pediatric Emergency Medicine.* 8, 59 - 64.

Guan, K.K. (2011). Surface and ambient air temperatures associated with different ground material: a case study at the University of California, Berkeley, Spring. (2011). Retrieved on 14 September 2015, from http://nature.berkeley.edu/classes/es196/projects/2011final/GuanK_2011.pdf

Gurusamy, K. (2005). Impact on the design life of buildings in a tropical hot wet environment. *10DBMC International Conference on Durability of Building Materials and Components LYON*. 17 – 20 April, France.

Hara, M., Kusaka, H., Kimura, F., Wakazuki, Y. (2011) Urban Heat Island intensity change over Tokyo metropolitan area during winter. *Geophysical Research Abstracts.* 13, EGU2011 - 7313.

Haslam, R.A. (1989). *An evaluation of models of human responses to hot and cold environments*. Ph.D Thesis. Loughborough University of Technology, Loughborough, United Kingdom.

Hazlini Dzinun, MD Din, M.F., Noor, Z.Z., Remaz, D., Iwao, K., Chellapan S. (2011). Analysis of heat impacted behavior at vertical facade building based on heat flux mechanism. *International Conference on Environment and Industrial Innovation, IPCBEE*. IACSIT Press, Singapore. vol.12, 74 - 78.

Hendriks, F. M., (2001). *Mechanical Behavior of Human Skin in Vivo: A Literature Review*. Unclassified Report 2001/820, Koninklijke Philips Electronics N.V.

Henry, C. (2002). Impact of Climate Change on Human Health, Discussion Paper C3 - 08. Climate Change Central.

Ho C.S., Matsuoka Y., Simson J., Gomi K. (2013). Low carbon urban development strategy in Malaysia - The case of Iskandar Malaysia development corridor. *Habitat International*. 37, 43 - 51.

Holmer, I. (2004) Thermal manikin history and applications. *European Journal of Applied Physiology*. 92(6), 614 - 618.

Holmes, M. J. and Hacker, J. N. (2007). Climate change, thermal comfort and energy: Meeting the design challenges of the 21st century. *Energy and Buildings*. 39(7), 802 - 814.

Höppe, P. (1999). The physiological equivalent temperature – a universal index for the biometeorological assessment of the thermal environment. *International Journal of Biometeorology*. 43, 71-75.

Hua, L.J., Ma, Z.G., Guo, W.D. (2008). The impact of urbanization on air temperature across China, *Theoretical and Applied Climatology*, 93, 179 - 194.

Hughes, K. (2006). The impact of urban areas on climate in the UK: a spatial and temporal analysis, with an emphasis on temperature and precipitation effects. *Earth &* E*nvironment*. 2, 54-83.

Humphreys, M.A., Nicol, J.F. (2000). Outdoor temperature and indoor thermal comfort – raising the precision of the relationships for the 1998 ASHRAE database of field. ASHRAE Transactions. 206, 485-492.

Hung, T., Uchihama, D., Ochi, S., Yasuoka, Y. (2006). Assessment with satellite data of the urban heat island effects in Asian mega cities. *International Journal of Applied Earth Observation and Geoinformation*. 8, 34 - 48.

Huynh, C. and Eckert, R. (2012). Reducing heat and improving thermal comfort through urban design - A case study in Ho Chi Minh city. *International Journal of Environmental Science and Development*, 3(5), 480 - 485.

Imagawa, H. and Rijal, H.B. (2014). Survey on the thermal comfort and occupant behaviour in the bedroom of Japanese houses. *Proceedings of 8th Windsor Conference: Counting the Cost of Comfort in a changing world*. 10 - 13 April. Cumberland Lodge, Windsor, UK.

Irmak, M.A., Yilmaz, S., Yilmaz, H., Ozer, S., Toy, S. (2013). Evaluation of different thermal conditions based on THI under different kind of tree types – as a specific case in ATA Botanic garden in eastern Turkey. *Global NEST Journal*. 15 (1), 131 – 139.

Jacquot, C.M.C., Schellen, L., Kingma, B.R. (2014). Influence of thermophysiology on thermal behavior: the essentials of categorization. *Physiology and Behavior*. 128, 180 - 187.

Jauregui, E. (1997). Heat island development in Mexico City. *Atmospheric Environment*. 31(22), 3821 - 3831.

Johansson, E. (2006). Influence of urban geometry on outdoor thermal comfort in a hot dry climate: A study in Fez, Morocco. *Building and Environment*. 41(10), 1326 - 1338.

Johansson, E., Emmanuel, R. (2006). The influence of urban design on outdoor thermal comfort in the hot, humid city of Colombo, Sri Lanka. *International Journal of Biometeorology*. 51(2), 119 - 133.

Johansson E., Yahia M.W. (2012). 387: Improving outdoor thermal comfort in warm-humid Guayaquil, Ecuador through urban design. *ICUC8 - 8th International Conference on Urban Climates*. 6 - 10 August. UCD, Dublin Ireland.

Jongtanom, Y., Kositanont, C., Baulert, S. (2011). Temporal variation of Urban Heat Island Intensity in Three major cities, Thailand. *Modern Applied science.* 5(5), 105 - 110. Canadian Center of Science and Education.

Jusuf, S.K., Wong, N.H., Hagen, E., Anggoro, R., Hong, Y. (2007). The influence of land use on the urban heat island in Singapore. *Habitat International*. 31, 232 - 242.

Kershaw, T., Sanderson, M., Coley, D., Eames, M. (2010). Estimation of the urban heat island for UK climate change projections. *Building Services Engineering Research and Technology*. 31(3), 251 - 263.

Kim, Y.H., and Baik, J.J. (2002). Maximum Urban Heat Island Intensity in Seoul *Journal of Applied Meteorology*. 41, 651 - 659.

Kim, Y.H., and Baik, J.J. (2005). Spatial and temporal structure of the Urban Heat island in Seoul. *Journal of Applied Meteorology*. 44, 591 - 605.

Klysik, K. and Fortuniak, K. (1999). Temporal and spatial characteristics of the urban heat island of Lodz, Poland. *Atmospheric Environmental*. 33, 3885 - 3895.

Kolokotroni, M., Giridharan, R. (2008). Urban Heat Island Intensity in London: an investigation of the impact of physical characteristics on changes in outdoor air temperature during summer. *Solar Energy*. 82(11), 986 - 998.

Kolokotsa, D., Psomas, A. and Karapidakis, E. (2009). Urban heat island in southern Europe: The case study of Hania, Crete. *Solar Energy*. 83(10), 1871 - 1883.

Konarska, M., Sołtynski, K., Sudoł-Szopińska, I., Chojnacka, A. (2007). Comparative Evaluation of Clothing Thermal Insulation Measured on a Thermal Manikin and on Volunteers. *FIBRES & TEXTILES in Eastern Europe*. 15, 2(61), 73 – 79.

Krishnan, G. (2007, June 19). Putrajaya is 5°C hotter than other cities. *The Star Online*. 19 June, 2007, from http://www.thestar.com.my/story.aspx/?file=%2f2007%2f6%2f19%2fcentral%2f17992083&sec=central

Kubota, T. and Ossen, D.R. (2009). Analysis of spartial and temporal characteristics of urban heat island in the tropics: A case study of Johor Bahru city, Malaysia. *The seventh International Conference on Urban Climate*. 29 June - 3 July, Yokohama, Japan.

Kuklane, K. (2008). Heat loss from a thermal manikin during wet tests with walking simulation. *7th International Thermal Manikin and Modelling Meeting*. September 2008. University of Coimbra.

Kuwabara, K., Mochida, T., Nagano, K., Shimakura, K. (2005). Experiments to determine the convective heat transfer coefficient of a thermal manikin. *Environmental Ergonomics - Elsevier Ergonomics Book Series*. 3, 423 - 429.

Kysely, J., Pokorna, L., Kyncl, J., Kriz, B., Nemesova, I. (2007). Relationship between human mortality and short-term variability of meteorological variables. *International Scientific Conference: "Bioclimatology and Natural Hazard"*.17 - 20 September. Polana nad Detvou, Slovakia.

Lee, S., Nogami, M., Yamaguchi, S., Kurabuchi, T., Ohira, N. (2013). Evaluation of heat transfer coefficients in various air-conditioning modes by using thermal manikin. *Proceedings of BS2013: 13th Conference of International Building Performance Simulation Association*. 26 - 28 August. Chambery, France.

Lim, G.E. (1980). *Pulau haba bandar dan aplikasinya terhadap kajian pencemaran udara di Georgetown, Pulau Pinang* (Urban heat island and its implication to pollution studies in Georgetown, Penang). Undergraduate dissertation. Department of Geography, UKM, Unpublished.

Lin T. P. (2009). Thermal perception, adaptation and attendance in a public square in hot and humid region. *Building and environment.* 44(10), 2017 - 2026.

Lin, T.P., de Dear, R., Hwang, R.L. (2011). Effect of thermal adaptation on seasonal outdoor thermal comfort. *International Journal of Climatology*. 31(2), 302 - 312.

Lin, C.H., Lin T.P., Hwang, R.L. (2013). Thermal comfort for urban parks in subtropics: Understanding visitor's perceptions, behaviour and attendance. *Advances in Meteorology*. vol. 2013, Article ID 640473, 8 pages. doi:10.1155/2013/640473. Hindawi Publishing Corporation.

Lin T.P., Matzarakis A., Hwang R.L. (2010). Shading effect on long-term outdoor thermal comfort. *Building and environment*. 45(1), 213 - 221.

Lind A. R., Hellon R. F., Weiner J. S., Jones R. M. (1955). Tolerance of men to work in hot, saturated environments with reference to mines rescue operation. *British Journal of Industrial Medicine*. 12(4), 296 - 303.

Liu W., Ji C., Zhong J., Jiang X., and Zheng Z. (2007). Temporal characteristics of the Beijing urban heat island. *Theoretical and Applied Climatology*. 87(1 - 4), 213 - 221.

Liu, Y.F., Wang, L.J., Liu, J.P., Di, Y.H., (2013). A study of human skin and surface temperatures in stable and unstable thermal environments. *Journal of Thermal Biology*. 38, 440 – 448.

Livingstone K. (2006). *London's Urban Heat Island: A Summary for Decision Makers*. Greater London Authority. City Hall.

Lo, J.H., Cheng, M.J. and Hwang R.L. (2008). The effect of plants on outdoor thermal sensation in subtropical climate. *The First International Conference on Building Energy and Environment (COBEE 2008)*. 13 - 16 July, Dalian, China.

Lugo-Amador, N. M., Rothenhaus, T., Moyer, P. (2004). Heat-related illness. *Emergency Medicine Clinics of North America*. 22(2). 315 - 327.

Luber, G. and McGeehin, M. (2008). The health impacts of climate change: Climate change and extreme heat events. *American Journal of Preventive Medicine*. 35(5), 429 - 435.

Lundgren, K., Kuklane, K., Gao, C., Holmer, I. (2013). Effects of heat stress on working population when facing climate change. *Industrial Health*. 51. 1 – 13.

Makaremi, N., Salleh, E., Jaafar, M.Z., and GhaffarianHoseini, A.H. (2012). Thermal comfort conditions of shaded outdoor spaces in hot and humid climate of Malaysia. *Building and Environment*. 48, 7 -14.

Makaremi N., Jaffar Z., Salleh E., Matzarakis A. (2012). 607: Study on outdoor thermal comfort in hot and humid context. *ICUC8 - 8th International Conference on Urban Climates*. 6 - 10 August. UCD, Dublin Ireland.

Mayer, H. and Hoppe, P. (1987). Thermal comfort of man in different urban environment. *Theoretical and Applied Climatology*. 38(1), 43 - 49.

McCullagh, P. (1980). Regression models for ordinal data (with discussion). *Journal of the Royal Statistical Society, Series B*. 42(2), 109-142.

McCullough E. A. (2005). The Use of Thermal Manikins to Evaluate Clothing and Environmental Factors. *Environmental Ergonomics - Elsevier Ergonomics Book Series*. 3, 403 - 407.

McGinley M. (2011). Weather and Climate: Climate of Malaysia. *The Encyclopedia of Earth*. Retrieved from http://www.eoearth.org/view/article/151260/.

McGuffin R., Burke R., Huizenga C., Hui Z., Vlahinos A., Fu G. (2002). *Human Thermal Comfort Model and Manikin*. SAE Technical Paper 2002- 01- 1955. Society of Automotive Engineers. DOI: 10.4271/2002-01-1955.

McKenzie, L. (2009). Climate, Public space and public health: the influence of heat on the use of public space and implications for public health, a Western Sydney case study. *Universitas 21 Internatinal Graduate Research Conference: Sustainable Cities for the Future*. 29 November - 5 December. Melbourne & Brisbane. 117 - 120.

MD Din, M.F, Dzinun, H, Ponraj, M., Shreeshivadasan, C., Zainun Noor, Z, Remaz, D., Iwao, K. (2012). Investigation of thermal effect on exterior wall surface of building material at urban city area. *International Journal of Energy and Environment*. 3(4), 531 – 540.

Mohan, M., Kikegawa, Y., Gurjar, B.R., Bhati, S., Kandya, A., and Ogawa, K. (2009). Assessment of Urban Heat Island Intensity over Delhi. *The seventh International Conference on Urban Climate*, 29 June - 3 July, Yokohama, Japan.

Montavez, J. P., Gonzalez-Rouco, J.F., Valero, F. (2008). A simple model for estimating the maximum intensity of nocturnal urban heat island. *International Journal of Climatology*. 28(2), 235 - 242.

Nasir, R.A., Ahmad, S.S., Ahmed, A.Z. (2012). Psychological adaptation of outdoor thermal comfort in shaded green spaces in Malaysia. *Procedia - Social and Behavioral Sciences*. 68, 865 - 878.

National Aeronautics and Space Administration, NASA, (2012), *NASA Finds 2011 Ninth Warmest Year on Record.* Update at 19 January 2012. Online at http://www.giss.nasa.gov/research/news/20120119/

National Oceanic and Atmospheric Administration, NOAA, (2012), *NOAA: 2011 a year of climate extremes in the United States.* Update at 19 January 2012. Online at http://www.noaanews.noaa.gov/stories2012/20120119_global_stats.html

Ng, E., Cheng, V., (2012). Urban human thermal comfort in hot and humid Hong Kong. *Energy and Building*. 55, 51 - 65.

Nicol, J.F. and Humphreys, M.A. (2002). Adaptive thermal comfort and sustainable thermal standards for buildings. *Energy and Buildings*. 34(6), 563 - 572.

Nikolopoulou, M., Lykoudis, S. (2006). Thermal comfort in outdoor urban spaces: Analysis across different European countries. *Building and Environment*. 41(11), 1455 - 1470.

Nikoloopoulou, M., Steemers, K. (2003). Thermal comfort and psychological adaptation as a guide for designing urban spaces. *Energy and Buildings*. 35, 95 - 101.

Nilsson, H.O. (2007). Thermal comfort evaluation with virtual manikin methods. *Building and Environment*. 42(12), 4000 - 4005.

Nilsson, H.O. and Holmer, I. (2003). Comfort climate evaluation with thermal manikin methods and computer simulation models. *Indoor Air*. 13(1), 28 - 37.

Noor Hanita, A.M. (2004). Thermal Comfort of Urban Spaces in the Hot Humid Climate. *The 21th Conference on Passive and Low Energy Architecture*. 19 - 22 September. Eindhoven, the Netherlands.

Occupational Safety and Health Administration, OSHA, (1999). OSHA Technical Manual, Section III: Chapter 4. *Heat Stress*. Occupational Safety and Health Administration.

Ohba, M., Yoshie, R. and Lun, I. (2010). Overview of extreme hot weather incidents and recent study on human thermal comfort in Japan. *APEC-WW2010,* Kwandong University. 22 - 23 October, Gangneung, Korea.

Oke, T.R. (1981). Canyon geometry and the nocturnal urban heat island: comparison of scale model and field observations. *Journal of Climatology*. 1, 237–254.

Oke, T.R., (1982). The energetic basis of the urban heat island. *Quarterly Journal of the Royal Meteorological Society*. 108, 1–24.

Oke, T.R. (1987). *Boundary Layer Climates*. (2nd Ed.). London: Routledge.

Oke, T.R. (1988a). Street design and urban canopy layer climate. *Energy and Buildings*. 11, 103–113.

Oke, T R (1988b). The urban energy balance. *Progress in Physical geography*. 12, 471 – 508.

Oliveira, A.V., M.; Gaspar, A.R.; Quintela D.A. (2011). Dynamic clothing insulation. Measurements with a thermal manikin operating under the thermal comfort regulation mode. *Applied Ergonomics.* 42(6). 890 - 899.

O'Neill, M.S. (2009). Preventing heat-related morbidity and mortality: New approaches in a changing climate. *Maturitas*. 64(2), 98 - 103.

Ooka, R. (2007). Recent development of assessment tools for urban climate and heat island investigation especially based on experiences in Japan. *International Journal of Climatology*. 27, 1919 – 1930.

Ong, K.S. (2009). Experimental investigations into solar-induced passive cooling with trombe wall and roof solar collector. In Goswami, D.Y., Zhao, Y. (Eds.). *Proceedings of ISES Wold Congress (2007) Vol.1 - Vol.5: Solar Energy and Human Settlement*. (pp. 415 - 419). New York: Springer.

OSH. (1997). *Guidelines for the Management of Work in Extremes of Temperature*. First Edition. Department of Labour, Wellington, New Zealand: Occupational Safety and Health Service.

Pallant, J. (2007). *SPSS: Survival Manual. A step by step guide to data analysis using SPSS for Windows*. Third Edition. England: Open University Press, McGraw-Hill.

Papanastasiou D.K. and Kittas C. (2012). Maximum urban heat island intensity in a medium-sized coastal Mediterranean city. *Theoretical and Applied Climatology*. 107(3 - 4), 407 - 416.

Parsons, K.C., (2011). Assessment of Heat Stress and Heat Stress Indices. In Vogt, J.J. (Ed.) *42. Heat and Cold, Encyclopedia of Occupation Health and Safety*. International Labor Organization, Geneva.

Pearlmutter, D., Jiao, D., Garb, Y. (2014). The relationship between bioclimatic thermal stress and subjective thermal sensation in pedestrian spaces. *International Journal of Biometeorology*. 58(2), 1 - 17.

Pongracz, R., Bartholy, J., Dezso, Z. (2006). Remotely sensed thermal information applied to urban climate analysis. *Advances in Space Research.* 37(12), 2191 - 2196.

Priyadarsini, R., Wong, N.H., Cheong, K.W.D. (2008). Microclimate modelling of the urbam thermal environemnt of Singapore to mitigate urban heat island. *Solar Energy*. 82(8), 727 - 745.

Rahola, B.S., Oppen, P., Mulder, K. (2009). Heat in the city: An inventory of knowledge and knowledge deficiencies regarding heat stress in Dutch cities and options for its mitigation. ISBN 978-90-8815-008-1.

Rashid, R., Mohd Hamdan B. Ahmed and Md Sayem K. (2010). Green roof and its impacts on urban environmental sustainability: The case in Bangladesh. *World Journal of Management*. 2(2), 59 - 69.

Rizwan, A.M., Dennis Y.C. Leung, Liu C.H. (2008). A review on the generation, determination and mitigation of Urban Heat Island. *Journal of Environmental Sciences*. 20(1), 120-128.

Rosly, D., Nor Zaliza and Mohd Puzi. (2010). Green township policy initiatives. *The Ingenieur*. 47, 7 - 14.

Rosenthal, J.K., Crauderueff, R. and Carter, M. (2008). Urban Heat Island Mitigation can Improve New York City's Environment: Research on the Impacts of Mitigation Strategies. *A Sustainable South Bronx Working Paper*.

Russell, R., 2010. Solar Radiation at Earth. Retrieved on 08.Sepetember.2015 from http://www.windows2universe.org/earth/climate/sun_radiation_at_earth.html..

Saaroni, H., Ben-Dor, E., Bitan, A., Potchter, O. (2000). Spatial distribution and microscale characteristics of the uran heat island in Tel-Aviv, Israel. *Landscape and Urban Planning.* 48(1 - 2), 1 - 18.

Sailor, D.J. (2011). A review of methods for estimating anthropogenic heat and moisture emissions in the urban environment. *International Journal of Climatology*. 31(2), 189 - 199.

Saitoh, T.S., Shimada, T., Hoshi, H. (1996). Modelling and simulation of the Tokyo urban heat island. *Atmosphere Environment*. 30(20), 3431 - 3442.

Sakakibara, Y. (1996). A numerical study of the effect of urban geometry upon the surface energy budget. *Atmosphere Environment*. 30(3), 487 - 496.

Sangkertadi, (2012). A field study of outdoor thermal comfort in the warm-humid environment. *International Conference "CONVEESH 2nd and SENVAR 13th*. 29 November 2012, Yogyakarta.

Santamouris, M., Synnefa, A., & Karlessi, T. (2011). Using advanced cool materials in the urban built environment to mitigate heat islands and improve thermal comfort conditions. *Solar Energy*. 85(12), 3085-3102.

Sarkar, H. (2004). Study of Landcover and Population Density Influences on Urban Heat Island in Tropical Cities by Using Remote Sensing and GIS: A Methodological Consideration. *3rd FIG Regional Conference*. 3-7 October, Jakarta, Indonesia.

Shaharuddin, A. (1992). Some effects of urban parks on air temperature variations in Kuala Lumpur, Malaysia. In Katayama & Tsutsumi (eds). *Proceedings of the Second Tohwa University International Symposium on Urban Thermal Environment (CUTEST'92)*. 7 – 10 September, Tohwa University, Fukuoka, Japan, 107 - 108.

Shahmohamadi, P., Che-Ani, A.I., Maulud, K.N.A., Tawil, N.M., and Abdullah, N.A.G. (2011). The Impact of Anthropogenic Heat on Formation of Urban Heat Island and Energy Consumption Balance. *Urban Studies Research.* Volume **2011**, Article ID 497524, 9 pages. Hindawi publishing Corporation.

Shaibu, V.O. and Utang, P.B. (2013). Human comfort and the microclimatic drivers across different land use types in Port Harcourt Metropolis, Nigeria. *Ethiopian Journal of Environment Studies and Management*. 6(6), 737 - 745. African Journal Online.

Sham, S. **(**1984). Urban development and changing patterns of night-time temperatures in Kuala Lumpur - Petaling Jaya area, Malaysia. *Jurnal Teknologi*. 5, 27-36.

Sham, S. (1986). Temperatures in Kuala Lumpur and the Merging Klang Valley Conurbation, Malaysia. Report prepared for UNESCO under the Ecoville Project. Institute of Advanced Studies, University of Malaya.

Sham, S. (1987). Urbanization and the atmospheric environment in the low tropics: experiences for the Klang Valley Region, Malaysia. Bangi, UKM press.

Sharmin, T., Kabir, S., Rahaman, Md.M. (2012). A Study of Thermal Comfort in Outdoor Urban Spaces in respect to Increasing Building Height in Dhaka. *The AIUB Journal of Science and Engineering (AJSE).* 11(1), 57 – 66.

Shashua-Bar, L., Pearlmutter, D., Erell, E. (2011). The influence of trees and grass on outdoor thermal comfort in a hot-arid environment. *International Journal of Climatology*. 31, 1498 – 1506.

Shishegar, N. (2013). Street design and urban microclimate: Analyzing the effects of street geometry and orientation on airflow and solar access in urban canyons. *Journal of Clean Energy Technologies*. 1(1), 52 – 56.

Silva, V. P. R., Azevedo, P. V., Silva, B. B. (2006). Assessment of the Discomfort Human Level and Urban Heat Island Using Automatic Weather Station Data. *In 4th CEAWS-International Conference on Experiences with Automatic Weather Station*. Lisboa : Instituto de Meteorologia de Portugal, 1, 1 - 7.

Sin, H.T. and Chan, N.W. (2004). The urban heat island phenomenon in Penang Island: Some observations during the wet and dry season. In Jamaluddin Md. Jahi, Kadir Arifin, Salmijah Surif and Shaharudin Idrus (Eds.). *Proceedings 2nd. Bangi World Conference on Environmental Management. Facing Changing Conditions*. 13-14 September, Bangi, Malaysia, 504-516.

Simpson, J.R. and Mcpherson, E.G. (1997). The effects of roof albedo modification on cooling loads of scale model residences in Tucson, Arizona. *Energy and Buildings*. 25 (2), pp. 127–137.

Smith C., Levermore G. (2008). Designing urban spaces and buildings to improve sustainability and quality of life in a warmer world. *Energy policy*. 36(12), 4558 - 4562.

Spagnolo, J. and de Dear R. (2003). A field study of thermal comfort in outdoor and semi-outdoor environments in subtropical Sydney Australia. *Building and Environment*. 38, 721-738.

Stathopoulou M. I., Cartalis C., Keramitsoglou I., Santamouris M. (2005). *Thermal Remote Sensing of Thom's Discomfort Index (DI): Comparison with In Situ Measurements*. Proceeding of SPIE 2005, Remote Sensing for Environmental Monitoring, GIS Application and Geology V. Brugge, Belgium. Vol. 5983, page 59830K.

Strugnell, N. C., and Lucht, W. (2001). An algorithm to infer continental scale albedo from AVHRR data, land cover class, and field observations of typical BRDFs. *Journal of Climate*. 14, 1360 – 1376.

Su, W.Z., Gu, C.L., Yang, G.H. (2010). Assessing the Impact of Land Use/Land Cover on Urban Heat Island Pattern in Nanjing City, China. *Journal of Urban Planning and Development.* 136(4), 365 - 372.

Susca, T., Gaffin, S.R., Dell'Osso, G.R. (2011). Positive effects of vegetation: Urban heat island and green roofs. *Environmental Pollution*. 159(8-9), 2119 - 2126.

Svensson, M.K. (2004). Sky view factor analysis - implications for urban air temperature differences. *Meteorological Applications*. 11(3), 201 - 211.

Svensson, M. K., and Eliasson, I. (2002). Diurnal air temperatures in built-up areas in relation to urban planning. *Landscape and Urban Planning*. 61(1), 37-54.

Synnefa, A., Dandou, A., Santamouris, M., Tombrou, M. (2006). Cool coloured coatings for passive cooling of cities. *International Workshop on Energy Performance and Environmental Quality of Buildings*. July, Milos Island, Greece.

Synnefa A., Karlessi T., Gaitani N., Santamouris M., Papakatsikas C. (2009). Measurement of optical properties and thermal performance of coloured thin layer asphalt samples and evaluation of their impact on the urban environment. *Second International Conference on Countermeasure to Urban Heat Islands*. 21 - 23 September, Berkeley, USA.

Synnefa, A., Santamouris, M., Livada, I. (2005). A comparative study of the thermal performance of reflective coatings for the urban environment. *International Conference "Passive and Low Energy Cooling for the Built Environment"*. May, Santorini, Greece.

Synnefa,A., Santamouris M., Akbari, H. (2007). Estimating the effect of using cool coatings on energy loads and thermal comfort in residential buildings in various climate conditions. *Energy and Buildings*. 39(11), 1167 - 1174.

Taha, H., Akbari, H., Rosenfeld, A., Huang, J. (1988). Residential Cooling Loads and the Urban Heat Island - the Effects of Albedo. *Building and Environment.* 23(4), 271 - 283.

Takahashi-Nishimura, M., Tanabe, S., Hasebe, Y. (1997). Effects of skin surface temperature distribution of thermal manikin on clothing thermal insulation. *Journal of Physiological Anthropology*. 181 – 189.

Takebayashi, H., Moriyama, M. and Sugihara, T. (2012). Study on the cool roof effect of Japanese traditional tiled roof: Numerical analysis of solar reflectance of unevenness tiled surface and heat budget of typical tiled roof system. *Energy and Building*. 55, 77 - 84.

Takeuchi, W., Noorazuan, H. and Khin, M.T. (2010). Application of remote sensing and GIS for monitoring urban heat island in Kuala Lumpur Metropolitan area. *Map Asia 2010 & ISG 2010. Theme: Connecting Government and Citizen Through Ubiquitous GIS*. 26 - 28 July, Kuala Lumpur, Malaysia

Thom, E.C., 1959. The Discomfort Index. Weatherwise. 12, 57 - 61.

Tian, Z., Zhu, N., Zheng, G., Wei, H. (2011). Experimental study on physiological and psychological effects of heat acclimatization in extreme hot environments. *Building and Environment*. 46, 2033 - 2041.

Tseliou, A., Tsiros, I.X., Lykoudis, S., Nikolopoulou, M. (2010)., An evaluation of three biometeorological indices for human thermal cofmort in urban outdoor areas under real climatic conditions. *Building and Environment*. 45(5), 1346 - 1352.

Tsutsumi, H., Tanabe, S., Harigaya, J., Isuchi, Y. and Nakamura, G. (2007). Effect of humidity on human comfort and productivity after step changes from warm and humid environment. *Building and Environment.* 42(12), 4034 - 4042.

Tsutsumi, J.G., Nakamatsu, R., Arakawa, R. (2005). Thermal comfort sensations of tourists in a subtropical region. *Environmental Ergonomics - The Ergonomics of Human Comfort, Health and Performance in the Thermal Environment*. 3, 217 - 224.

Valsson S. and Bharat A. (2011). Impacts of air temperature on relative humidity - A study. *Architecture - Time Space & People*. Environment. February, 38 - 41.

Vanos, J. K., Warland, J.S., Gillespie, T.J., Slater, G.A., Brown, R.D., Kenny, N.A. (2009). Modelling spatial variations in energy budgets of humans exercising in outdoor urban recreational parks and spaces. American Meteorological Society.

Villaseñor-Mora, C.; Sanchez-Marin, F.J.; Calixto-Carrera, S. (2009). An indirect skin emissivity measurement in the infrared thermal range through reflection of a CO2 laser beam. *Revista Mexicana de Física*. 55(5), 387-392.

Voogt, J.A. and Oke, T.R. (2003). Thermal remote sensing of urban climates. *Remote Sensing of Environment*. 86(3), 370 - 384.

Voogt, James A. (2004). Urban Heat Island: Hotter Cities. American Institute of Biological Sciences. Online at: www. actionbioscience.org.

Wallace, R.F., Kriebel, D., Punnett, L., Wegman, D.H. and Amoroso, P.J. (2007). Prior heat illness hospitalization and risk of early death. *Environmental Research.* 104(2), 290 - 295.

Wang F. (2008). A comparative introduction on sweating thermal manikin "Newton" and "Walter". *7th International Thermal Manikin and Modeling Meeting*. University of Coimbra, September.

Wang, Y. and Akbari, H. (2014). Effect of Sky View Factor on outdoor temperature and comfort in Montreal. *Environmental Engineering* Science. 31 (6), 272 – 287.

Wang, F.M., Gao, C.S., Kuklane, K., Holmer, I. (2009). A study on evaporative resistances of two skins designed for thermal manikin tore under different environmental condition. *Journal of Fiber Bioengineering and Informatics*. 1(4), 301 - 306.

Wang F., Gao C., Kuklane K. and Holmer I. (2011). Determination of Clothing Evaporative Resistence on a Sweating Thermal Manikin in an Isothermal Condition: Heat Loss Method or Mass Loss Method?. *The Annals of Occupational Hygiene.* 55, 775 - 783.

Wang F., Kuklane K., Gao C. and Holmer I. (2010). Development and validity of a universal empirical equation to predict skin surface temperature on thermal manikins. J*ournal of Thermal Biology*. 35(4), 197 - 203.

Watson, I.D., Johnson, G.T. (1987). Graphical estimation of sky view factors in urban environments. *International Journal of Climatology*. 7, 193–197.

Weng Q. (2003). Fractal Analysis of Satellite-Detected Urban Heat Island Effect. *Photogrammetric Engineering & Remote Sensing*. 69, 555 - 566. American Society for Photogrammetry and Remote Sensing.

Wenzel H.G., Mehnert C., Schwarzenau P. (1989). Evaluation of tolerance limits for human under heat stress and the problems involved. *Scandinavian Journal of Work, Environment & Health*. 15(1), 7 - 14.

Wijewardane, S. and Jayasinghe, M.T.R. (2008). Thermal comfort temperature range for factory workers in warm humid tropical climates. *Renewable Energy*. 33(9), 2057 - 2063.

Williamson, T.J., Coldicutt, S., Penny, R.E.C. (1991). Aspects of thermal preferences in housing in a hot humid climate, with particular reference to Darwin, Australia. *International Journal of Biometeorology*. 34(4), 251 - 258.

Wong, N.H. and Peck, T.T. (2005). The impact of vegetation on the environmental conditions of housing estates in Singapore. *International Journal on Architectural Science*. 6(1), 31 - 37.

Wong, N.H., Kardinal, J.S., Aung, L.W.A., Kyaw, T.U., Syatia, N.T., Xuchao, W. (2007). Environmental study of the impact of greenery in an institutional campus in the tropics. *Building and Environment*. 42, 2949 - 2970.

Yau, Y. H. (2008). A preliminary thermal comfort study in tropical buildings located in Malaysia. *International Journal of Mechanical and Materials Engineering (IJMME)*. 3(2), 119 - 126.

Yang W, Wong, N.H., Jusuf, S.K. (2013). Thermal comfort in outdoor urban spaces in Singapore. *Building and Environment*. 59, 426 - 435.

Yilmaz, S., Toy, S., Yilmaz, H. (2007). Human thermal comfort over three different land surfaces during summer in the city of Erzurum, Turkey. *Atmosphere*. 20(3), 289 - 297.

Yin, J.F., Zheng, Y.F., Wu, R.J., Tan, J.G., Ye, D.X., Wang, W. (2012). An analysis of influential factors on outdoor thermal comfort in summer. *International journal of Biometeorology*. 56(5), 941 - 948.

Zainab, S. (1980). *Pulau haba dan aplikasinya terhadap keupayaan pencemaran udara di Johor Bahru, Johor* (Urban heat island and its implication to air pollution potential in Johor Bahru, Johore). Undergraduate dissertation. Department of Geography, UKM, Unpublished.

Zeng, Y, Qiu, X.F., Gu, L.H., He, Y.J., Wang, K.F. (2009). The urban heat island in Nanjing. *Quaternary International*. 208, 38 - 43.

Zhang D.L., Shou Y.X., Dickerson R. R. (2009). Upstream urbanization exacerbates urban heat island effects. *Geophysical research letters.* 36(24), L24401, 5 pages, doi: 10.1029/2009GL041082.

Zhang, Y.F., Zhao, R.Y. (2008). Overall thermal sensation, acceptability and comfort. *Building and Environment*. 43(1), 44 - 50.

Zhou, Y., Weng, Q., Gurney, K.R., Shuai, Y., Hu, X. (2011). Estimate of the relationship between remotely sensed anthropogenic heat discharge and building energy use. *ISPRS Journal of Photogrammetry and Remote Sensing*. 67, 65 - 72.

Zulkiple Ibrahim (2013, June 20). Many parts of Malaysia experiencing dry and hot spell. *Borneo Post Online*. Retrieved June 20, 2013, from http://www.theborneopost.com/2013/06/20/many-parts-of-malaysia-experiencing-dry-and-hot-spell/