Effect of Urban Structure on Thermal Comfort And Walking Comfort in Jakarta

M Donny Koerniawan*
2012 DBB 402

*Lecturer, Department of Architecture, Institute of Technology, Bandung, Indonesia
*Phd Student, Faculty of Environmental Engineering, The University of Kitakyushu

The University of Kitakyushu
Japan 2016

Effect of Urban Structure on Thermal Comfort
And Walking Comfort in Jakarta

ABSTRACT

The build environment accelerates the absorption of the heat during the daytime and slow down release the heat at the night time these formations known as the Urban Heat Island where the hot region surrounded by the cooler adjacent area.

City modifies meteorological conditions surrounding significantly; increasing radiation higher; average temperatures of the city become hotter than the surroundings; decreasing wind speeds due to the presence of buildings in the city; therefore make relative humidity much lower in the city than surrounding. Activities conducted the city residents outside of the building, such as walking and using public transportation should be convenient and possible widely can interact with the urban environment comfortable. Using the field measurement and simulation this research shows the parameters of the urban structure, in the parks (Green Plot Ratio and Sky View Factor) and urban area (Hide per width / H/W, Volumetric Compactness/Buildings Surface Area To Volume, and SurfacePlot size including plot area of site to volume ratio), affected the thermal comfort (PET and PMV).

The thermal comfort in theme parks in Jakarta was not comfortable. The value of PET reached 35 ^{o}C average, that means people feel hot. The comfortable condition, 26^{o}C-28^{o}C PET, happens in morning 7am-9am, and in the evening 3pm-5pm. The significant parameters that affect the thermal comfort in parks are shadowing (Sky View Factor/SVF) and Green Plot Ratio (GnPR/the ratio of greenery in the study area). Based on the coldest month (in March) and hottest month (in September) measurement, the results show that the position of vegetation and building placement affect the thermal comfort condition because of the sun position.

In the superblock, the sun radiation (Tmrt) is the significant factor affected the thermal comfort, therefore shadowing (SVF) and greenery in the urban area is needed to control the comfort condition in the urban. The Buildings, represented by Volumetric Compactness, hinder the wind, which needed to release heat trapping among the buildings. Not only thermal comfort, but also walking comfort is affected by the shadowing and Green Plot Patio. The average distance of Walking Comfort in the hot

humid urban area like Jakarta reaches 350 m. The long distance can be reached is 1 km in shaded area of vegetation in the morning. Walking comfort simulation can depict how the urban designer or architect have to consider where to put the significant facilities that can be reached in the walking comfort distance.

In the tropical humid climate city like Jakarta, open space used is almost during the years, and they must have thermal comfort properly. The thermal comfort studies in this open space are critical for evaluation studies and as a guideline for urban design and architectural projects. Climate circumstances take part in a particular responsibility in this context not only because climate change causes new challenges for urban areas, but also because urban areas can play a lead task in humanity's pursuit for an association with the natural environment that permit societies to thrive and prosper for a long time to come.

CONTENT

List of Figures

List of Tables

Chapter 1
INTRODUCTION

1.1. Background

Some researchers explain that the climatic conditions in the city affected by climate and the built environment (Landsberg 1981; Eliasson 2000; Oke 1984, 2006). The build environment accelerates the absorption of the heat during the daytime and slows down to release the heat at the night time these formations known as the Urban Heat Island where the hot region surrounded by the cooler adjacent area.

City modifies meteorological conditions surrounding significantly; increasing radiation higher; average temperatures of the city become hotter than the surroundings; decreasing wind speeds due to the presence of buildings in the city; therefore make relative humidity much lower in the city than surrounding (Landsberg 1981).

Along with global climate change, and the existence of several urban development and uncontrolled industrial area at this time will result in a very detrimental to society. The impact can be felt in the atmosphere with heat island above the city. Atmospheric intense heat is an important factor to consider in this issue because it affects the microclimate. According to Mangunwijaya, YB. (2000) in his book, Introduction to Building Physics, five environmental problems in the hot humid region that we need to consider are sunburn and sun glare, temperature, humidity and weather, noise disturbance, and brighter of the light.

In hot-humid areas, such as in the country of Indonesia, the issue that is important to note is the matter of thermal comfort. According to Vaughn Bradshaw (2006) thermal comfort will affect the attitude of psychology and health for the residents. This thermal influence can lead to a stroke or loss of consciousness when the condition of the room or open space was too hot, and metabolism of blood does not normally run when it gets too cold; it is said to be a very uncomfortable thermal condition.

Thermal comfort conditions become a very significant influence in many places where human beings gather at the same time, as in the open space or the recreation area. Where According to Oke (1996), Tourism Recreation is one travel form, which is like the tourism goal journey is to restore the physical and mental strength after doing work or routine daily tasks. So it becomes a critical thermal comfort in the recreation area because it is the task of a human restore the physical and mental freshness.

Man in tropical regions tends to be looking for a cold than hot. They will utilize shadowing areas around buildings or under a tree during the day to do activities. The characteristics of the microclimate in open space and the effects of thermal comfort in humans are vital to be known so it can be a tool to design the open space to be more comfortable and livable. For designers, it makes the way how they design, is much easier not much effort were made to determine the thermal comfort in open spaces, because of the complexity and the width of the data variable which they should prepare.

1.2. Problem Statement

One of the goals of the design of urban environments is creating the building and the creation of thermal comfort in open space. According to Katzschner (2003) that the consideration of thermal comfort in the design of open space is critical, because environmental conditions will affect the wear rate of human behavior. The opinion was supported by Nikolopoulou (1998) that the quality of life will increase with the increasing environmental quality of open space because there is a positive relationship between physical open space for the social interactions that occur within.

Environmental parameters and micro-climatic conditions will affect thermal comfort. There are six variables that affect thermal comfort in open space. Solar radiation, which affect climate change. Wind speed and direction, which can make changes convection heat on the human body. Two other climate elements that affect thermal comfort are temperature and humidity, and two additional factors are the level of human activity and the type of clothing worn.

Thermal comfort is defined as a state of mind which expresses the satisfaction level of human to thermal environmental conditions. Sometimes thermal environments occupied by people not give the expected conditions.

1. What factors are affecting the quality of the microclimate in achieving thermal comfort in open space?
2. How to develop criteria for empirical assessment and perceptional quality of the microclimate in achieving thermal comfort in open space?

3. What methods are appropriate for the assessment of the quality of the microclimate in achieving thermal comfort in open space?
4. How do the empirical characteristics and perceptional quality microclimate in achieving thermal comfort in open space?
5. How does the urban structure development affect the performance of thermal comfort and walking comfort in urban open spaces?

1.3. Objective of Study

This study has some objectives, as follows:

1. Mapping the actual conditions of thermal comfort in both open space, i.e.: in the Theme Parks and Superblock in Jakarta.
2. Knowing the gap between the real and the ideal conditions of thermal comfort in both open space, i.e.: in the Theme Parks and Superblock in Jakarta.
3. Analyzing the effect of the environment characteristics of open space, the microclimatic conditions, and thermal comfort of both open space, i.e.: in the Theme Parks and Superblock in Jakarta.
4. Performing physical interference of open space to improve the microclimate conditions so that the minimum ideal condition of thermal comfort can be achieved.
5. Performing the physical change of urban structure to improve the microclimate condition to achieve the performance of thermal comfort and walking comfort.

1.4. Operational Definition Of Research

Thermal comfort is defined as a state of mind which expresses the satisfaction level of human to thermal environmental conditions. Sometimes thermal environments occupied by people not give the expected conditions. Therefore, people have to make efforts to achieve the conditions they want.

Microclimate is contained in a relatively small area. The difference between microclimate and macroclimate, mainly due to the distance of the surface of the earth (Gosling, 20014). Factors that influence the microclimate is the morphology of the area. Morphology can be region-forming geometry, material or texture of the area, and the number of vegetation. Geometry can be shaped curved in region (valley), convex shape (mountain), and the lake. The location of the area also affects the microclimate, such as industrial areas, urban areas, rural areas, and so on. Vegetation regions can be formed by the plants that grow in swamps, forests, and others that affect the amount of radiation and affect the wind profile.

Public open space, according to Handy (2005), is the basic form of the open space of the building that can be used by the public or any person, and provide an opportunity for various activities, such as roads, pedestrian, parks, plazas, cemeteries, field flies, and sports fields.

The recreation area is part of the tourist activities that divided according to the target and the purposes. Recreation is a type of tourism area to restore the physical and mental strength after doing the task daily routine.

The urban structure is the combination of built environment and the natural environment that effect on how people everyday-life and move to the city. The urban structure development should consider developing the overall performance of the whole society and living environment. Local actions towards a sustainable city have to be mapped as the key strategy for urban development (Bourbia, F, Awbi, H.B 2004).

1.5. Scope of Study

The extent of this study is to discuss the existence of thermal comfort and walking comfort to improve the microclimate that affect the urban structure.

The scope of the present study was to measure the micro-climatic conditions that affect thermal comfort recreational open space in Jakarta. The selected open space is the central open space of three biggest recreation park and superblock in Jakarta where most visitors congregate. Recreational Parks in Jakarta measure determined in large-scale recreation park most tourists that visit, i.e.: Taman Mini Indonesia Indah, Taman Impian Jaya Ancol, and Ragunan Zoo.

Research conducted on aspects that affect the quality of the microclimate that directly influence to the thermal comfort in open space in Jakarta.

1) The assessment focused on the microclimate of open space in Recreation Park and superblock in Jakarta.

2) The Measurement of thermal comfort and the activities do not involve human clothing worn. The activities and the value of clothes are determined as a fixed variable with a value of 2.5 as the activity of medium activity and value Clothing (Clo) 0.9 (trousers and shirts) which is the average value of clothing of visitors wore in the recreation and open space area.

3) Thermal comfort values to be determined by the scale of PMV and PET. Thermal comfort assessment by PMV and PET is a physical value assessment by combining environmental and personal circumstances at the time the feeling of comfort.

4) Measurement of thermal comfort focuses on the three largest recreation areas in Jakarta, i.e.: Taman Mini Indonesia Indah, Ragunan Zoo and Taman Impian Jaya Ancol and the famous superblock in Jakarta, namely: Mega Kuningan.

The open space planning has to take into account the climatic influence; thus, it is necessary to conduct a more specific discussion about the climate. Climate talks as a special topic with a broad enough coverage for the following purposes:

1) To deepen understanding of the nature and character of the place of human conduct its activities to resolve the climate effect.

2) Deepening the understanding of 'macro environment' (macro environment) with the parameters that affect the environment and its principles to achieve the microenvironment by its inhabitants.

3) More scientific convince the form (as the final product of the work of architecture, thus that the form in architecture is not only aesthetically pleasing but also logical.

1.6. Dissertation Outline

This dissertation will be divided into several chapters:

Chapter 1 contains a description of the background research topics and issues. AKN described in this chapter the research problem, research objectives and outcomes to be achieved in the study. The end of this section, the analytical writing

Chapter 2 describes the literature review of urban microclimate with theoretical descriptions of relevant theories that can be used to explain the variables to be studied, as well as the basis for giving a temporary answer to the problem formulation and preparation of research instruments. Also contains state of the art of research are among the research that has been done.

Chapter 3 is a literature review of thermal comfort and walking comfort in this chapter thermal comfort and walking comfort assessment and threshold are learned more detail. The relevant theories are described and explained which to be used to make framework of research and research methodology in the next chapter. Also in this chapter the state of the art of thermal comfort and walking comfort is dug more deeply

Chapters 4, the framework and research method that will discuss the framework for conducting research and research stages. Stages of research contain research-preparation, a tool used in the study, data collection techniques and how to analyze the data, and how to state the research location.

Chapter 5 and 6 is the main body of research that shows the existing conditions of the case studies examined. In this chapter described three conditions exist of thermal comfort and walking comfort in the recreation park in Jakarta; Taman Impian Jaya Ancol, Taman Mini Indonesia Indah and Ragunan Zoo and superblock of Mega Kuningan.

Chapter 7 Finding discusses the result and analysis after digging the existing location assessment.

Chapter 8 contains details of elaboration and conclusion of the study in submitting suggestions for further research and practical implications of this research.

The outline diagram of the dissertation can be seen in Figure 1.1.

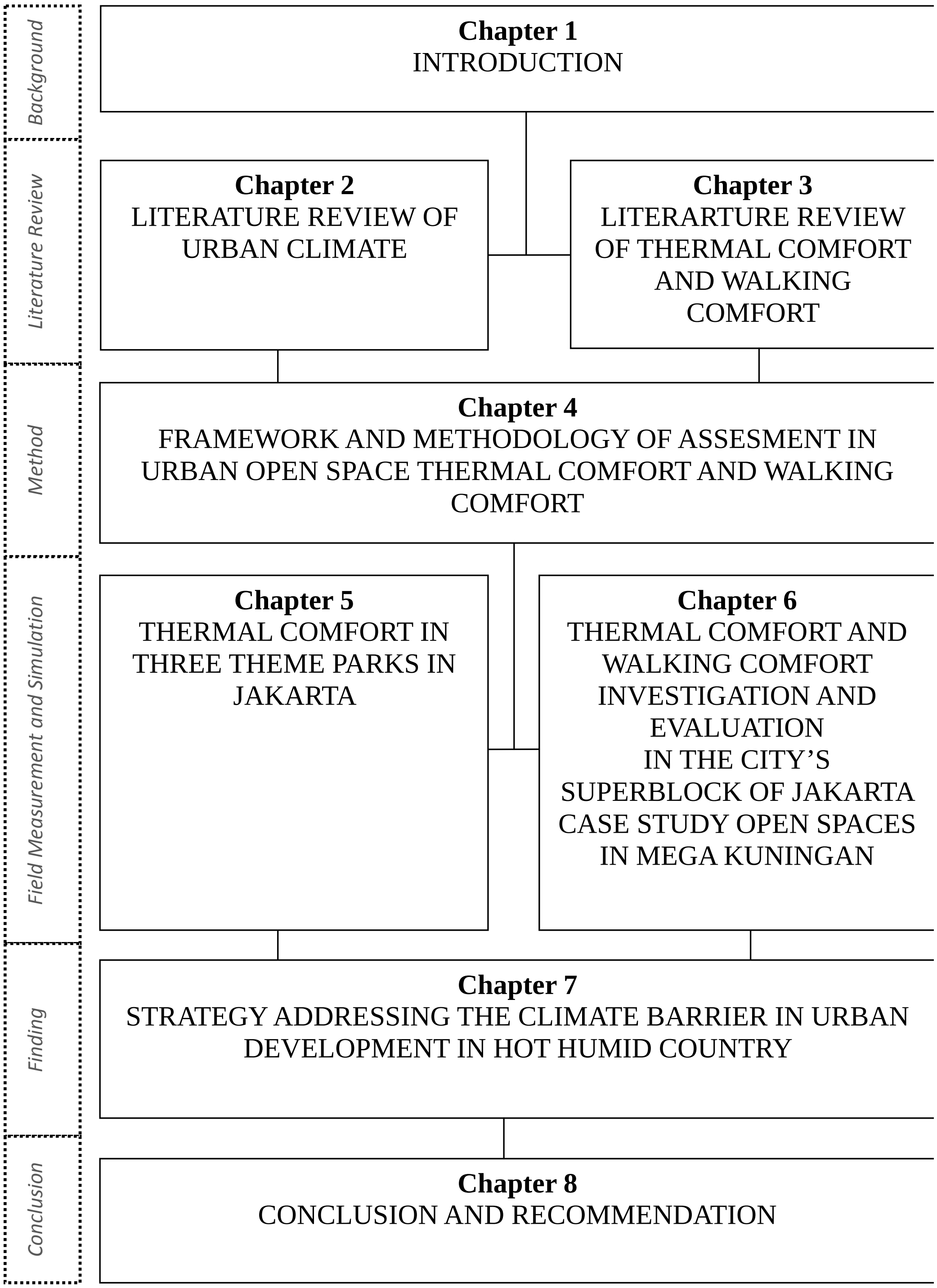


Figure 1.1. Outline of Dissertation

Chapter 2

LITERATURE REVIEW OF URBAN CLIMATE

Summary

In the tropical humid climate city like Jakarta, open space used is almost during the years and they must have thermal comfort properly (Koerniawan 2014). The thermal comfort studies in this open space are important for evaluation studies and as a guideline to urban design and architectural projects.

Climate circumstances take part in a particular responsibility in this context not only because climate change causes new challenges for urban areas, but also because urban areas can play a lead task in humanity's pursuit for an association with the natural environment that permit societies to thrive and prosper for a long time to come.

2.1. Role Of Theory In Urban Climate

Some researchers explain that the climatic conditions in the city are affected by climate and the built environment (Landsberg 1981; Eliasson 2000; Oke 1984, 2006). The build environment accelerates the absorption of the heat during the daytime and slows down to release the heat at the night time these formations known as the Urban Heat Island where the hot region surrounded by the cooler adjacent area.

City modifies meteorological conditions surrounding significantly; increasing radiation higher; average temperatures of the city become hotter than the surroundings; decreasing wind speeds due to the presence of buildings in the city; therefore make relative humidity much lower in the city than surrounding (Landsberg 1981).

In the measurement of albedo in the city, the area covered by paved area is hotter than natural ground. The heat, re-radiated back to the atmosphere by the paved areas, creates the city hotter; therefore, a shady area is necessary to open spaces and pedestrian areas, by creating a microclimate of shade (Akbari et al. 2001, 2009).

O'Hare (2006) stated that urban development tends to steer the development in the use of private transport modes and excessive air conditioning appliances. System development and use of technology are not friendly to the environment. The city must understand microclimate if a city does not want to tend to the development-oriented mode of personal transport. Activities conducted the city residents outside of the building, such as walking and using public transportation should be convenient and possible widely can interact with the urban environment comfortable. In Jakarta, the city with the conditions of the hot humid tropical city, the extreme heat conditions, high humidity and many rainy Transit Oriented Development (TOD) to be a challenge for developers to create a more comfortable atmosphere.

2.2. Climate And Urban Study

Microclimate definition according to the Britannica Concise Encyclopedia is a climatic condition in a relatively small area. Microclimate can reach several meters above and below the earth or only on the area under the canopy of trees. Microclimate is influenced by several factors such as temperature, humidity, the wind, dew, evaporation, soil, vegetation, the topography of an area, geography, altitude above sea level, and weather. Sometimes even the weather and macroclimate in some ways are influenced by the balance of microclimatic conditions.

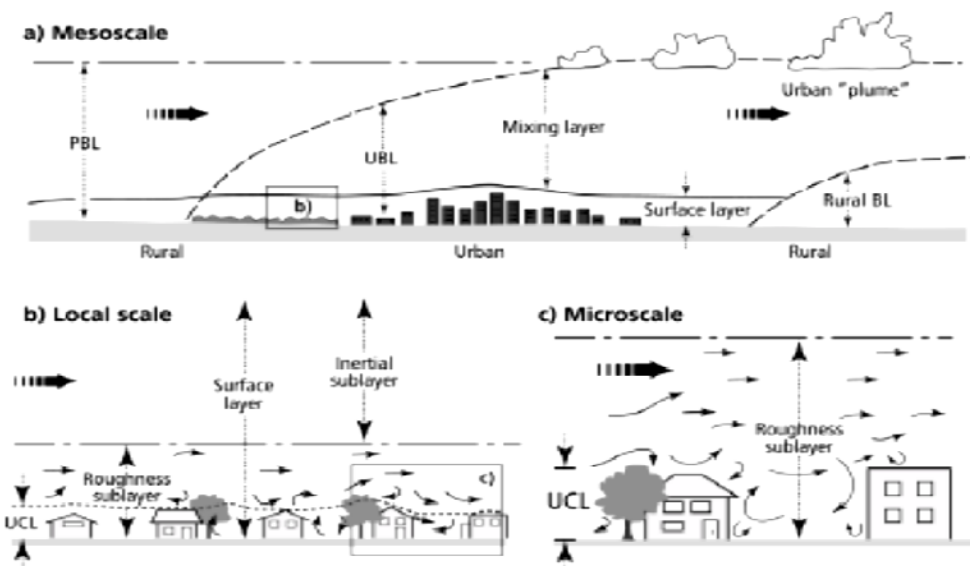


Figure 2.1.. Climate scale division according to space and vertical layers in the city (Shepherd, 2005)

According to Valsson (2008), microclimate is the climate patterns in the relatively small region. Microclimate may occur in the area under the shade of a tree, the area around the pool or in the open space area that has similar climate patterns.

Microclimate influenced by climatic variables, i.e.: temperature, humidity, wind speed and wind direction, season, time, and physical characteristics of the region.

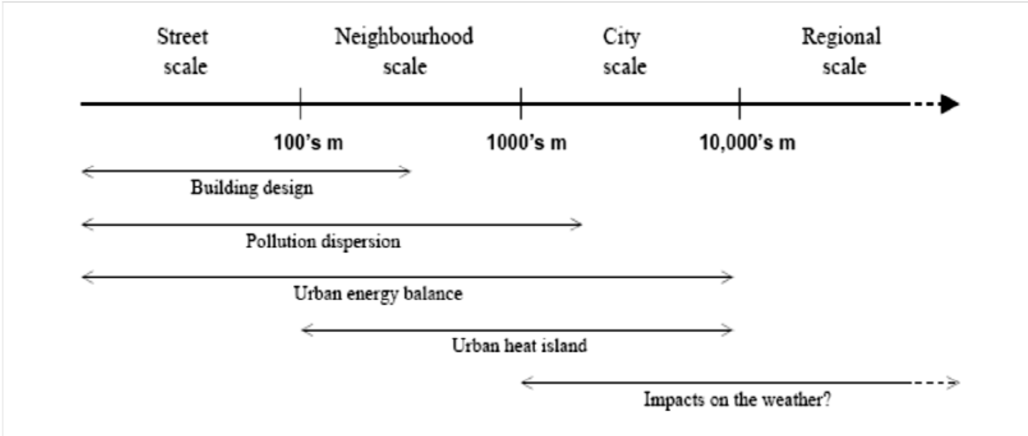


Figure 2.2. The division of the distance scale climate based on the distance (Harman, 2003)

According to Oke (2006), about the elements of spatial climate formation, the climate is divided into time and space scale in atmospheric. The division of the climate regions can be seen in Figure 2.1 and Figure 2.2. On a scale of time and space, the climate can be divided into three spatial scales.

2.2.1. Macro, Meso, and Microclimate

Microclimate: the order of the range until the unit kilometers, and the time scale of the order of seconds to several minutes. This scale is often referred to as the Local Scale. In the micro-scale, local meteorological factors have a significant effect, such as the wind land and sea breezes coastal areas, air circulation urban and rural, urban heat, and so on. Local scale transport processes, generally cause an accumulation of relatively above pollution sources of pollution, due to the atmospheric inversion layer that limits the dispersion of pollutants.

Mesoscale, with a range of kilometers up to hundreds of kilometers, and the timescale of minutes to hours. This scale is often also known as a regional level. The wind that affects the movement of the atmosphere from the geostrophic wind level is above the boundary layer of the earth (Planetary Boundary Layer). The release of the pollution by the direction of the wind, in the horizontal and vertical range that is much greater.

Macro scale or scale of continental, with a range of over thousands of kilometers, with time scales greater than one day. The elements are relatively stable pollutants, will be able to survive, remain in shape, and achieve distance away.

Medium Harman (2003) states that climate influence macro distance, local and microclimate can be distinguished based on distance. As illustrated in Figure 2.2.

With a scale of 100m, the climate is influenced by the climate of the planning level on a scale of roads and buildings. Furthermore is the scale neighborhood (housing) 1000 m, the climate will be affected by the spread of pollution to the extent of the effect of planning on Urban Energy Balance. 10,000m city scale climate effects must be considered is the Urban Heat Island, while the regional-scale climate influences the weather becomes very significant.

Therefore, the earth's rotation on its axis that is always changing in the journey around the sun, and then each of latitude on the Earth receives much different solar heat.

2.2.2. Temperature

Hottest areas on the surface of the earth are the most affected areas in the equatorial.

The amount of heat received by the earth's surface area is dependent on:

1) The length of the place or the area exposed to the sun

2) The angle of sunlight on earth

The maximum heat received at the earth is when the sun is above our heads and the minimum acceptable amount of heat when the sun lies low because the energy that reaches the earth lost by a certain degree of the line to the earth's atmosphere due to the longer distance.

The fall sun angle decreases with spot away from the equator, but instead the days of summer will be longer because the effects of the sun. So the maximum daily solar radiation will occur between latitudes 300 - 450. However, for the average value due to the influence of winter highest annual irradiation located at latitude 150.

Also, the temperature is also affected by place between land and sea. In the land the temperature will be hot two times faster than in the water about the same size, this is due to many areas of the water lost to evaporate the Enertia.

The air temperature is determined by the air that touch the ground so there was a high temperature coupled with low humidity and vice versa high humidity will accompany low temperatures. These symptoms occur at the same latitude and season at the same time, lowest temperature occurs above the water surface, and the maximum temperature on the mainland, and would be otherwise in the winter.

In normal daily temperature, highest heat will be achieved in 2 hours in the afternoon, because solar radiation at that time immediately join with the already high air temperatures.

The temperature outside the building will affect the temperature inside the building. It can be seen that the largest hot occurs on the west facade of the building. Also, the temperature is also influenced by the height of a point on the sea surface. The higher the location of a place, then the lower temperature. The decrease of temperature on the average height is 0.6 ^{o}C every increase of 100m or 3.6 ^{o}F every rise 1000feet.

2.2.3. Relative Humidity

Humidity is the moisture content in the air. Humidity can be high depending fluctuated of temperature changes. The higher the temperature, the higher the air's ability to absorb moisture. Absolute humidity is the density of the water that is on every unit volume of dry air, which are expressed in grams per kilogram of dry air. The humidity is expressed in percent (%) is often referred to as the relative humidity (Rh). This moisture can also be measured at the pressure that is on the air in Kilo Pascal (kPa) as the water vapor pressure. Relative humidity shows a comparison between the water vapor pressure of the water vapor pressure of the maximum possible (degree of saturation) in particular air temperature conditions.

Saturation water vapor depends on temperature. The air is saturated air at a given temperature which cannot absorb water, it has been the achievement of maximum water vapor pressure. Hot air can load the moisture content of the air cooler. The upper limit for the amount of water vapor charge the certain air with a certain temperature is measured by the quantity of the charge saturation and refers to the absolute number of air humidity levels.

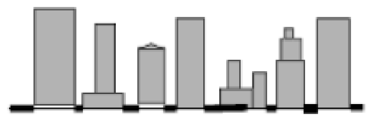
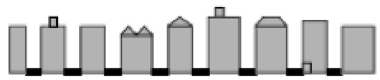
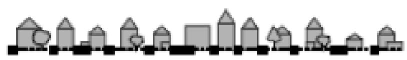
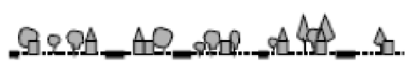
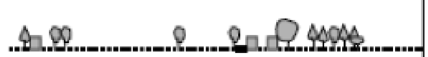
It can assume that at 38 ^{o}C the air can absorb ten times more water than the temperature at 0 ^{o}C, the saturation point of the air will rise with increasing temperatures. Wet Bulb Temperatures (WBT) or so-called humid temperature shows a combination of dry-temperature measured at standard conditions and levels of humidity.

The higher moisture content a combination of high temperatures. Evaporation of water from the skin, which causes cooling, start hard occurred at high humidity because the air is saturated and people began to be felt unpleasant. On the building, the degree of humidity in a room depends on the level of humidity of the outside of the building and the proposed use of the space. Comfortable humidity is at around 40-70% with temperatur18-25 ^{o}C.

2.2.4. Air Velocity

The solar radiation reaching the earth's surface affect the intensity heat on earth and causes the difference in heat or temperature at the surface of the earth and the distinction in air density. The air pressure is directly relative to its density. The difference in air pressure in certain areas of this the air will move from areas of high pressure to areas of low pressure, the flow is called the wind.

Macro wind movement is having causal inter-regional or inter-oceanic continent, so very broad movement. Others are commonly called micro or local winds. The wind movement often experiences barriers that promote the occurrence of a change of direction in the horizontal, vertical, changes in wind speed and the turbulence. The resistance experienced by the movement of the wind depends on the shape and type of surface in its path. Style wind movement barriers would be even greater if the closer to the surface. The wind speed will increase in the higher location above the land and in the open area. Can be seen in Figure 2.3.

Urban Climate Zone, UCZ[1]	Image	Roughness class[2]	Aspect ratio[3]	% Built (impermeable)[4]
1. *Intensely developed urban with detached close-set high-rise buildings with cladding, e.g. downtown towers*		8	> 2	> 90
2. *Intensely developed high density urban with 2 – 5 storey, attached or very close-set buildings often of brick or stone, e.g. old city core*		7	1.0 – 2.5	> 85
3. *Highly developed, medium density urban with row or detached but close-set houses, stores & apartments e.g. urban housing*		7	0.5 – 1.5	70 - 85
4. *Highly developed, low or medium density urban with large low buildings & paved parking, e.g. shopping mall, warehouses*		5	0.05 – 0.2	70 - 95
5. *Medium development, low density suburban with 1 or 2 storey houses, e.g. suburban housing*		6	0.2 – 0.6, up to >1 with trees	35 - 65
6. *Mixed use with large buildings in open landscape, e.g. institutions such as hospital, university, airport*		5	0.1 – 0.5, depends on trees	< 40
7. *Semi-rural development, scattered houses in natural or agricultural area, e.g. farms, estates*		4	> 0.05, depends on trees	< 10

Key to image symbols: buildings; vegetation; impervious ground; pervious ground

Figure 2.3. Level of wind speeds on different surfaces (Oke, 2004)

Air movement can be seen on the scale of Beaufort (Figure 2.3) which define the magnitude of the wind stream smoke rising symptoms vertically until the onset of a hurricane with a speed of 120 km/h.

Air movement is a crucial factor in the planning because the influence of climatic conditions. The larger the air flows faster evaporation of existing on the skin of the human body this happens when the air temperature is lower than the temperature of the skin. If the temperature is higher, there will be warming the body.

2.2.5. Solar Radiation

Solar radiation is the cause of all the common characteristics of climate and influence on human life. An effective strength is determined by the energy of the emitted directly, reflection on the surface of the earth, the reduced radiation by evaporation, and radiation flows. All this formed the thermal balance on earth.

As many as 43% of solar radiation reflected back, 57% is absorbed, 14% by 43% by the atmosphere and the earth's surface. The shortest distance vertically radiation is radiation, theoretically insolation (radiant energy) will occur if the highest beam reaches the face of the earth is perpendicular.

Solar radiation conditions at a place determined by:

1. Duration of the Sun

The length of solar radiation will depend on:

a) The Season

b) The geographical latitude

c) Dense cloud

In tropical regions like Indonesia, a dimly lit morning and dawn relatively short time, the irradiation time of approximately 11 hours starting around 06.00 and ends at 17.00. Light lunch begins and ends about 180 below the horizon line.

2. The intensity of irradiation

The intensity of solar radiation is determined by:

a) The absolute solar energy

b) The loss of energy in the atmosphere

c) The angle falls on exposed areas

d) The spread of radiation

3. Angle Fall Irradiation

In astronomy, the Sun does not move, but the earth revolves around the sun. However, in the depiction of the sun, we can imagine walking on the surface of the earth. The sun rises from the east and sets in the west.

To measure the position of the sun at any given point in time required angle is:

a) Solar altitude angle: is the angle between the earth's surface and the line from a point on the earth to the sun

b) Azimuth angle is the angle between the north-south axis of the earth and a line from a point on the earth to the sun

Broadly speaking, the fall sun angle depends on the position of the sun during its circulation in one year, season or month, and time of irradiation (irradiation time daily).

Sunlight irradiation conditions that come to the surface has to be considered for the location, relation to the circle of the sun line. If the building is in the south of the equator, the sun is in the northern hemisphere longer than in the southern hemisphere. If the location of the building on the equator, the sun in the north circulation time equal to the time movement in the south.

Solar declination angle is the angular distance of the sun from the equator of time to time. The declination angle varies continuously between 23.50 LU corner on 21 or June 22 and 23.50 LS on 21 or December 22. On 21 March and 21 September, the sun is directly above the equator, so that the length of night and day alike. On that date, the sun rises exactly in the east and sets exactly in the west. Orbits the sun can be seen in Figure 2.4.

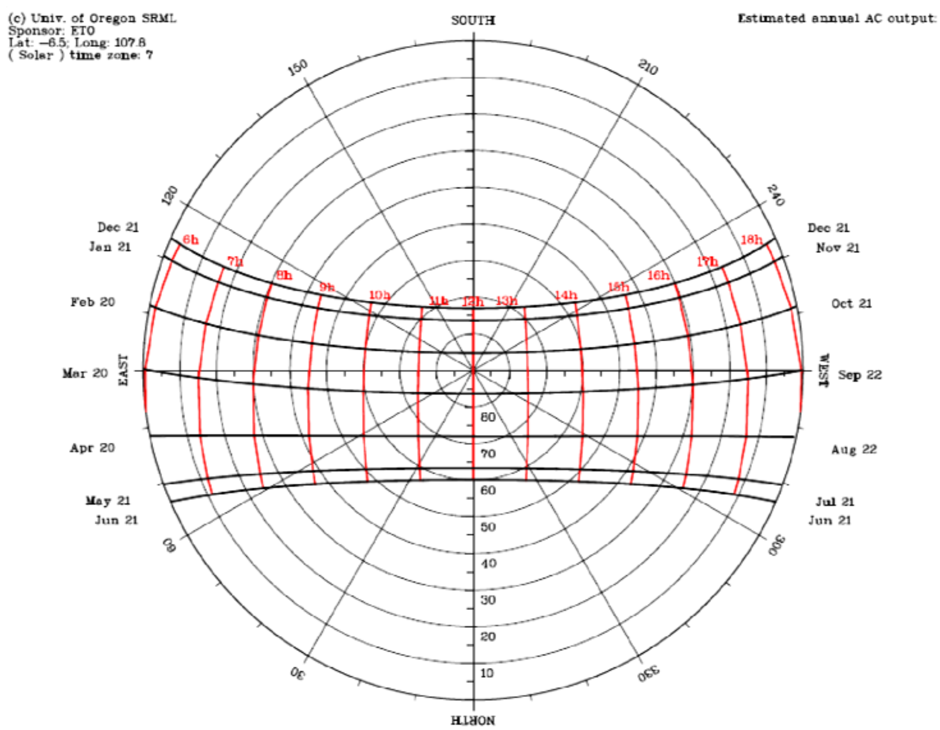


Figure 2.4. Orbit of the sun in the tropical (Oregon University, 2010)

Indirectly, a building will receive direct solar radiation, diffuse solar radiation, and radiation reflection. Besides, the building also receives and emit long-wave radiation. Also, the reflection of sunlight is affected by certain building materials and colors that will be able to affect certain thermal conditions.

2.3. Classification And Definition System Of Urban Climate

2.3.1. An Urban Open Space Configuration

A. Recreation Park

Recreation, Yoeti (1996), is part of the tourist activities are divided according to the intent and purposes is done. Recreation is a type of tourism that is the intent journey to restore the physical and mental strength after doing the task daily routine

Moderate travel is travel activities or in part of these activities are carried out voluntarily and temporarily to enjoy the objects and tourist attraction. Tourism is essentially an activity related to the movement of people, both large and small quantities, of a place or region of origin to the destination. This displacement based on the interests that vary, in general, it can be said to represent the interests of the quest for new things, one that has not been known or unknown, and the atmosphere and the new environment that is different from everyday life.

2.3.2. The Albedo of Urban Open Space

Open space, according to Judge Rustam (1987), is the space formed by the surrounding buildings, this space can be used by the public or any person, and provide an opportunity for various activities, such as roads, pedestrian, parks, plazas, cemeteries, airfields, sports fields.

According to Roger Trancik (1986), Finding Lost in Space disclosed that open space is divided into:

1. Hard Space

Hard Space is everything in principle limited by the wall architectural and usually as a place together for social activities. The realization of this is hard space: square and street, open space, great space, and intimate space, and open space.

2. Soft Space

Soft Space is everything that is dominated by the natural environment, such as parks, public gardens, and the green line that can provide opportunities for recreation.

Form of Open Space

A form of open space by Rob Krier in the Urban Space (1979) classified into two types, that is:

1. Shaped lengthwise:

This open space only has boundaries on the sides, for example, roads, rivers, pedestrian. It creates an open space corridor.

2. Shaped cluster:

This public space has boundaries around it, for instance, plaza, square, square, and circle. This open space forms pockets that serve as spaces of activity accumulated in urban activities.

Recreational open space is not just a physical form, one of the design elements of the entire recreation area, but should be seen as a single integrated spatial region, see Figure 2.5. Recreational open space is not only physical function as an open space, but the core of its existence in a recreation area is a place of social interaction without having to look at the social status, regardless of their interests, but the need for self-actualization as residents, which is not limited. Where the process of social interaction has the potential to generate a variety of new cultural diversity, a culture that can enrich the treasury of human beings as living beings.

According to the PPS (Project for Public Spaces, 2000), four aspects affect the quality of open space, to be precise, 1) sociability 2) Uses and Activities 3) Access and Linkage 4) Comfort and Image. Leisure / Comfort related in some ways, namely, thermal comfort, visual and audible.

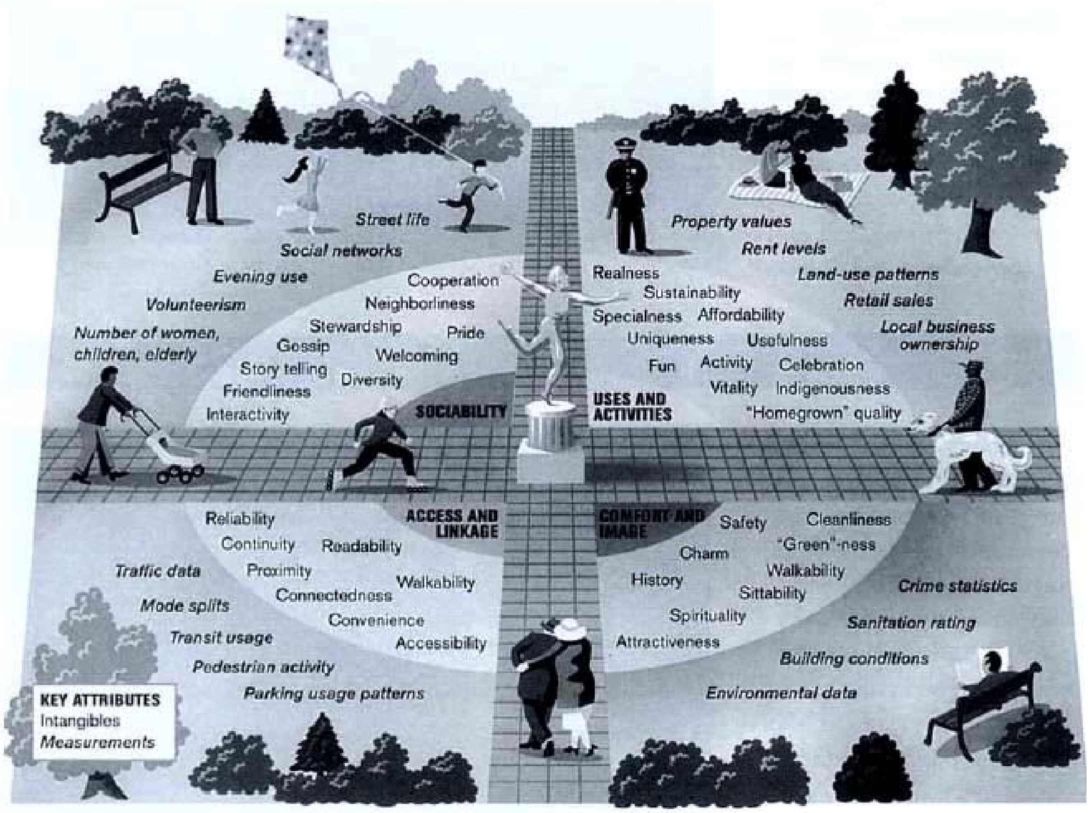


Figure 2.5. Some aspects that make the quality of open space are useful for humans. (PPS, 2000)

While Avila (2001) says seven factors affect the quality of open space 1) The characteristics of the environment (including topography and climate) 2) socio-cultural Community 3) physical features and functions 4) Politics 5) economic system 6) Recreational and 7) health needs of society. It is told that the system environment, especially the climate and topography will greatly affect the quality of their life in the open space and natural setting in the open space. In the comfortable conditions of life will be more dynamic open space. Nature will provide the balance of the natural-man-made, and natural open space which will give live quality in open space.

The Fundamental human needs for recreation is also an important consideration presence in the midst of urban communities that are too crowded and saturated with walls of concrete barrier activity.

In the end, should be seen in the presence of open space in the recreation area as a unity between culture and layout, that man showing their culture through the forms of space to accommodate its activities. The relationship between culture and spatial, and how the arrangement of space creates a cultural environment that is functional for the structures of certain activities.

2.4. Characteristics of Outdoor Environment

Over the last years, the interesting research on an issue concerning making cities easier to live has considerably grown, some of the most important issues are climatology and thermal comfort. The usefulness of open space and the green area has increased the awareness of sustainable city development raised. Open space and green area are essential elements of the city in giving possibilities for relaxation, physical workout, and people interaction. Reported by Landsberg (1981), that quality of outdoor spaces contributes to the satisfactory quality and generate social interaction. This agreement is similar to the results obtained by several authors (Eliasson 2000; Oke 1984, 2006).

In the tropical humid climate cities, open spaces are used during the year, and they must provide proper levels of thermal comfort. The condition surrounds buildings, vegetation, shading, water pond, and open field influence site environmental conditions. The thermal comfort in open spaces is essential for evaluation studies and to guide urban and architectural projects. A critical aspect is the understanding of the activities that will take place in a given space so that the planning promotes the user's comfort. Mayer (2008) reported the usage of open public places in cities is more numerous if they propose thermophysiological comfortable microclimate.

O'Hare (2006) stated the parameters that interfere with thermal comfort in open space are similar to those of inside spaces, but they are more extended and variable. Due to that complexity, regarding variability, temporality, and specialty, as well as the immense possibilities of different activities of the users, the understanding of comfort conditions in these spaces has been the object of many past studies.

Akbari et al. (2001,) reported the microclimatic analysis of open space must consider conditions such as solar incidence and radiation exchanges, local characteristics of the wind, topography, vegetation and the presence of water. Bruse (2007) has shown that beyond these factors, the urban design, the morphology of the buildings, the characteristics of the surfaces and the behavior of the individuals are also factors that influence the thermal conditions of these spaces.

Thermal comfort studies are mostly limited to the temperate regions, the lack of thermal comfort indices are shown in the tropical climate region. There are some studies from the tropical climate region could be seen by several researchers (Chen, 2012; Honjo, Mishra, 2013). Tropical climate region cities have some challenging conditions; everyday life during the year faces abundant sunshine, solar radiation, high rainfall, and high humidity in the tropical climate region cities. Sunshine is about six hours per day. Thus, thermal comfort investigation based on climatology parameters along with human parameters is required in the humid tropical climate.

According to Valsson (2008) characteristics that affect the microclimate region can be divided into three, as follows:

2.4.1. Buildings Configuration

A building will receive direct solar radiation, diffuse solar radiation, and radiation reflection. Besides, the building also receives and emit long-wave radiation. Also, the reflection of solar radiation is affected by certain building materials and colors that will be able to affect certain thermal conditions. Measurement of radiation levels can be seen in three ways, namely:

1. Albedo / Solar reflectivity, which measures the ability of a material to reflect sunlight (visible light, infra-red and ultra-violet). Scale albedo (SRI = Solar Reflection Index) of 0-1 (0% - 100%), 0 means that the material absorbs all the sun, 1 means reflects all solar radiation

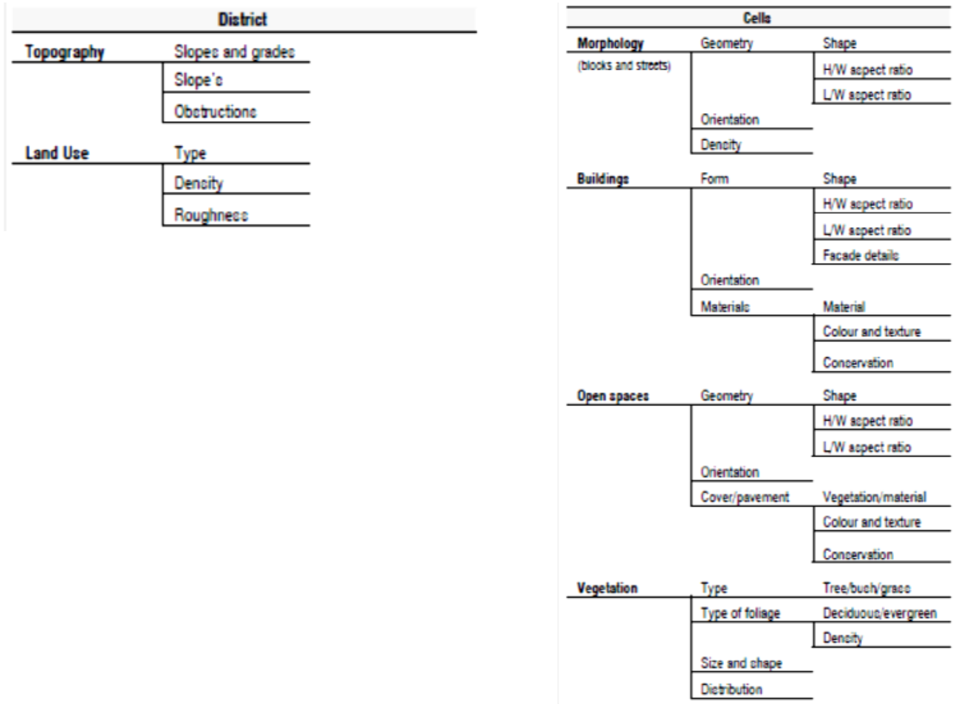


Figure 2.6. Physical variables that affect the microclimate change (Pinho, 2003)

2. The ability emissivity material re-release the heat received on the scale 0 -1 (0% - 100%).

3. Infrared emissivity is a measure of the ability of the surface of the material to release energy received from the sun in the form of solar radiation.

Configuring the building period that affects the microclimate is determined by the density of buildings, aspect ratio, and the sky view factor. In a study conducted by Oke (1997) phenomenon of urban areas will experience high temperatures in rural areas compared to that indicated that the higher the temperature of the solid buildings of the area.

According to Pinho (2003), physical characteristics affect microclimate variations can be divided into two parts, 1) Building (dimensions, material, color, and texture) 2) open space (land cover materials, colors, textures, designs and green space distribution, and the type of trees and vegetation). Pinho split the microclimate change can be influenced by the physical characteristics of the district scale and cells.

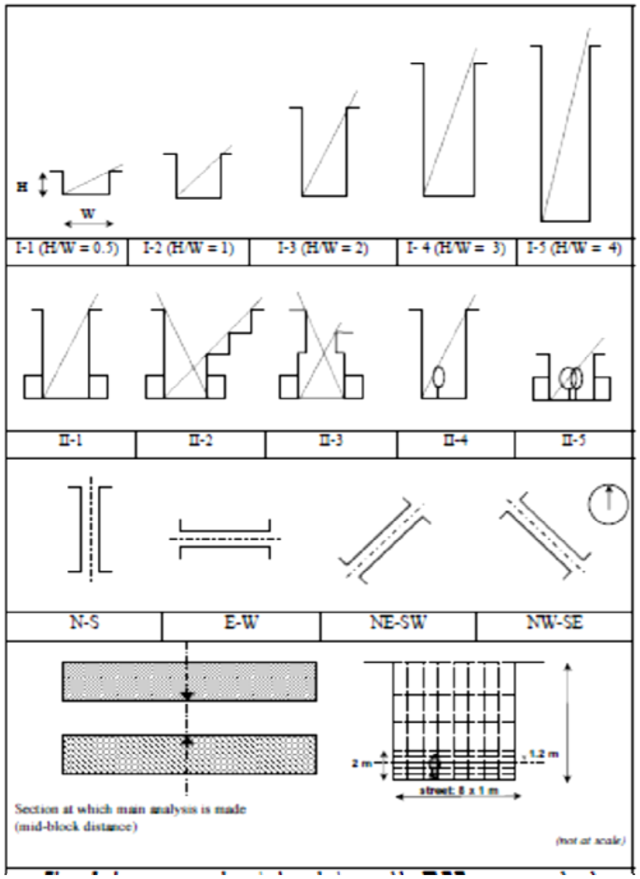


Figure 2.7. The level of the aspect ratio of a building will affect the microclimate in the region (Toudert, 1997).

In a district scale topographic an effect on the area of micro-climatic conditions. Mountain regions will have lower temperatures than the coastal regions. The wind speed is also different; coastal winds will bring the heat while mountain winds will bring cold temperatures. Higher areas will have a lower air pressure than the lower area. A complete this further division can be seen in figure 2.6.

Also, to the physical characteristics presented by Pinho, Ali Toudert (1997) suggests that the aspect ratio also influences the microclimate. The aspect ratio is the ratio of building height and width of the road (H / W) which affects the temperature of the region due to the influence of shadowing in the area. High aspect ratio means the strong level of shadow and the low-temperature region. The level of aspect ratio can be seen in Figure 2.7.

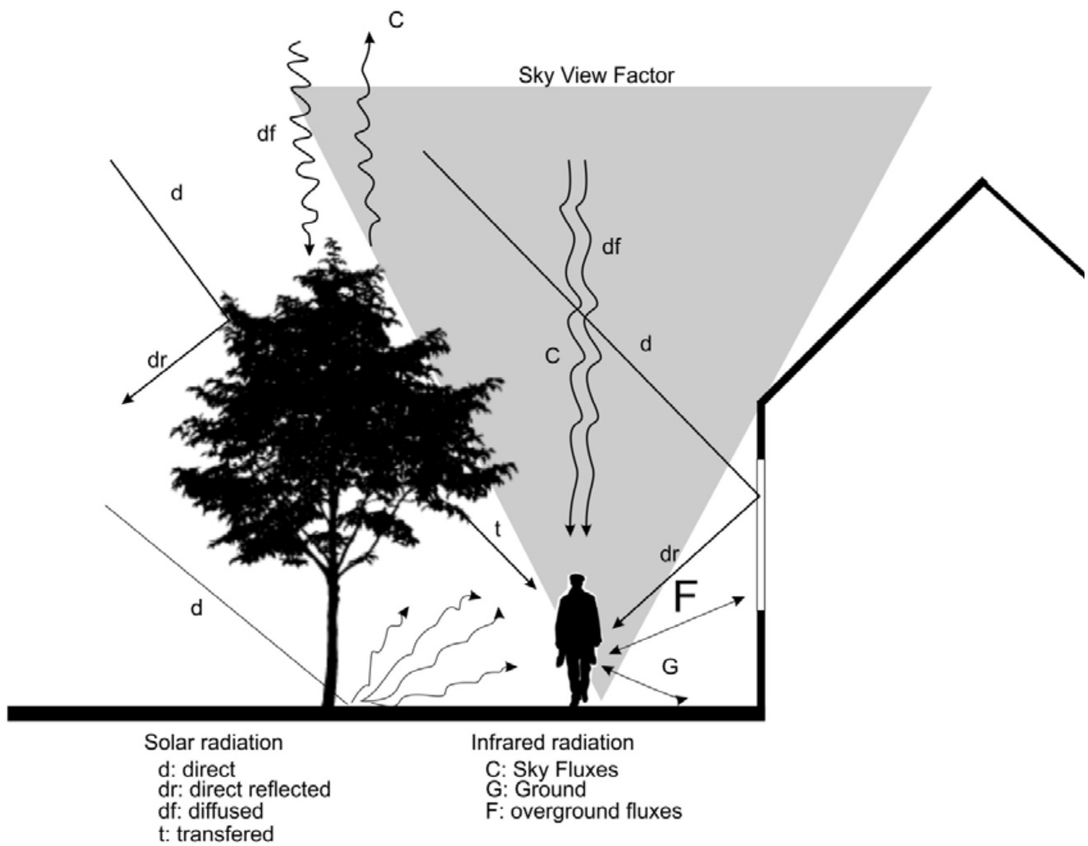


Figure 2.8. Radiation values are included in an area under the influence of Sky View Factor and albedo (Scudo, 2000).

Also, to the aspect ratio of a regional climate can be measured by the level of sky view factor (SVF). SVF is a measurement of the degree of obstruction incoming solar radiation in the open space. Obstruction can be a building, a tree, or a combination of both. This obstacle will affect the level of the incoming radiation levels in the open space. SVF 1 means that there is no obstruction of radiation into the open space while SVF 0 is a full obstructed where direct sunlight cannot enter the area. With this obstacle level can be measured how much the effect of radiation on micro-climatic conditions in the region. This can be seen in Figure 2.8.

2.4.2. Land Use And Materials

According to Valsson (2008) that the differences in land use in the open space will affect the microclimate temperature conditions. Temperatures around the element of water in open space will be lower than the temperature in the area with paving blocks.

Table 2.1. Reflectivity value of various types of material (Valsson, 2008).

Surface	Details	Albedo
Soil	Dark & wet versus	0.05
	Light & Dry	0.4
Sand		0.15 - 0.45
Grass	Long	0.16
	Short	0.26
Agriculture Crops		0.18 - 0.25
Tundra		0.18 - 0.25
Forest	Deciduous	0.15 - 0.20
	Conferos	0.05 - 0.15
water	Small zenith angle	0.03 - 0.10
	Large zenith angle	0.10 - 1.0
Snow	Old	0.4
	Fresh	0.95
Ice	Sea	0.30 - 0.45
	Glacier	0.20 - 0.40
Clouds	Thick	0.60 - 0.90
	Thin	0.30 - 0.50

This area covers material effect on the level of reflectance, permeability, and temperature of the material. Reflectance level, permeability, and temperature of the material are influenced by the material color, texture, and material Bulk Thermal Properties.

Quality material (Bulk Thermal Properties) can be measured by:

1. Heat Capacity, which is a measure of heat capacity material, the greater the heat capacity of the material, the greater the amount of heat that can be stored
2. Thermal Conductivity, which is a measure of thermal conductivity expressed in:

A). R-value or resistance value is the ability of a material to withstand the heat flow rate. Materials with high R means being able to withstand the heat flow rate.

B). U-value, which is a measure of thermal conductivity of the material. The high U-values mean that the material forward amount of high heat nevertheless.

Some research results show that the material of land cover can affect thermal comfort. In his research, Akbari (1999) stated the quality of the material in the open space will affect the microclimate of open space, that the old building materials will be worse in its albedo. Emmanuel (2000) stated that Land Use and Land Cover changed affect the microclimate of open space. Land Cover is divided into two types: hard cover (buildings, roads and pavement of the soil) and soft cover (trees, green area/grasslands, shrubs and water bodies). Hardcover more provide thermal discomfort. Reflectivity values of various regions covering material can be seen in Table 2.1.

2.4.3. Urban Structure

City is designed with the goal to make the urban areas functional, attractive, and sustainable, which consists the larger scale of group buildings, public space, streets, district and neighborhood, and entire cities. The connectivity between people and places, movement and urban form, nature and the built environment shape the element of urban form. Baurdic (2012) stated that urban forms influence the environmental, social and economic aspects of sustainable development, but urban forms continue to maintain their own autonomy.

Urban form indicators describe the component of urban fabric, that give the details on the urban structure components (buildings, streets, and urban networks). Bourdic stated that Volumetric Compactness is the urban structure indicators to analyze urban heating. There are three variables in the Volumetric Compactness (Bourdic, 20102); Traditional Compactness, equal to surface area, S, of the building's envelope divide the volume of the buldings; Size Factor, tto the equivalent cube of its length; and Form Factor is the bias introduced by the different size of the analysed objects has been removed. Another factor that related to the urban microcimate parameters is Street form Index (H/W) .

In this research Form Factor and Size Factor are not used because of in his research of microclimate analysis in Dhaka, Bangladesh, Sharmin (2015) stated that Form Factor and Size Factor are not ideal parameters to address the variation in microclimate for the homogeneous geometry and land use pattern. However, it can be really strong indicator for urban areas having variety in form. All the factors that related to the urban structure in this research can be seen in Figure 2.9.

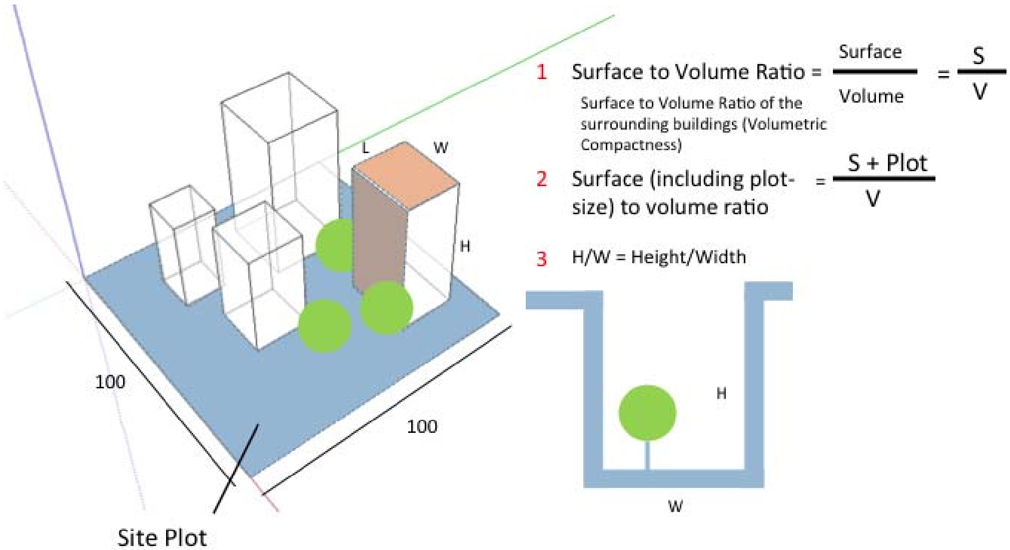


Figure 2.9. Urban Structure Parameters related to Urban Microclimate (Bourdic, 2012)

2.4.4. Vegetation

Trees can reduce the level of incoming solar radiation in the open space using shadowing and minimize the amount of sunlight that reaches the ground (EPA, 2004). In addition to functioning as a radiance barrier function, other trees are absorbing CO2 and replace it with O2, the tree can absorb water, which is then incorporated into the soil so that the land would be cool to be able to lower the temperature underneath. Vegetation can also affect wind speed, wind direction and wind pressure around it.

Trees by function in influencing the microclimate can be distinguished according to height, width and geometry twigs, and the type of leaves. Placement and how to classify trees also affect the microclimate beneath. Parts of the tree and its function can be seen in Figure 2.10.

The value of vegetation in an area can be expressed in Green Plot Ratio (GnPR) (Ong, 2002). GnPR is the value used to calculate how green the area. GnPR expressed in units of the numbers. In calculating the value of GnPR can be distinguished into three categories, namely vegetation of trees, shrubs and grass. This class is based on the value of the coverage that is inscribed underneath the leaves. The value of each scope is determined by the LAI (Leaf Area Index) is the ratio of the amount of leaf surface of vegetation divided by the surface area of the land where the plant grows. Can be seen in Table 2.2.

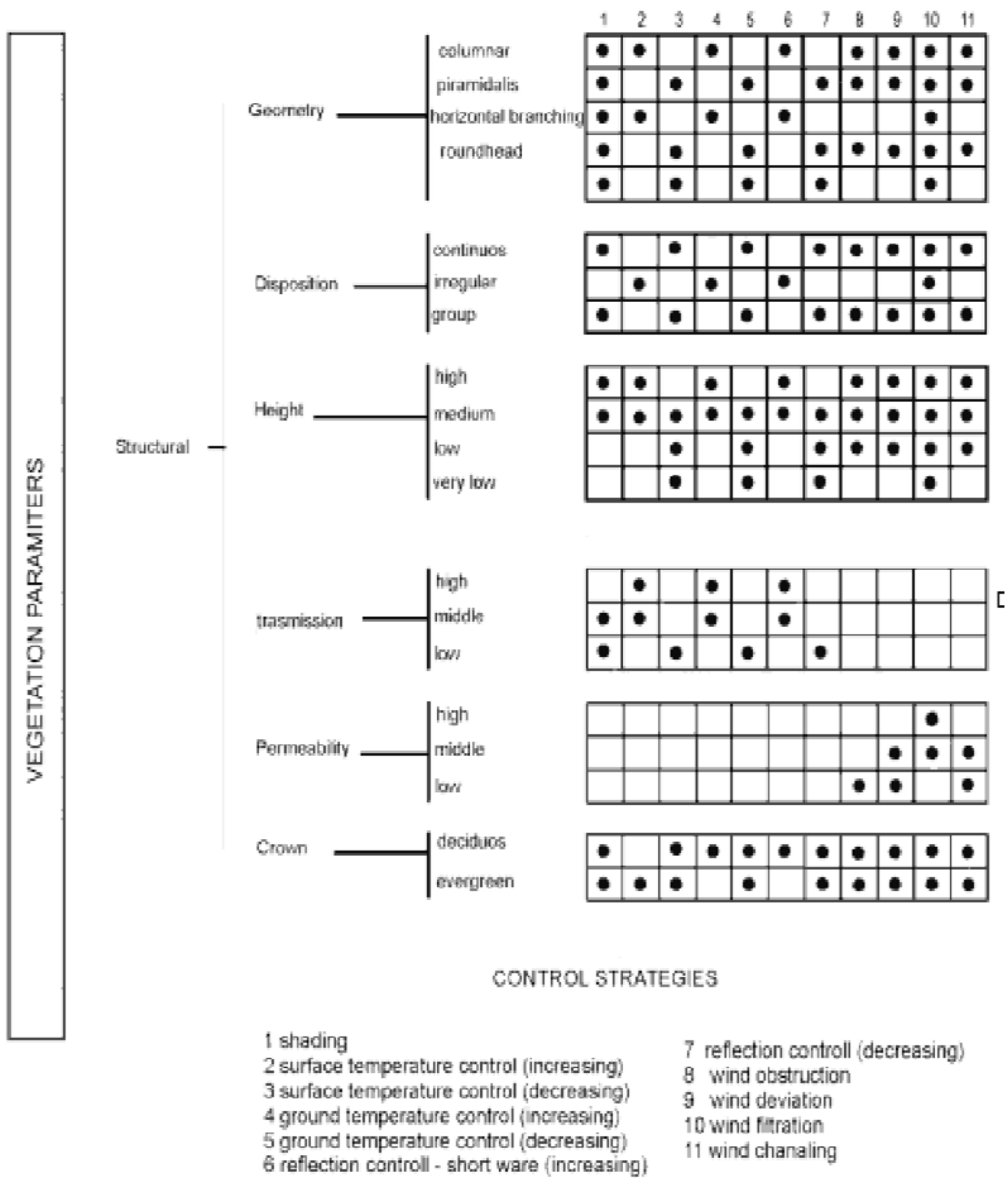


Figure 2.10. The parts and functions of trees in open spaces (Scudo, 2001)

Here are the details of GnPR calculation, also can be seen in Figure 2.11.

Tree Value = (Coverage shade trees) / (Area calculated) x 6 .... (1)

Brush value = (Coverage shaded bush) / (Total Area calculated) x 3 .... (2)

Grass Value = (Coverage shaded grass) / (Total Area calculated) x 1 .... (3)

GnPR = Value Shrubs Trees + Value brush + Value Grass .... (4)

Plant	Grass	Shrub	Tree
Leaf Area Index (LAI)*	Grass LAI = 1	Shrubs LAI =3	Trees LAI = 6
Proportion Planted	6/6	2/6	1/6
Green Plot Ratio	6/6 x 1 = 1	2/6 x 3 = 1	1/6 x 6 = 1

Figure 2.11. The coefficient value based on GnPR Leaf Area Index (Ong, 2002)

2.5. Thermal comfort

Fanger (1970) stated that the thermal comfort is defined as a state of mind which expresses the satisfaction level of human to thermal environmental conditions. Sometimes thermal environments occupied by people not give the expected conditions. Therefore, man to make efforts to achieve the conditions they want.

Humans are warm-blooded living beings undergoes metabolic processes. This metabolic process, also, generating energy for the human body also produces heat. Heat is generated to maintain the temperature of the body in ideal conditions at 37°C range. Naturally, the human body has a low tolerance range to temperature changes. Increasing the temperature by five to eight degrees or decrease in temperature up to 12^{o}C of temperature ideally can cause death to humans.

Humans always maintain the ideal temperature use various attempts. The work done is not only affecting the temperature directly, but also other criteria that are directly related to human thermal comfort, such as:

a. Dry air temperature

Dry air temperature normal to read on the thermometer chamber is free of air temperature measured are not affected by radiation and humidity.

b. Relative humidity

Relative humidity is the concentration of water vapor contained in the air. Humidity conditions influence the ability of air to remove sweat on the surface of human skin. The sweat produced aims to maintain the temperature of the human body. However, if not immediately evaporate, then sweat it, it is inconvenient.

c. The average of radiant temperature (Radiant Mean Temperature)

The average radiation temperature is the temperature of the radiation received by the entire surface of the object obtained from the surrounding environment.

d. Airspeed

Table 2.2. The Influence of air speed on thermal sensation of human

Wind Speed		Temperature reduction (^oF)	Thermal Sensation
fpm	m/s		
10	0.05	0	Stagnant air, a little less convenient
40	0.20	2	Barely perceptible, but comfortable enough
80	0.40	3.5	comfortable
160	0.81	5	Deeply felt and is suitable for areas with high activity
200	1.01	6	The upper limit for the conditioned environment, good speed for hot and dry areas
400	2.03	7	Good speed for natural ventilation in hot and humid
900	4.57	9	Feels like a breeze

Air movement affects the human body's ability to maintain body temperature. The flow of air going on the surface of the human skin will cause convection and evaporation of sweat on the surface of the skin. The ability of air to cool the skin through evaporation is referred to as evaporative cooling.

The cold sensation caused by the wind commonly known as the wind chill effect. Table 2.2 demonstrates the influence of the flow velocity of air flowing on the surface of the human skin will give the impact of a certain temperature reduction.

In many cases, using the air conditioning can be more comfortable. However, if the air temperature exceeds 37 ° C temperature of the human body, the convection that occurs on the surface of the human’s skin is no longer convenient to give the expected effect. This condition increases the amount of heat that is in the body, so, in this case, the more air that is in contact with the human body the less cooling factor occurs.

While Katzschner (2006) stated that the primary cause of thermal comfort outside of the building can be divided into four groups of causes, i.e.: thermal compound, air pollution, actinic complex, and the biotherapy. The four groups are referred to as atmospheric environment or influence the microclimate. This division can be seen in Figure 2.12.

1) The thermal complex is the influence of meteorological factors include air temperature, humidity, wind speed and solar radiation also affects the health of the human factor.
2) Air pollution including solids, liquids, and gasses that affect air. Air pollution is a factor in the thermal comfort because it is highly relevant to human health conditions. Air quality is also affected by thermal conditions above.
3) Actinic Complex associated with the appearance rate and wavelength radiation emitted by the sun. Ultraviolet solar radiation that has a very short wave affect the thermal effect.
4) Biotrophy is visible impacted on the human body due to climatological factors.

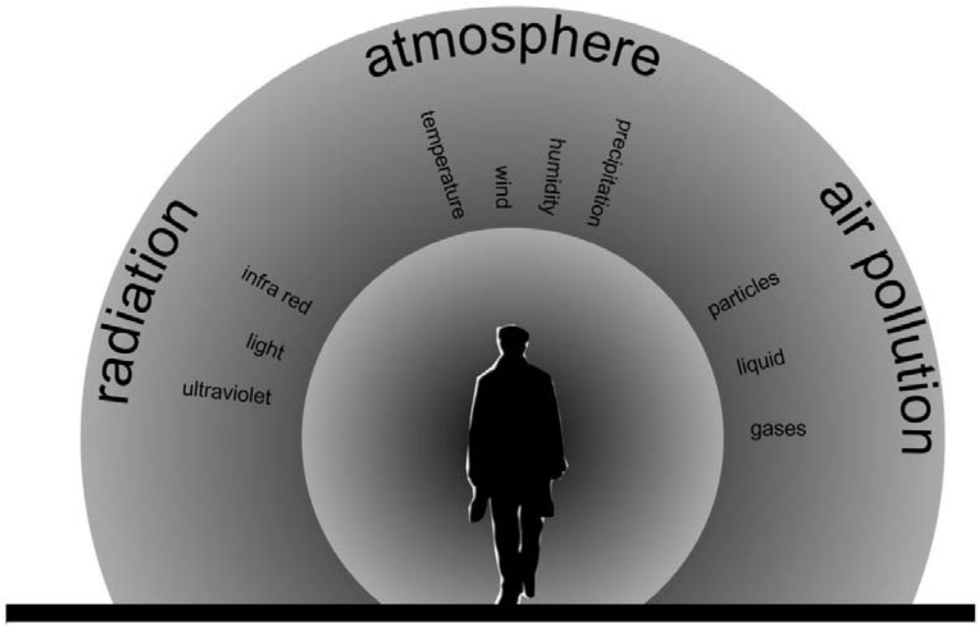


Figure 2.12. The Relation between the atmospheric environment and human thermal comfort (Katzschner, 2006)

Conclusion

Human thermal comfort is affected by six primary factors: Air temperature, Radiant temperature, Airspeed, Humidity, Metabolic rate, Clothing insulation. Outdoor Thermal Comfort studies that do exist have traditionally been predicated on the assumption that indoor models will work outside, but some studies has shown that this is not necessarily the case (Spagnolo & de Dear, 2003; Ahmed 2003). Spagnolo and de Dear (2003) identified three areas on which outdoor thermal comfort research has tended to focus:

1) Modifying the microclimates of outdoor locations which have been modified in some way to moderate the full impact of the outdoor environment,
2) Climate and tourism,
3) The thermal comfort of pedestrians.

Chapter 3

LITERARTURE REVIEW OF THERMAL COMFORT AND WALKING COMFORT

Summary

City significantly modifies meteorological of surrounding conditions. The city can increase the radiation higher cause the average temperatures of the city become hotter than the surroundings. The presence of buildings can decrease wind velocity in the city, therefore, make relative humidity much lower in the city than surrounding (Landsberg 1981). Planning and urban design can improve or worsen this situation. A better understanding of climate and thermal comfort, especially outdoor environment, can contribute improving the quality of urban spaces to live (Nikolopolou et al., 2001). In the measurement of built environment elements in the outdoor spaces show that the area covered by the paved area is hotter than natural ground. The heat re-radiate back to the atmosphere by the paved area and it creates the city hotter. Therefore a shady area is important for open spaces and pedestrian areas, by creating a microclimate of shade (Akbari et al. 2001, 2009).

3.1. Assessment of Thermal Comfort in Outdoor Environment

Many researchers have carried out the thermal comfort assessment study. In the early 1920s, Houghten and Yauglou (1923) in the laboratory of ASHVE (American Society of Heating and Ventilating Engineers) attempted to determine the 'comfort zone.' In the UK, the motivation comes from industrial hygiene at the limits of thermal comfort in working conditions. Vernon and Warner (1932) and then Bedford (1936) conducted an empirical study among factory workers. Analytical work began in the United States in the mid-1930s, where Winslow, Herrington and Gagge (1937) made a significant contribution to the study of thermal comfort assessment.

During and after World War 2 increased research activities and the many disciplines involved, in addition to engineering, from physiology and medicine, geography and climatology. In architecture Victor Olgyay (1963) was the first to unify the findings from various disciplines and interpret this research for practical purposes the architecture.

According to Hoppe (2002), there are three approaches to thermal comfort assessment: psychological approach, thermophysiological approach, and the approach on the Human Body Heat Balance. These each approach have respective advantages.

The psychological approach is based on the thermal comfort of human perception; the interview is a technique to perceive the human thermal comfort. The thermophysiological approach is thermal comfort assessment approach based on physiological data, such as age, gender, activity, clothing was worn at the time. The data were the basis for conducting interviews that human perception of thermal comfort and physiological data can be in comparison to determining the level of thermal comfort.

Heat balance approach on the Human Body is the assessment of the thermal balance in the body and from the outdoor environment. If this balance is too hot, then occur thermal uncomfort. There are some approaches to determining the thermal comfort indices outdoor environment, are as follows:

3.1.1. Human Energy Balanced

The human energy balanced is the energy exchange balance produced by humans and microclimate. Assessment of thermal comfort is very complex because of the influence of human, and his environment is very complex. **Error! Reference source not found.** shown that the energy is absorbed and released by human influence perceived thermal comfort. Illustrated that the human condition, clothing, and activities that are being carried out, became a major influence on the perceived thermal comfort.

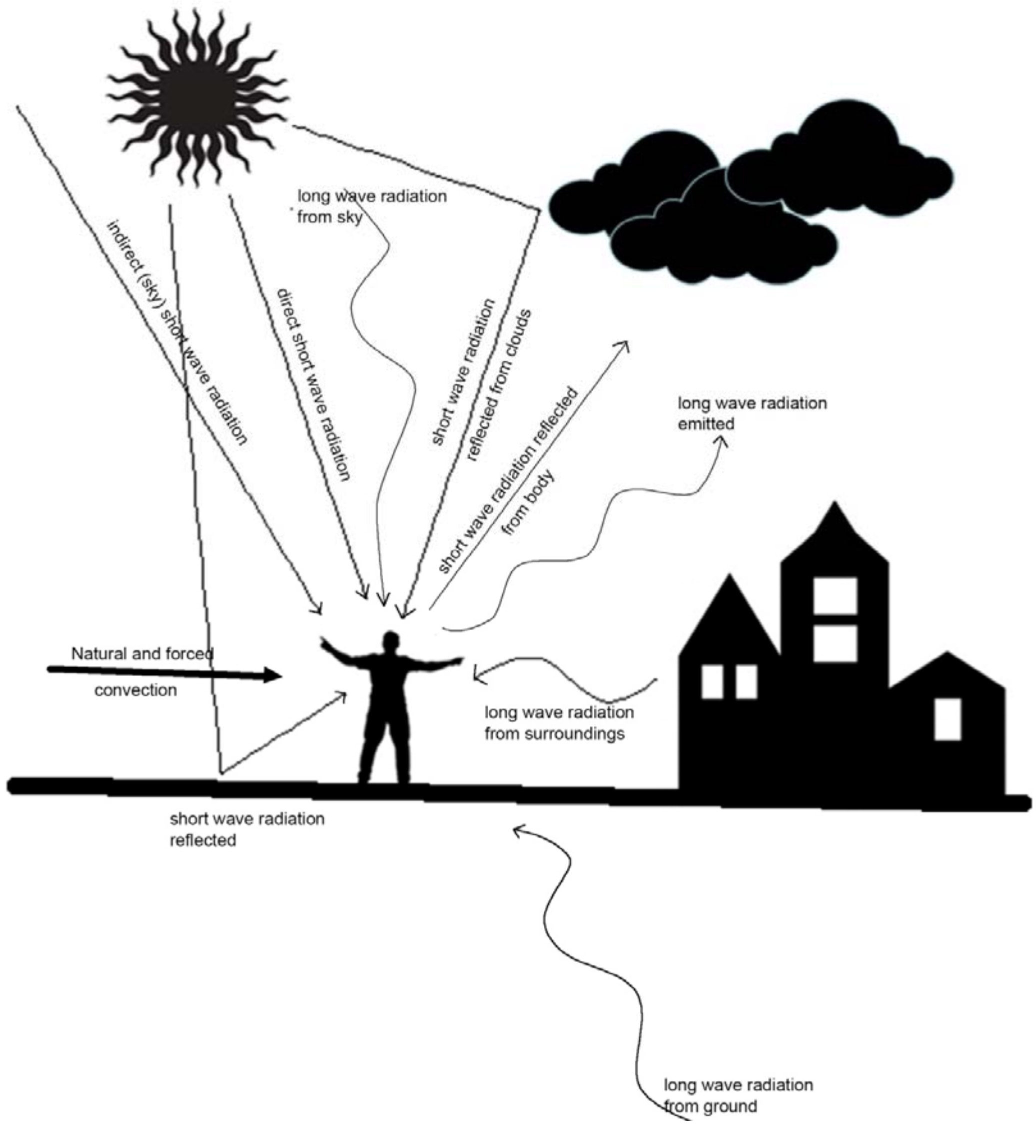


Figure 3.1. Components of energy balance produced by humans and the environment, (Houghton, 1977)

$$M + W + Q^{*} + Q_H + Q_L + Q_{SW} + Q_{RE} = S$$ -- (5)

Where:

$Q_H = f\,(T_a,\ v);\ Q_{RE} = f\,(Ta,\ RH);\ Q_{SW} = f\,(RH,\ v;\ and\ Q* = f\,(T_{mrt}).$ ----(6)

M : energy generated due to the body's metabolism

W : Human activities

Q * : The net amount of radiation by the body

Q : Heat transfer by convection

Qsw : The movement of the latent heat of evaporation of sweat effect.

QWS : Changes in heat due to respiration

QRE : Changes in heat due to respiration

S : The amount of heating or cooling.

3.1.2. . Heat Transfer In The Human Body (Human Energy-budget)

Human activity increase energy, such as eating, generates energy that is produced in the body. The total energy produced is only about 20% is used by the body, while 80% of which is surplus heat must be removed or disconnected environment. The amount of heat production in the human body depends on human activity, clothing worn at the time, gender, health, and age.

Temperatures in the human body must remain balanced and constant, at about 37^{o}C. To maintain the temperature to stay at this temperature, then all surplus heat must be removed to the environment, both the heat from the body and the heat gained from the environment such as heat from solar radiation or the air hot. The heat of the body release in several ways. Four major mechanisms at work: Radiation, Evaporation, Convection, and Conduction.

The heat that generated from the body is given off to the surrounding atmosphere. Radiation heat transfer is strongly influenced by the body's surface temperature and surface temperatures of objects that deal. The amount of evaporation will influence evaporation depends on the humidity and the amount of evaporation depends on the humidity and the amount of air contained vapor evaporated in the dry air, the faster evaporation.

Convective heat transfer is heat transfer from one place to another location by the movement of fluids. A heat transfers from the body into the air when associated with skin or clothes, and then picked up and moved and replaced by cooler air. Wind speed affects the convective heat release.

In Human Comfort (ISO 7730-1993) thermal comfort depends on human activity and clothing. Human activity is measured on a scale of 0-4. A scale of 0 means that people who do not do the slightest movement or the dead people while the scale of

4 is people doing work that raises the loudest most energy. The scale of 1.5 is the only standing people, the scale of 2 is walking people, the scale of 3 is running people.

While the clothing has the scale from 0 to 1, a scale of 0 means the man naked without clothes on his body, scale 1 is the clothing worn by the north pole to bear up the cold.

Heat released from the human body to the surrounding environment can be done by convection, radiation, and evaporation. Koenigsberger, (1973), Bradshaw (2006), stated thermal balance in the body can be described as follows:

MET – EVP ± CND ± CNV ± RAD = 0 -------------------------------------(7)

Where:

MED : Metabolism

EVP : Evaporation

CND : Conduction

CONV : Convection

RAD : Radiation

3.1.3. Assessment of Thermal Comfort in Outdoor Environment

The complexity of the evaluation of thermal comfort becomes a constraint on any research thermal comfort. For the evaluation of a particular place or a particular region is not only the meteorological parameters are required, but the complexity of the parameters of the climate and the thermo-physiological values needed to describe the effects of thermal environment on humans.

In the development of many standard thermal comforts found. Szokolay (2007) in Thermal Comfort; *Passive and Low Energy Architecture International Design Tools And Techniques* wrote nearly 25 ways assessment of thermal comfort.

To introduce thermal comfort indices outdoor environment need to remember the fundamental differences between indoor and outdoor space. While the indoor environment tends to have a relatively stable microclimate and controlled, the condition of the outdoor environment has a more complex radiation, and convection is defined by the daily and seasonal variations that affect the microclimate of the Human Energy-budget and subsequent thermal comfort.

In previous research of comfort in outdoor environment conducted by Thom, EC, 1959, Steadman, RG, 1971, J. Unger, 1999, Matzarakis, A., et al. 2004, focused on the bioclimatic index (Discomfort Index, thermohygrometric index (THI)) This study only considers some meteorological parameters only. Then the new model is based on research on human energy balance equation, generating what is called thermal comfort indices that generate thermal comfort assessment of outdoor space, for example, Predicted Mean Vote (PMV), Physiological Equivalent Temperature (PET).

To evaluate the thermal stress on the body, Fanger, PO 1972, Jendritzky, G. et al. 1990, Hoppe, PR, 1993, 1999, VDI 1998, Matzarakis, A. et al. 1999, Spagnolo, J. - de Dear, R., 2003, making Outdoors Standard Effective Temperature (OUT_SET *). Some research thermal comfort index also did to be applied in a limited space. This research was conducted by G. Jendritzky 1990, Matzarakis, A., 1999, Koch, E., 2005, this index for example, to describe the thermal comfort of a relatively small area (around the building , part of the way), which is useful for architects and urban designers (Matzarakis, A., 2001, Mayer, H. Matzarakis, A. 1998).

Micro-scale studies (urban scale) conducted to provide data for urban planning thermal comfort (Unger J. et al., 2005). Research to a larger area (scale territory or state) is not only scientific value but the results of this study could be the basis of regional planning, development of recreational areas and the development of tourism, the study was conducted by Mayer, H., Matzarakis, A., 1997, Matzarakis, A. et.al, 1999, Matzarakis, A. et.al. 2004.

The thermal comfort outdoor environment is not only influenced by the physiological response parameter that is highly variable microclimate, but also by psychological and cultural adaptations that regulate a variety of environmental stimuli to avoid fluctuations in thermal stress and discomfort.

In recent years, many climatic and thermal comfort indices outdoor environment has been elaborated. In a very simple way they can be classified into the following four groups:

a. Thermal index little empirical linking climate parameters are usually spelled out for specific climate-Wind Index Cill example, and the discomfort index.

b. Psycho-sociological index-climatic, connect the subjective perception (Actual Sensation Vote / ASV, satisfaction index.) with a variable microclimate and thermal comfort index (Nikolopoulos 2002).

c. Index-energy balance equation based on two models of heat transfer in the human body and the evaluation of all relevant climate parameters, which are usually made in pairs between the heat balance equation with a simplified model for evaluating the average radiation temperature. The examples in this index are: PET (Predicted Effective Temperature) (Hoppe, 1999), the New Effective Temperature / ET New (Gagge et al. 1971), Standard Effective Temperature (SET) and OUT_SET combined together outdoor radiant temperature OUT_MRT (J. Pickup, R. de Dear, 2000).

d. The energy balance equation is an index developed from the equation of balance of energy in the human body, for example the index are Perceived Temperature (PT) index developed from the index model Fanger combined with the evaluation of solar radiation in the outdoor environment example of this index is a Thermal Comfort Model, Comfort Formula (COMFA), developed by Brown and Gillespie to assess thermal comfort in the landscape, and the BEST which is developing a model of COMFA.

3.1.4. . Physiological Effective Temperature (PET)

In many studies of thermal comfort outdoor environment thermal comfort index used is Physiological Effective Temperature (PET) and Predicted Mean Vote (PMV). In some studies one of the most widely used index is a bioclimatic index (PET) as it is known to have units in ºC (degree Celsius) as an indicator of thermal stress and thermal comfort. This makes the results easy to be understood, especially for planners, decision makers, and even people who may not be familiar with the theory of modern-biometeorological.

PET significantly uses physiological ways to evaluate the thermal condition (Hoppe, PR, 1999, Matzarakis, A. et al. 1999). It is defined as the air temperature in which the Human Energy-budget for the condition of the building is assumed by the temperature and the temperature of human skin on the state of the actual sweat on the outdoor environment to be assessed. PET allows various users such as, to compare the integrative effects of complex thermal conditions in an outdoor environment with a space in the building. Besides PET can be used throughout the year and in different climates (Hoppe, PR, 1999, Mayer, H. - Matzarakis, A. 1997).

Meteorological parameters that affect the human energy balance, such as air temperature, humidity, wind speed and radiation of short wave and long wave, also represented in the values of PET. PET is also considering the heat resistance of the transfer of clothing (clo value) and the internal heat production (Value Met). The condition of the balance between the human body and climatic conditions can be seen in Figure 3.2.

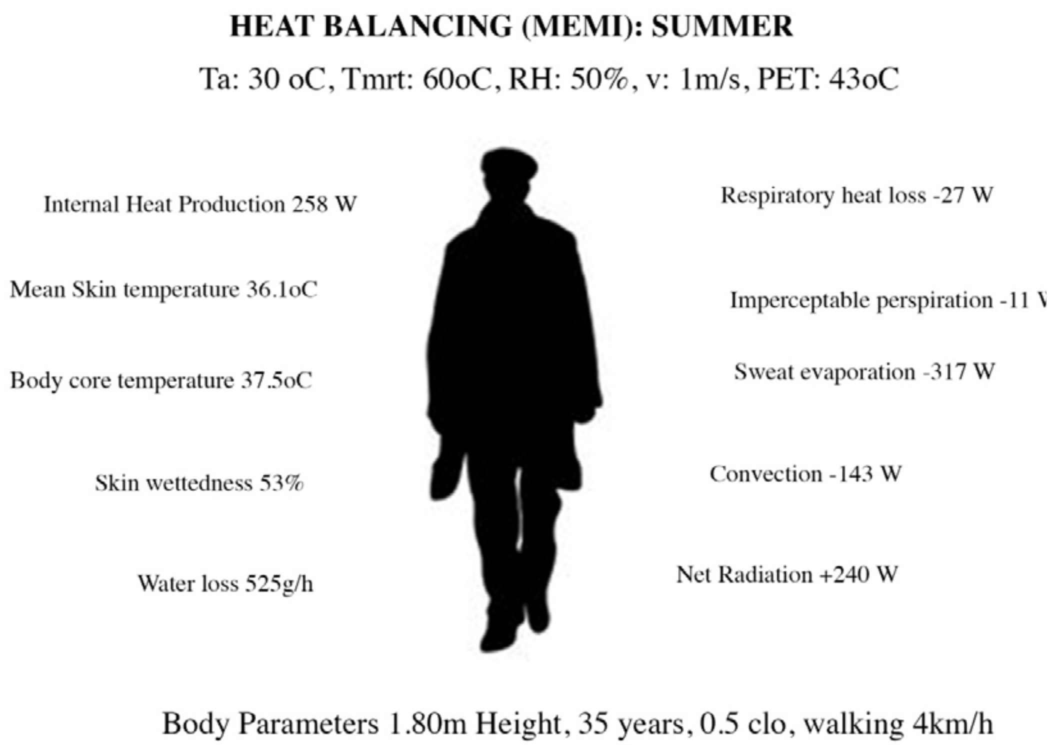


Figure 3.2. Thermal equilibrium conditions in humans based on microclimatic conditions, internal heat production and heat resistance of clothing. (Scudo, 2002)

Figure 3.2 explains that the value of PET is hot at 43 °C with a combination of microclimate and physiological data of the person. The value of PET as we can see affected by Ta is at 30 °C, Radiation at 60 °C, and with wind speed 1 m/sec and a humidity of 50%. Then the adjustment of the thermal environment is needed to obtain a more comfortable thermal. This adjustment can regulate physiological data or looking for a better place microclimate, such as shaded areas or under trees. Table 3.1 is a table of thermal comfort scale PET based on research Matzarakis, A. - Mayer, H. 1996.

Table 3.1. PET scale and the scale of thermal comfort and the correlation of the level of physiological stress (Matzarakis, A. - Mayer, H. 1996)

PET	Thermal Sensation	Physiological stress level
	Very cold	Extreme cold stress
4	……………..	……………..
	Cold	Strong cold stress
8	……………..	……………..
	Cool	Moderate cold stress
13	……………..	……………..
	Slightly cool	Slight cold stress
18	……………..	……………..
	Comfortable	No thermal stress
23	……………..	……………..
	Slightly warm	Slight heat stress
29	……………..	……………..
	Warm	Moderate heat stress
35	……………..	……………..
	Hot	Strong heat stress
41	……………..	……………..
	Very hot	Extreme heat stress

3.1.5. .Predicted Mean Vote (PMV)

Predicted Mean Vote (PMV) based on the study of the thermal comfort index is an index of thermal comfort developed not only assessing microclimate with all its elements but also involves psychological and physiological side of the wearer. Danger (2002) revealed that human activity and clothes in determining the useful life assessment of thermal comfort.

Based on the study Fanger analysis showed that the narrow range of skin temperature and sweat evaporation rate determines the most significant sensation of thermal comfort, which depends on the level of activity (more active people who feel comfortable in a low skin temperature and evaporation rate is higher). By combining this information and thermal energy balance equation above, he developed a set of correlations that PMV as a function of six variables: air temperature, average radiation, temperature, air velocity, air humidity, resistant clothing, and activity level.

Based on subjective criteria to determine the influence of environmental parameters and individual (thermal equilibrium between man and the environment), and given the sensation of analysis of thermal comfort suggested by PMV this model shows seven-point scale, from very cold to very hot, combining the individual parameters (metabolism and resistance clothing) and environmental parameters (temperature, humidity, air temperature and radiant temperature). In this study, for the reception of the thermal environment, the percentage of people who are not satisfied to be determined is less than 10% (ISO 7730, 1994).

Based on the theory above PMV equation can be seen in the following equation (ISO 7730, 1994):

$$PMV = [\ 0,303.\exp(-0,036.M) + 0,028]\ L \qquad (8)$$

Where:

PMV : Predicted Mean Vote

M : Heat production due to metabolism in the human body (W / m²)

L : The actual temperature of the human body (W / m²)

Table 3.2. PMV Scale

PMV	Thermal Sensation
+3	hot
+2	warm
+1	Warm comfort
0	Comfort
-1	Cold comfort
-2	cool
-3	Cold

From these equations can be derived that the people who are on a scale of -3, -2, +2 and +3 expressed dissatisfaction thermally while those who claim to be between -1 and +1 indicate that they are satisfied thermally. From these data can be derived satisfaction scale in assessing a person's environment. Table 3.3, The following is the PMV scale associated with a person's thermal sensation.

Hope (2000), brings together two values of thermal comfort between PMV and PET and give the sensation of thermal comfort levels in two regions between Europe and Tropical. As Table 3.3. as follows.

Table 3.3. Comparison Scale PMV and PET in Europe and Tropical thermal sensation with physiological stress level (modification Hoppe, 2000)

PMV	PET °C	Thermal Comfort Europe Area	Thermal Comfort Tropical Area	Physiological Value
		Extremely Cold	Extremely Cold	Stress feels cold
-3.5	4			
		Very Cold	Very, very Cold	Feels very cold
-2.5	8			
		Cool	Very Cold	Feels Cold
-1.5	12			
		Cold Comfort		
-0.5	16		Cold Comfort	Feels Comfort little bit cool
	20	Comfort		
0.5	24		Comfort	Feel Comfort
		Warm Comfort		
1.5	28		Warm Comfort	Feels Comfort little bit warm
		Warm		
2.5	32		Warm	Feels warm
		Hot		Feels hot
3.5	36	Extremely hot	Hot	
	40		Extremely Hot	Stress feels very hot

3.2. Open Space and Activity

There is a relationship between open spaces users and thermal comfort that stated by several studies (Nikolopolou et al., 2001; Thorsson, 2004; Zacharias et al., 2004; Nikolopolou et al., 2006; Lin, 2009). Outdoor thermal comfort is one of the most important impacts immediate and directly can be recognized that influenced by the built environment. Recent years, most thermal comfort studies are about building environment post-occupancy evaluation by applying field measurements or simulation of outdoor thermal comfort parameters to predict models of human thermal comfort. Moreover, the field measurement by involved large samples of actual occupants can lead to a clearer understanding of thermal interactions between occupant and built environment, a more comprehensive understanding of how thermal comforts interact with outdoor built environment elements to impact overall occupant satisfaction. Understanding outdoor thermal comfort is needed to improve the design of outdoor more attractive and the quality of life of outdoor.

In the tropical humid climate city like Jakarta, open spaces are used almost during the years and they must have thermal comfort properly. The thermal comfort studies in this open space are important for evaluation studies and as a guideline to urban design and architectural projects. Climate circumstances take part in a particular responsibility in this context not only because climate change causes new challenges for urban areas, but also because urban areas can play a lead task in humanity's pursuit for an association with the natural environment that permit societies to thrive and prosper for a long time to come.

Spagnolo and de Dear (2003) stated buildings can become shadowing elements of urban, thus buildings can shade pedestrians from direct solar radiation and deflect wind velocity. Murakami et al. (1999) showed the vegetation is the important element in the city, he mentioned about the effect of wind condition around the buildings. Vegetation can reduce ground temperature by 2 to 4 degrees Celcius. Meanwhile, Nikolopoulo et al. (2001) stated people tend to choose comfortable places to sit, and they found the human response to microclimate is intuitive, and it was proof that the modeling outdoor thermal comfort is more complex than the modeling physiological effect.

Bekele et al. (2008) showed in their research that hot-humid climate cities need maximum shade. Vegetations as natural elements of the city are the primary technique to provide shade (Goncalves and Duarte, 2008). While Makamuri et al. (1999) found surface temperature can be reduced 2 to 4 degrees Celsius by planting the vegetations along the street. Lin et al. (2010) also stated shading area significantly affects outdoor thermal environment. Natural vegetation has advantages not only providing shade in the summer but also directing breezes. Goncalves and Duarte (2008) stated trees positioning is important due to providing shade in urban area. Luxmoore et al. (2004) in their research showed vegetation in cities is an exercise of re-vegetation due to natural plant-life lost to urban development.

Studies of outdoor thermal comfort in tropical climates have shown by several researchers (Chen, 2012; Honjo, 2009; Mishra, 2013). Cities that located at the equator encounter abundant sunshine and solar radiation while the average sunshine is about six hours per day. According to Bekele et al. (2008) statements, hot-humid cities need street ventilation to release the heat quickly. They conducted wind-tunnel tests to determine the optimal orientation and building placement to promote ventilation and air circulation in the urban area. They found orient buildings at 45 degree angle to existing winds creates both positive and negative air pressure that allowing breeze to be carried out around buildings and promoting air circulation at the pedestrian level. While the buildings which have a parallel orientation to existing wind directly facing the winds under negative pressure creates a channeling effect that allows for less air circulation at the pedestrian level. High rise building can block the existing wind before they can move to the area. High rise buildings create wind velocity in the windward side while causes decreased wind velocity on their leeward side due to the shielding effect. To create better wind circulation among buildings, street-to-canyon ratios should be 0.7 or less. Dominated high rise buildings in the city create a different pattern of air circulation. Bekele et al. (2008) also recommended to promote further better air circulation cities should have varying building heights.

The outdoor thermal comfort studies were mostly limited to the temperate regions (Nikolopolou, 2001; Nikolopolou et al., 2007; Metje, 2008). There is a lack of information on the outdoor thermal comfort in the tropical region in relation with the quality of outdoor environment (Ahmed, 2003; Johanson and Emmanuel, 2006; Lin, 2009; Lin et al, 2010). Thus, investigation of outdoor thermal comfort condition in the hot-humid climates based on weather condition along with human parameters is needed.

3.2.1. City and Walkability

O'Hare (2006) stated that urban development tends to steer the development in the use of private transport modes and excessive air conditioning appliances. System development and use of technology is not friendly to the environment. The city must understand microclimate if a city does not want to tend to develop oriented mode of personal transport. Activities conducted the city residents outside of the building, such as walking and using public transportation should be convenient and possible widely can interact with the urban environment comfortable.

A social interaction in the city is a key asset of livable cities which people can access a wide range jobs, goods, services, and business value city location. A walkable place which more convenient and more lively is a place with a variety of services and destination in close proximity to one another. Walking is a marker of urban spaces-places where people walk between destinations than to take other modes of transportation.

Jacobs (1961) stated that the heart of urban vibrancy is walkability, where there are a mix of urban function like short blocks, population density and diversity and a mix of users, and building types and ages that all plays out in their own role. A walking places that frequently used have characteristic: they are generally denser, better served by transit, more central, and have more of a mix of different land uses. Litman (2007) stated most walking research is a part of the urban transportation system study, which transportation often focus exclusively on car and transit trips, ignoring pedestrian travel as an important component. Consequently, they did not put walkability as a vital form of urban transportation.

Carvaro et al., (2003) stated outdoor activities like walking, and using public transportation naturally require interaction with the natural environment. Exposure to extreme heat, humidity, and rainfall conditions are recognized as a significant barrier in outdoor activities. The extreme heat conditions, high humidity and low air velocity are a challenge for urban designers and architects to create a more comfortable space atmosphere in Jakarta.

3.2.2. . Walking Activity and Climatic factors

More than 15 years, researchers on urban design have investigated that well-connected street are associated with more walking. In the theory of urban design, the basic building block of walkable neighborhoods is defined as the area covered by a 5-minute walk (about 400 meters). Handy (2005) found that built-environment causes some measure of physical activity. The key role of placing residential density, commercial destination, and transit connectivity contribute make walking a more efficient form of transportation and allow individuals to complete the tasks of daily living without needing a car. The physical and social environment construction that builds surround us create a healthy context for our lives (Lovasi, 2012).

While walkability as topics are frequently discussed, climatic factors is not a significant theme. Eliasson (2000) found the result from the survey that the majority of urban designers did not take into account climatic factor in their decision-making process. Some literature reviews have discussed walking activity in detail, but did not mention to climatic factors. Greenwald and Boarnet (2001) stated that Pedestrian Environmental Factor was significant in determining the probability of non-work walking travel at the neighborhood level but did not significantly talked about climatic factors. Cervero and Duncan (2003) found that nonmotorized transport can be induced by well-connected streets, small city blocks, mixed land uses, and proximity to retail activities. They emphasized there were other stronger factors affected walking and bicycling choice than built-environment factors; such as topography, weather, and demographics, but they need more evidence data. The climate is barely mentioned in several literature that discussed about neighborhood design and walkability from urban planning, transportation design, and environmental health fields (Besser and Dannenberg, 2005; Ewing et al., 2006; McGinn et al., 2007; Kashef, 2010).

The most literature stated how climate affects the walkability in the urban setting comes from the public health field. O'Hare (2006) noted about active transportation, it recognizes that walking, a part of the physical activity, is an inherent component of transit use. Buys and Miller (2010) found that walking was more difficult in the climatic conditions in Brisbane, Australia. Merril et al. (2003) found the physical activity has been affected by the season and climate for adult in the United States. Psychological factors play an important role in how people perceive weather and climate, stated by Hoppe (1999); Nikolopoulo (2001); and Ahmed (2003).

The study of the impact of climate on the walkability in the pedestrian has not been extensive. However, the studies from the thermal comfort literature found that variables of biometeorological can be used to calculate the walkability. Furthermore, walkability that affected by climate is implied walking comfort in this paper. It is how far an individual might be able to walk before experiencing discomfort in an outdoor setting. The distance is examined for how far the body's physiological response can walk while maintaining thermal comfort; it's called comfort shed (DeVau, 2011).

Jakarta, the capital city of Indonesia, had experienced increasing temperature since 1990 (Katarina and Syaukat, 2015). Abundant sunshine, high humidity, and rainfall are conditions can be felt daily in this city. There are leaks of information of outdoor thermal comfort studies in tropical cities needs to consider. This paper seeks to investigate and evaluate the thermal comfort and walking comfort in the hot-humid city. The results can be used as information creating walkable and comfort area in an outdoor environment in the superblock for urban designer and architect.

3.3. . Human Thermal Comfort

3.3.1. . Studies of Heat Balance

The establishing of heat balance will work when heat is equal to gains and losses on the human body. Sometimes the external environment does not allow the heat balance work, and then the thermoregulation will be triggered. The human body will produce sweat; it may evaporate, to take the heat away from the body to restore the balance back (Hoppe, 1993). Producing extreme sweating to maintain the body heat balance can make an uncomfortable situation, besides the clothes getting wet; there will make the organic power tangled in the sweat secretion, and cause to the undesirable effect leave on the skin (Alvarez et al., 1991). The ideal thermal comfort can be achieved when the balancing of different energy/heat flow's works, so the heat loss through sweating can be negligible in the summer. Even so, sweating will be required when one the source of the heat gain increase, in terms of losing heat from the body and getting thermal comfort. Regarding the heat balance equation, it is potential to calculate all the parameters and to measure the different gains and the possibility of losses.

The thermal comfort situation can be achieved by increasing the favorable heat flows (losses) and reducing the unfavorable ones (gain) wherever possible or by transforming them into losses when the problems come. Natural techniques can be used as a tool of heat balance through shading, for example: via trees, or specific cultivation, as a natural shaded area, in other hand artificial shade has to be provided or with a combination of technique employed.

For urban planner or landscape designer, in practice, these issues should be taken into account to design open space which can control the variable such as solar radiation, one of the biggest sources of heat gain, or in which can eliminate extreme heat through convection by using the element of the landscape, such as water bodies or fountains. There are two focuses parameters has to be taken into account regarding open space design: 1) The meteorological parameters. Thermal comfort calculation cannot be taken just from general parameters of the city which, measured by the meteorological service bureau. The parameters have to be measured from field measurement because of the urban structure that surrounded by buildings, vegetation, and road, modify those parameters in micro-spaces. 2) Measurement in situ of the meteorological parameters should involve human-biometeorological indices to calculate the balance equation with the values obtained.

3.3.2. . Outdoor thermal comfort indices

Morgan and Baskett (1974) stated current studies of thermal comfort based on two basic approaches: 1) An analytical or rational approach. The human energy balance is used as a basic theory of this approach. 2) A synthetic or empirical approach. The combination of variable of various meteorological is used to calculate the formula of thermal comfort, unfortunately this approach does not consider the key role played by human activity, thermal physiology, clothes and other human's personal data (sex, weight, height, age, etc.). Currently, as what Hoppe (1993) stated Rational indices much to be used, relatively newer, match to the human energy balance, and easy to be used by computing technique.

Recently, rational indices are widely used by many international researchers and closely linked to the urban planning research. The Rayman Model by Matzarakis developed for the calculation of the mean radiation temperature and thermal indices in simple and complex environment, which based only on data of air temperature, air humidity, and wind velocity (Matzarakis et, al., 2007), the model based on VDI Guideline 3787, published by the Association of German Engineers (1998). Ochoa et al. (1998) from The University of Sonora has published Microclimatic analysis of some urban scenarios, based on research of Brown and Gillespie (1995). Nikolopoulou et al. (2004) carried out the RUROS (Rediscovering the Urban Realm and Open Spaces) Project for the European Union.

Psychological factors in the perception of individual comfort become an important factor in research of thermal comfort in open space (Nicolopoulou and Steemers, 2003; Nikolopoulou and Lykoudis, 2006; Lin, 2009; Lin et al., 2011; Lin and Matzarakis, 2011; Lin et al., 2012, 2013). Jendritzky et al., (2012), studied about comparing UTCI and PET last ten years, and some studies latter highlighted both indices are ease to use.

The physiological equivalent temperature, PET, is used to calculate the thermal comfort indices because of it is widely known using °C in its unit. Therefore, PET has the advantage compared to other thermal indices. Base on the human energy balance of the human body PET is very well matched to the humanbiometeorological evaluation of the thermal component of different climates. Therefore, PET significantly and consistently matches to thermophysiologically (Mayer and Hoppe 1987; Hoppe 1999; Matzarakis, Mayer and Iziomon 1999).

PET value can be calculated using free software packages by Rayman (Matzarakis, Rutz, and Mayer 2007), which can make precise predictions of thermal environment (Gulyas et al. 2006; Lin et al. 2006). Rayman has been used to calculate in several of outdoor thermal comfort with complex shading patterns. PET is easier to estimate by temperature, RH (or VP), v, Tmrt, human clothing, and activity in the model (Lin et al, 2010). Several parameters can be added to calculate following analyses, i.e. Tmrt (the most important factor during hot condition when calculating PET). Using Rayman Tmrt can be also estimated by global radiation (Gr), cloud cover (Cd), fisheye photographs, and albedo. The Bowen ratio of ground surface and the Linke turbidity including the shading effect can be estimated while calculating short- and long-wave radiation fluxes.

Outdoor thermal comfort studies have been conducted in various spaces. Nikolopoulou and Lykoudis (2006) conducted thermal comfort study in outdoor and semi-outdoor environment in five European countries (subtropical country) and found there is a strong correlation between thermal comfort and microclimate. Lin and Matzarakis (2008) studied outdoor thermal comfort in Taiwan showed that the neutral temperature of Taiwan is higher than that of western and central Europe.

Makaremi et al. (2012) studied outdoor thermal comfort in a context of hot-humid climate at a university in Malaysia. Their results showed that the value of the thermal comfort index (PET) in the selected shaded outdoor spaces was higher than the comfort range defined for tropical climate (PET < 30 degree Celsius). Normally condition that acceptable (PET < 34 degree Celsius) occurred during the early hours of their measurement (9-10 am) and late afternoon (4-5 pm) while the high level of shading is obtained from the plants and surrounding building had a longer thermal acceptable period.

According to the previous investigation, research on outdoor thermal comfort in hot-humid region is still very incipient. Makaremi et al. (2012) in their research outdoor thermal comfort in Malaysia used thermal comfort index from Lin and Matzarakis (2008). In order to identify thermal comfort range for hot-humid tropical region, Lin and Matzarakis (2008) conducted thermal comfort study in an outdoor environment of Taiwan. Their study focused to modify PET classes from moderate climates to suit the condition of tropical and subtropical climates. Table 3.4 shows the comparison between PET index hot-humid climate and subtropical region climate. In comparison with the Western/middle European scale where the neutral temperature of PET between 19 and 23 °C, the tolerance of higher neutral temperature of Taiwan's resident corresponds to PET values between 26 and 30 °C. The result showed that the thermal comfort range of Taiwan's respondents was significantly higher than in Europe represented of the moderate climatic condition. In this study, the thermal comfort range is applied from the value of a PET hot-humid/Tropical region stated by Lin and Matzarakis (2008), see Table 3.4.

3.3.3. . Walking comfort Simulation

The literature of walking comfort has a limitation, much of them comes from the public health field and public transportation fields. O'harre (2006) stated walking, including walking to public transit is a part component of physical activity that relate to active public transportation. Buys and Miller (2010) conducted research using 24 qualitative interviews with resident of high-density dwellings in the subtropical climate of the inner-city of Brisbane, Australia. The study showed a general perception that walking in the climatic condition of Brisbane is difficult to achieve especially walking in hot weather.

Table 3.4. PET value *Source:* [a]Matzarakis and Mayer (1996); [bling] and Matzarakis (2008)

PETa Moderate Region (°C)	PETb (Sub) Tropical Region (°C)	Thermal Perception	Grade of Physiological Stress
		Very Cold	Extreme Cold Stress
4	14		
		Cold	Strong Cold Stress
8	18		
		Cool	Moderate Cold Stress
13	22		
		Slightly Cool	Slight Cold Stress
18	26		
		Comfortable	No Thermal Stress
23	30		
		Slightly Warm	Slight Heat Stress
29	34		
		Warm	Moderate Heat Stress
35	38		
		Hot	Strong Heat Stress
41	42		
		Very Hot	Extreme Heat Stress

Uncomfortable position also was seen when combining walking with the use of public transit. In the other hand, they remarked that walking in sweaty condition to public transport stop on hot-humid subtropical summer day was unbearable.

Merril et al. (2003) showed their research result at United State that season and climate have a significant impact on the physical activity of adults. They remarked that the results had stronger effect in areas with climates similar to Florida's. Eves et al. (2008) found physical activity can be more depressed in the summer season at subtropical climate. They observed the number of individuals willing to climb stairs or walk at least half of length of moving sidewalk in hot-humid climate of Hong Kong, and the result showed the willingness of individuals to climb stairs or walk decreased along with humidity increased.

Brown and Banister (1985) stated that solar radiation significantly increased heart rate and cardiovascular strain. Meanwhile Eve et al. (2008) stated that high humidity is an obstacle removing heat from the human body. Sheffield et al. (1997)

showed from their research that the humid condition and lower humidity can increase rates of perceived exertion and discomfort.

3.3.4. Comfortable Measurement of Skin Wettedness

According to (deVau 2011, pp. 46) skin wettedness (w) are a suitable measurement to calculate walking comfort. There are three variable to calculated skin wettedness: subject surface area (m^2), clothing units (clo), and metabolic rate ($W.m^{-2}$). The equation of skin wetedness is derived from (Fukuzawa and Havenith, 2009):

$$w = (q_{max}/q_{emax}) + 0.06 \quad (9)$$

Where; Qsw = required evaporative heat loss ($W./m^2$) and Qemax= maximal evaporative capacity of the environment (W.m-2), 0.06 is dimensionless of minimal skin wettedness by skin diffusion.

Fukuzawa and havenith (2009); Djongyang et al. (2010) stated that discomfort is strongly associated with skin wettedness in warm environments than skin temperature. Gagge (1937) developed the measurement of skin wettedness over the body (w), and Winslow et al. (1939) suggested as well to measure thermal discomfort using skin wettedness (w). Havenith (2002); Fukuzawa and Havenith (2009) recognized skin wettedness as one of the most convenient indices to predict the thermal comfort level for human in warm conditions.

Djongyang (2010) stated the skin wettedness is a rationally derived from physiological index. Skin wettedness is the ratio of the actual sweating rate to the maximum sweating rate that occur when the skin is completely wet, and related to the skin temperature that indicate the sensation of comfort and discomfort caused by perspiration. Skin wettedness is used to determine the evaporative heat lose. The value of skin wettedness ranges from 0.06 to 1. The value of 0.06 caused by the evaporative heat loss due to the moisture diffusion through the skin alone (i.e. with no regulatory sweating) for normal condition, and the value 1 occurs when the skin surface totally wet with perspiration, a condition that occurs rarely in practice (Djongyang, 2010, p. 2364).

De Dear from the University of Sydney in Australia developed the web-based tool calculator of Human-Heat Balance, he uses the source code originally developed by Huizenga (1995) for ASHRAE’s comfort tool. The web-based calculator is available at http://web.arch.usyd.edu.au/~rdedear/. De Dear calculator calculates values of thermal comfort indices such as PMV/PPD and SET* using standard biometeorology inputs. Furthermore, deDear calculator displays the results of two-node models main physiological models (UTCI, 2011). One of these values is total evaporative heat loss from the skin (Esw) that is equivalent to Qsw defined by Fukuzawa and Havenith (2009), see equation 1. Another value which is important is skin temperature (Tsk). Tsk is necessary to calculate qemax later. De Dear's calculator not only can display the result of Qsw and Tsk as the final values at the end of a set period of time, but also can display values for each minute over a period of time. The result of every minute over a period of time is needed for the purposes of the walking comfort analysis. All Qsw and Tsk values on this paper were calculated using this tool.

3.3.5. Partitional Calorimetry

Atkin and Thompson (2000) from University of Sydney developed Partitional Calorymetry Calculator using a spreadsheet. This program uses Visual Basic to calculate the heat storage and heat lost or gained through dry and evaporative heat transfer pathways. The spreadsheet can be downloaded at http://www.sportci.org/jour/003/ka.html, and the calculation manual are explained in the accompanying article by Atkins and Thompson (2000).

q_{emax} is calculated by Atkins and Thompson (2000), as follows: Calculation of q_{emax} (the maximal evaporative capacity of the environment) formula is taken from McIntyre (1980):

$$q_{emax}\,(Wm^{-2}) = f_{pd} \times h_e \times (P_s - P_a) \qquad (10)$$

Where f_{pd} is the permeation efficiency factor of clothing, h_e is the evaporative heat transfer coefficient (W.m^{-2}.kPa^{-1}), P_s is the partial water vapor pressure at the skin surface (kPa), and P_a is the partial water vapor pressure of ambient air (kPa) (McIntyre, 1980).

Beginning calculation, there are two variable that have to be calculated using automated Visible Basic element on the EnvironData tab of the spreadsheet, i.e.: radiative heat transfer coefficient h_r (W.m^{-2}.K^{-1}) and the partial water vapor pressure of ambient air Pa (mmHg). To calculate h_r require specific data of human activity (in this case, walking) not include the clothing temperature, and to input Tmrt values in degrees Celsius along with the relative humidity (Rh).

The converted Pa value from mmHG to kPa use the following equation by Atkins and Thompson (2000):

$$Pa\ (kPa) = \ Pa\ (mmHg) * 0.1333 \tag{11}$$

Where f_{pd}, the permeation efficiency factor of clothing is taken from Parson (1993) formula:

$$f_{pd}\ = 1/[1 + (0.344\ \times\ h_c\ \times\ l_{cle})] \tag{12}$$

Where h_c is the convective heat transfer coefficient (W.m^{-2}.K^{-1}), and l_{cle} is the effective clothing insulation (clo units) (parson, 1993).

Effective clothing insulation (l_{cle}) is taken from McIntyre (1980);

$$I_{cle}(clo\ units) = l_d - [\frac{f_{cl}-1}{0.155 \times f_d \times h}] \tag{13}$$

Where l_d is the intrinsic clothing insulation (m^2.^{o}C.W^{-1}), f_{cl} is the clothing area factor (ND), and h is combined heat transfer coefficient (W.m^{-2}.K^{-1}) (McIntyre, 1980). The l_d is determined from the standard clothing values from a variety of sources, including ASHRAE 55P.

Clothing area factor (f_{cl}) (Parson, 1993), as follows:

$$f_{cl} = 1 + [0.31\ \times \left(\frac{l_{cl}}{0.1555}\right)] \tag{14}$$

Where l_{cl} is the intrinsic clothing insulation (m^2.°C.W^{-1}) (Parson, 1993). l_{cl} Values are determined from the value given in the literature.

h_c (Convective heat transfer coefficient) is taken from (Kerslake, 1972), as follows:

$$h_c(W.m^{-2}.K^{-1}) = 8.3 \times (v_a{}^{0.6}) \qquad (15)$$

Where v_a is air velocity in $m.s^{-1}$ (Kerslake, 1972).

Calculation of evaporative heat transfer coefficient (h_e) is taken from Kerslake (1972), as follows:

$$h_e(W.m^{-2}.K^{-1}) = h_c * 16.5 \qquad (16)$$

Calculation of Combined heat transfer coefficient (h) is taken from Parson (1993), as follows:

$$h(W.m^{-2}.K^{-1}) = h_c + h_r \qquad (17)$$

Where h_c is the convective heat transfer coefficient ($W.m^{-2}.K^{-1}$), and h_r is radiative heat transfer coefficient

Calculation of h_r as follows (from Parson, 1993):

$$h_r(W.m^{-2}.K^{-1}) = 4.E.s.A_1A_{d.}((273.2 + (\frac{T_{cl}+T_{mrt}}{2}))^3) \qquad (18)$$

Where E is the emissivity of the skin surface (0.98: Gonzales, 1995, pp.299), s is Stefan-Boltzmann constant (5.67 x 10^{-8} $W.m^{-2}.K^{-4}$), A_1A_d = ratio of the area of the body exposed to radiation versus total body surface area (0.70 for seated postures, 0.73 for standing postures), T_{cl} is mean surface temperature of the body, and T_{mrt} is mean radiant temperature.

Calculation of saturated water vapor pressure at the skin surface is taken from Fanger (1970), as follows:

$$P_s(mmHg) = 1.92 \times T_{sk} - 25.3 \tag{19}$$

Where T_{st} is skin temperature in degrees Celsius (Fanger, 1970). This calculation of skin temperature is valid for skin temperature between 27 and 37 °C (Atkins and Thompson, 2000). Transient values of skin temperature are provided by de Dear's calculator.

Some of the values are constant while others change depending on environmental and physiological variables. Clothing area factor (f_{cl}) is directly change based on the clo values which derived from literature, in this case clo clause use typical tropical business clothing, 0.49. The clothing variables (f_{pcl}) and l_{Cl} are changed along with altered in heat transfer coefficient and/or clo value. P_s changes along with altered skin temperature of the subject.

It is important to calculate q_{emax} value in minute-by-minute in order to calculate skin wittedness at the same resolution as skin temperature values (t_{sk}) provided by de Dear's calculator.

As mentioned by (Gagge, Fobelets and Berglund 1986); (Hartog and Havenith 2009), 0.3 of wettedness is the limit condition of thermal comfort in the whole body. Whilst (Djongyang, Tschinda and Njomo 2010) mentioned that thermal discomfort will progressively increase when the value of whiteness reaches 0.3-0.05. An offering by (Havenith, Holmer, and Parsons 2002) the walking comfort comfort based on skin wettedness is reliant on activity level when w is less than 0.0012 M (metabolic rate) + 0.15.

Conclusion

Recently, research in urban climatology in term of making the city easier to live in become popular issue. One proposed definition of a better place of the city is how much outdoor space is acceptable in the presence of people activity. The build environments speed up the absorption of the heat during the daytime and slow down release the heat at the night time. These formations are known as the urban heat island where the hot region surrounded by the cooler neighboring area. Some researchers explain that the climatic conditions in the city affected by climate and the build environment (Landsberg 1981; Eliasson 2000; Oke 1984, 2006).

Of the many assessments of thermal comfort thermal comfort studies in the outdoor environment a new study. Formerly the scope of thermal comfort is intended only for indoor, now can be used in the outdoors. The basic theories of human responses to thermal stimuli under conditions also apply in space in an outdoor environment. The fundamental difference from the assessment of thermal comfort and space in an outdoor environment is the outdoor space has a condition that is always changing rapidly, so the physiological adaptation of the micro-climatic conditions (acclimatization) is a factor that affects the human preference for thermal comfort. Thus, the actual level of discomfort cannot be stated with certainty, except by comparison of field surveys.

Chapter 4

FRAMEWORK AND METHODOLOGY OF ASSESMENT IN URBAN OPEN SPACE THERMAL COMFORT AND WALKING COMFORT

Summary

Thermal comfort is defined as a state of mind that expresses satisfaction rate human to the conditions of the thermal environment. Sometimes the thermal environment occupied by humans, not give the expected conditions.

Environmental parameters like macroclimate and micro-climatic conditions will affect thermal comfort. There are six variables that also include climate-forming elements that affect thermal comfort in open space, i.e: solar radiation, wind speed, and direction can make changes in the human body. Two other climate elements that affect thermal comfort also, temperature and humidity, and two additional factors are at the level of human activity and the type of clothing which worn by the people.

Environmental characteristics strongly contribute to the microclimate change can alter the thermal comfort. The elements are the environmental characteristics of building configuration, albedo, and Green Plot Ratio. Characteristic of this neighborhood more influence change in wind and quantity of incoming solar radiation in the area. By changing the elements of the environment can be achieved quality better thermal comfort.

4.1. Conceptual Framework

Thermal comfort is defined as a state of mind which expresses satisfaction rate man to the conditions of thermal environment. Sometimes the thermal environment occupied by humans is not give the expected conditions.

Environmental parameters (climate Macro) and micro-climatic conditions will affect thermal comfort. Six variables also include elements forming the climate affects thermal comfort in open space. Solar radiation, affecting climate change. Wind speed and direction, which are convection heat can make changes in the human body. Two other climate elements that affect thermal comfort as temperature and humidity, plus two additional factor is the level of human activity and the type of clothing worn.

Environmental characteristics strongly contribute to the climate change that can alter the micro thermal comfort. The elements are the environmental characteristics of building configuration, albedo and Green Plot Ratio. Characteristic of this neighborhood more lead changes in the wind and the quantity of incoming solar radiation in the area. By changing the elements of the environment can be achieved quality better thermal comfort. Illustration of this relationship can be seen in Figure 4.1.

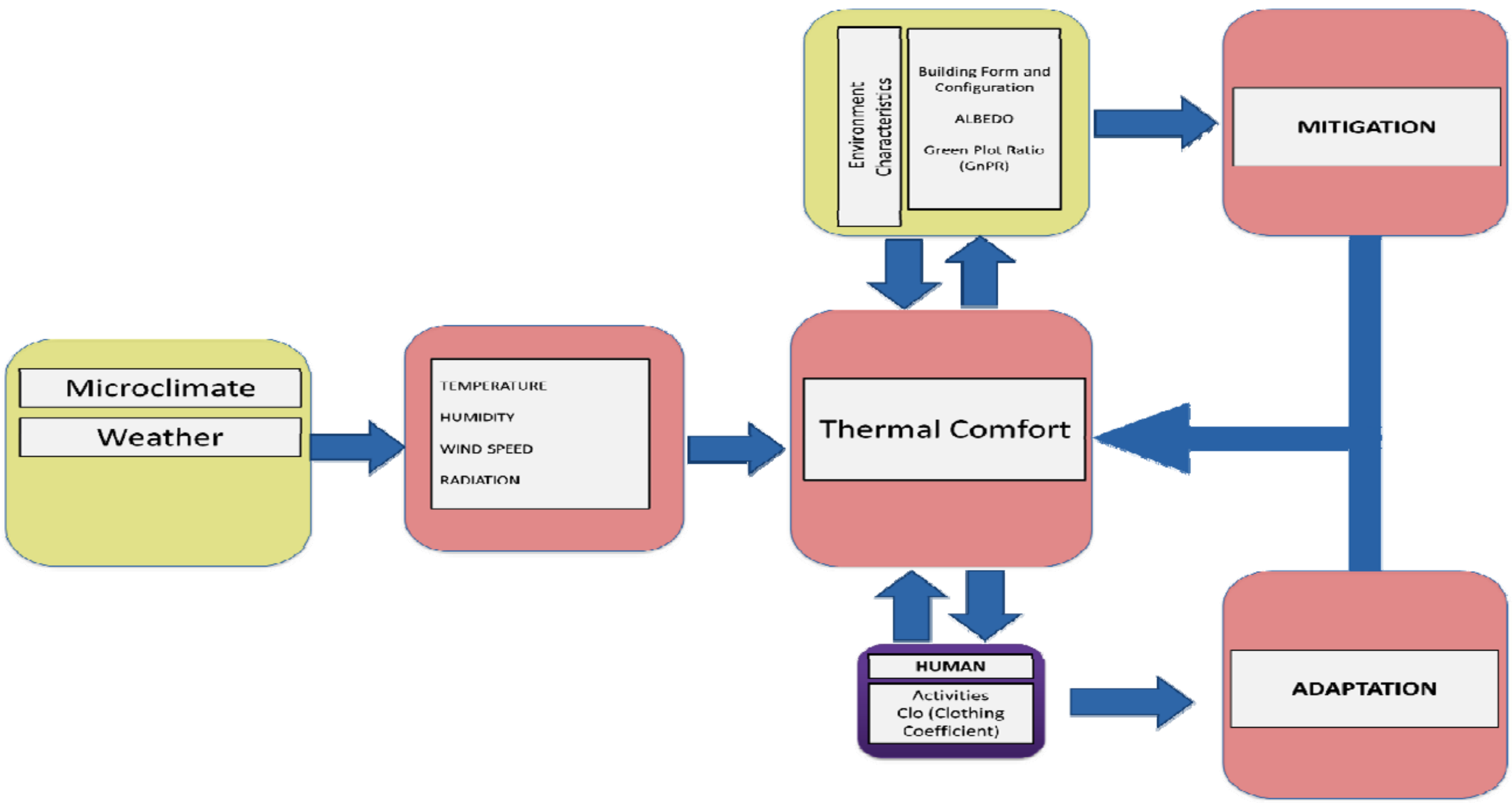


Figure 4.1. Research of Thermal Comfort diagram

4.2. Structure of Research

The first phase of this research is to study and search of literature from books or expert opinion relevant to the theme of the research on thermal comfort of outdoor environment. Then The literature review was developed in the review and evaluation of thermal comfort in the humid tropical climates such as Jakarta.

Deepening the study and search of literature is intended that the outdoor environment research thermal comfort can be more focused as the basis for analysis and evaluation. From the study of literature is obtained the theory of outdoor thermal comfort and how the outdoor thermal comfort affects the urban structure. How the literarture review, assessment method, and research analysis are explained as follows. For more details see Figure 4.2:

1) The development of the theory of the microclimate and thermal comfort
2) Develop assessment, thermal comfort of open space.
3) Development of a theory to establish the physical characteristics that affect the microclimate and thermal comfort in open space.
4) Develop element analysis of physical characteristics affecting the microclimate and thermal comfort.
5) Getting the case studies used as the test material for the assessment of thermal comfort in outdoor environment.
6) Case studies later in the measuring field simultaneously to get its existing thermal comfort.

Overall Framework of research can be described in Research Phases, see Figure 4.3. The Phase of research. At this stage of literature review found theories of microclimate, thermal comfort assessment of open space, open space characteristics and Green Plot Ratio.

This stage is getting more detailed microclimate variables, i.e. humidity, temperature, wind speed, and solar radiation. Assessment of thermal comfort further developed into a value that can be used later in the field of measurement and simulation, thermal comfort assessment here used by way of measurement and calculation of the scale the PMV and PET.

While the environmental characteristics after more in-depth study found the buildings, and outdoor environment as a variable to be measured in the field, including the interior and the orientation. Even though Green Plot Ratio (GnPR) including GnPR environmental characteristics, but this has its own way in its calculations, which have been discussed in chapter 2 Literature Review.

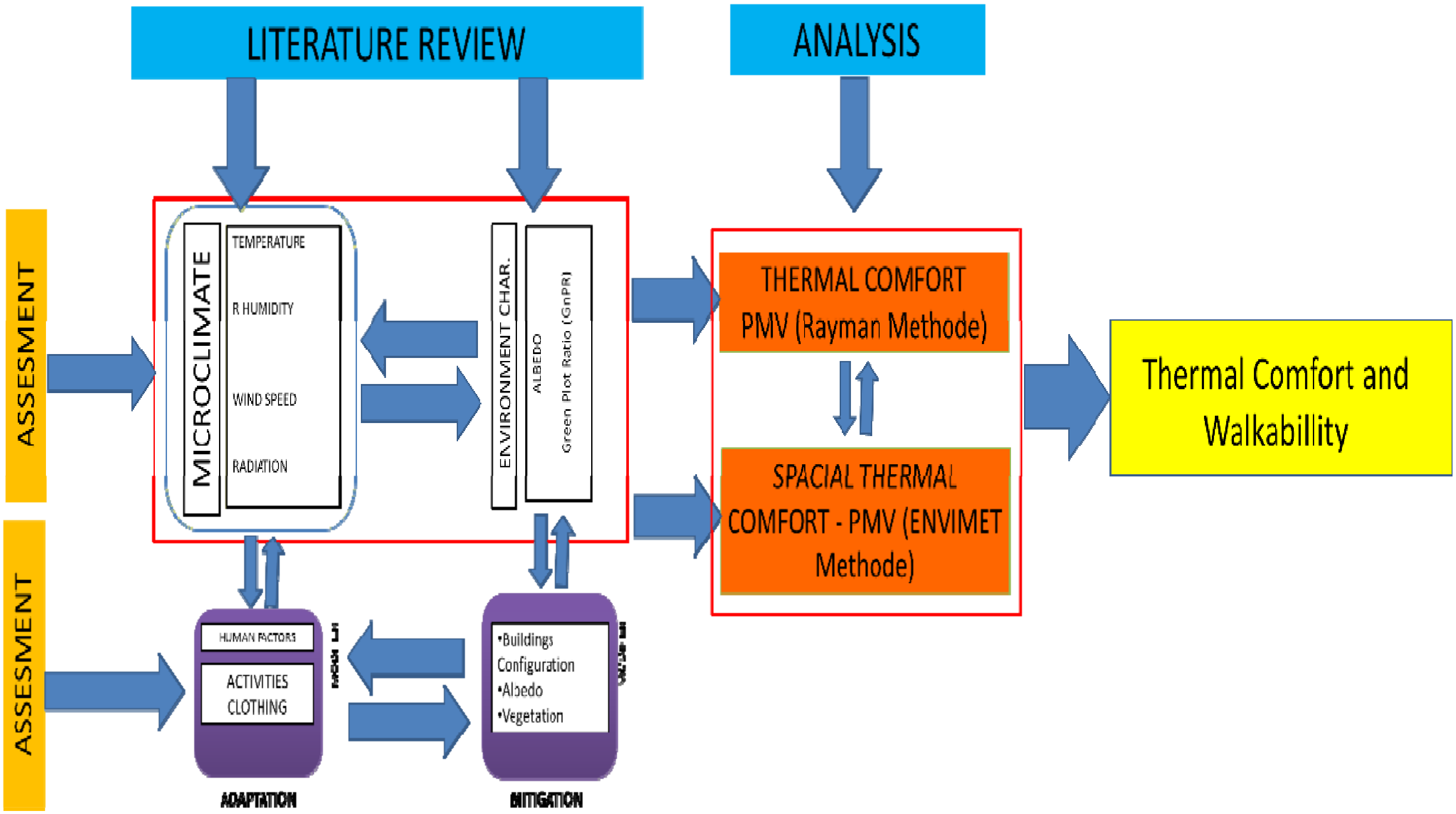


Figure 4.2. Research Framework

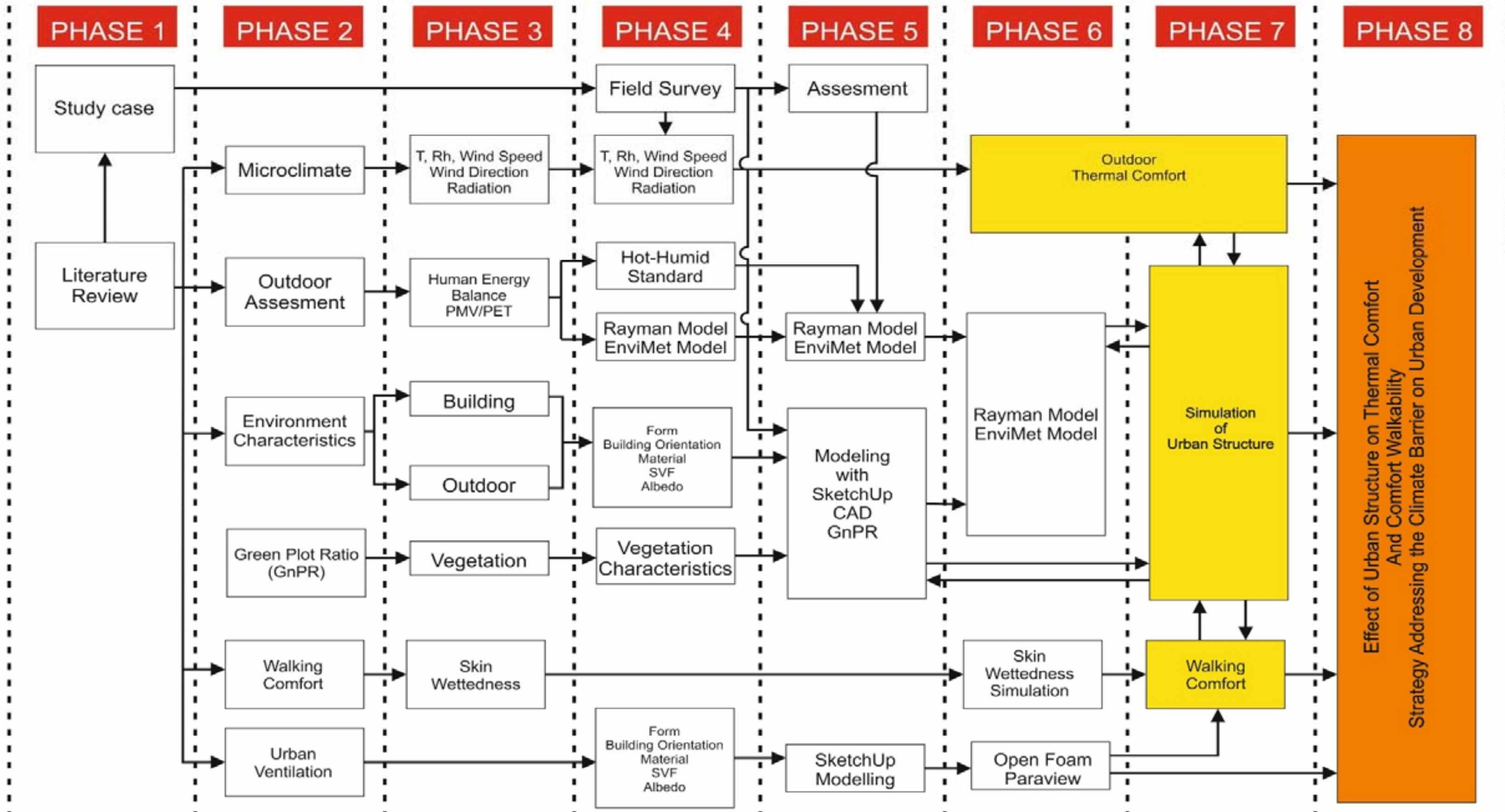


Figure 4.3. The Phase of research

4.2.1. . Field Measurement

Field measurements based on the existing studies on earlier stages. The stage is divided in several ways, namely data collection, the equipment used, measurement locations or points of measurement and the measurement of environmental characteristics. More detailed stages are as follows:

The field measurement is the method to collect the data. Airy, Yacobs and Razavich stated that the field measurement method was designed to obtain information about the status of symptoms at the time the research was conducted in order to describe what variables or conditions that exist in an existing (Rinehart, 1999).

In this stage, the measurement of microclimate variables that affect thermal comfort, namely:

- Temperature / temperature (Ta, OC),
- Humidity (Rh, %)
- Air velocity (v, m / Sec).
- Solar radiation (° C)

This variable measurement technique is measured at a height of 1.5 m from the ground at each location or point of measurement.

Time measurements were performed on each sunny conditions, i.e. conditions that show a state where the skies are not cloudy or partly cloudy and in the absence of rain. Time measurement is done in the rainy season in March and the dry season months of September in 2009. Elections in March and in September based on the movement of the sun, which are moving just above the equator. Time measurements were taken at 7am pm it open recreation time is up to 5pm pm. Measurements carried out later every 60 minutes or 1 hour.

4.2.2. . Measurement Tool

The equipment used in this study was REED LM-8000 using AA battery power. This measuring tool has a feature the multi-function four-in-one (4-in-1), the anemometer (to measure wind speed), RH meter (measuring moisture in%), Lux meter (light gauge) and thermometer (air temperature gauge) digital K-type.

This tool has the level of detail in the measurement as follows: Humidity 10 to 95% RH, Lux meter: 0 to 20,000 Lux / 0 to 2,000 Ft-cd with units to choose between

Lux / Foot-candle, Anemometer (air flow rate) 80 -5900 fpm (feet per minute) with units to choose between m/s (meters/second), km/h (kilometers/hour), mph (meters per hour), knots, or ft/min (feet/min) , the detail of digital thermometer types of -K has the -100 to 1300 °C with a unit that can be chosen between °C / °F. This tool can record the maximum, minimum and average at each unit of measurement.

The black globe thermometer is used to measure the solar radiation. The black globe thermometer is a thermometer which placed in a black globe, due to the limited equipment, the black globe thermometer is then made by using a table tennis ball painted with black and inserted the thermometer in it. Black globe temperature gauge consists of 150 mm (6 inches) black ball with a thermometer located in the center. Temperatures on the black ball is a reflection of the effects of radiation and wind.

Other tools are the i5 and laptop computers to record the data at the field measurement. Software for data analysis used MS Word 2010 for writing reports and Excel 2010 for statistical data analysis and graphics.

Cameras Nikon D80 to document images in the field at the time of the survey and data retrieval. The term was in the field measurement, as follows:

- Ta: temperatures / Temperature (DBT ° C)
- Rh: Humidity (RH in%)
- V: Wind speed (v in m / s)
- GT: The temperature of the radiation. (GT in ° C)

Measurements of thermal conditions in the outside recreation space in Jakarta were done by coding at each measurement point location.

4.2.3. . Measurement of Environmental Characteristics

During the microclimate measurement variables also performed environmental characteristics measurement. This measurement was done in two ways: direct measurement in the field and measurement through image scale using a CAD drawing.

Environmental characteristics were measured to assess the albedo, the orientation of the building, open space orientation, Green Plot Ratio (GnPR), and Sky View Factor (SVF). Figure 4.2 shows how the environmental characteristics assessed in an outdoor environment. Determination of the measured areas was the area of coverage microclimate, which is 100m x 100m (Oke, 2006). The value of the albedo can be seen in Table 4.1.

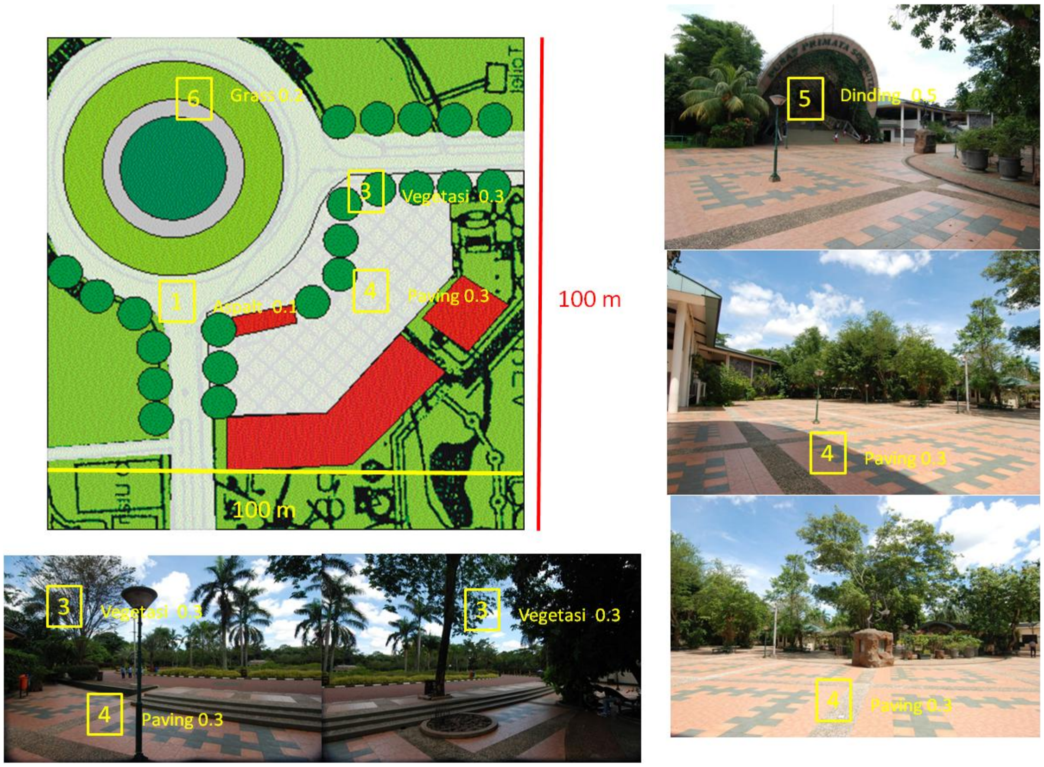


Figure 4.4. The Environmental characteristics was crossed checked using CAD images with the actual conditions in the area of measurement.

Table 4.1. The Data of albedo, emissivity and heat Admittance (DR Brown and Gillespie, 1995)

	ALBELDO (%)	EMISIVITY (%)	HOT ADMITANCE
			($J/M^2S^{1/2}k$)
Land	5 – 75		
Deep Valley	5 -1 5	90 - 98	
Valley	10 - 20		
Dry Sand	25 – 35	84 - 91	
Wet Sand	20 – 30		
Hill Sand	30 – 75		
Tanah Kering			600
Tanah Basah			2500
VEGETATION	3 – 30	90 - 99	
Grass	20 – 30	90 - 95	
Green Park	3 – 15		
Padi Field	15 – 25		
Grass Field	10 – 30		
Dry Weeds	25 – 30		
Forest	10 – 20		
Clumps Forest	5 – 16	97 - 98	
Swamp Forest	12	97 - 99	
WATER	5 - 95		1500
Water	5 - 95	92 - 97	
Snow	40 - 70	82 - 99	130 - 600
URBAN AREA	1 - 90		
Aspal	1 - 15	95	
Concrete	10 - 50	71 - 90	
Brick	20 - 50	90 - 92	950
Stone	20 - 35	85 - 95	
Pebble	8 - 18	92	
Roof tile	10 - 35	90	
Crab Grass Roof	15 - 20		
Zinc Roof	10 - 16	12 - 28	
White paint	50 - 90	85 - 95	
Red Paint	20 - 35	90 - 98	
Black Paint	2 - 15		
AIR			
Steady			5
Turbulence			400

The final result of the measurement was the environmental characteristics such as environmental characteristics table that contain the value of albedo and Green Plot Ratio (GnPR). As shown in Table 4.2.

Table 4.2. Examples of field measurement data and CAD measurement compared with the measured area (100 m x 100 m)

Paving (%)	30,38
GnPR (Green Plot Area)	0.4+0.86+0.46 = 1.92
Building Height (m)	6
Building (%)	0.1
Wall (m2)	2696
SVF	0.43

4.3. Phase of Analysis

Phase analysis was done in two stages, the calculation of thermal comfort which depicted in the field measurements, drawings made with AutoCAD scale. Furthermore, the calculation values included in the environmental characteristics, i.e.: albedo, SVF, and GnPR.

In the analysis of the thermal comfort of outdoor environment, there were two models that used in the analysis 1) analyzed by Rayman and 2) analyzed by EnviMet models. The two models are described in the literature review both of these models use a Thermophysiologis index system, but the results of these two models are different, Rayman generates the value of PMV and PET in the form of numbers while EnviMet produce an image map in the form of the color scale of PMV.

Climate variables that have been measured in the field incorporated into the Rayman model to calculate PMV and PET value. Rayman models produces numerical thermal comfort in each measurement location. Furthermore, the figures were included in the Exel software to be viewed graphically numbers, thermal comfort and its influence on the value of environmental characteristics. All measuring and calculation results compared one by one to find out the differences and the effect of any small microclimate, and environmental characteristics for thermal comfort. This phase is done using Intel quad-core computer.

While the observation was conducted to determine the outline of human activity and the clothes he wore. By default the value of the activity and the value of clothing taken from Table 4.3 and Table 4.4. Leisure activity has a metabolic rate between 45 to 110 W/m^2, the value of clothing worn in the recreation area is typical tropic clothing outfit and light summer clothing with a value of up to 0.5 Clo 0.3 Clo.

AutoCAD images provide input on the model, climate and environmental characteristics of the measurement in the main data in the simulation of EnviMet.

Table 4.3. The value of human activity (http://personal.cityu.edu.hk/~bsapplec/thermal.htm)

Basic activity	Metabolic Rate (W/m2)
Lying	45
Sitting	58
Standing	65
Walking on an even path at 2km/h	110
Walking on a level even a path at 5km/h	200
Going upstairs (0.172m/step)80 stairs per minute	440
Transporting a 10kg load on level at 4km/h	185

Correlation values expressed in the scale of thermal comfort PMV (Predicted Mean Vote) while the Scudo in 2002 stated that the thermal comfort of the outdoor environment more precise in describing the scale of PET (Physiological Effective Temperature). Relationship assessment of thermal comfort can be seen in Table 4.4 as follows:

Table 4.4. Coefficient values human clothing worn (Clo) for calculating thermal comfort (http://personal.cityu.edu.hk/~bsapplec/thermal.htm)

Clothing combination	Clo	m2K/W
Naked	0	0
Short	0.1	0.018
Typical tropic clothing outfit	0.3	0.047
Light summer clothing	0.5	0.078
Working Cloths	0.8	0.124
Typical indoor winter clothing	1	0.155
Heavy traditional European Business	1.5	0.233

The results obtained are PMV and PET thermal comfort maps. PMV and PET value are compared to the scale of PMV and PET to obtain thermal comfort values exist in an outdoor environment in the recreation area being measured. Thermal comfort values stated in the table space outside the thermal comfort in accordance with the measurement between the hours of 7am to 5pm at each measurement point. While the thermal comfort maps of outdoor environment will be depicted in the model of EnviMet simulations.

If the value of the thermal comfort of outdoor environment thermal comfort is not met, then the next step is to create a simulation of changes in environmental characteristics so that the optimum thermal comfort in outdoor environment can be achieved. Changes in environmental characteristics such as changes in albedo, SVF and GnPR most probable at each measurement point.

The last stage of this research is making a conclusion. Conclusions drawn after the simulation phase change characteristics of the environment is done. The conclusions drawn from all aspects of the research that can be seen from 0stages of research.

Suggestions contribute to the improvement of thermal comfort in the space outside recreational area, especially in Jakarta. While the recommendation is research that can be developed from this research.

4.3.1. . Rayman Model

Rayman models allow to calculate short-term radiation flux and wavelength that affects the human body. This model estimates the flux of radiation and cloud effects in the short wave radiation flux. Rayman, taking into account the complex urban structure models and suitable for planning purposes in urban areas. The end result of this is Rayman models calculate the average temperature, which is needed to balance the human energy and the end result is the urban bioclimate using PMV index, PET or SET (Standards Effective Temperature).

The model was developed based on Guideline VDI-Germany, 3789. The model was developed to calculate the Environment Meteorology, interaction between the atmosphere and the surface, calculation of short-wave radiation and long based VDI-3787, biometeorological humans, evaluation of climate and air quality in urban planning and regional.

The model requires data on human energy balance, meteorological data (air temperature, wind speed, humidity and flux of short and long wave radiation) and thermo physiological data (the activity and clothing) are required for the calculation of thermal index.

Rayman additional features of the model can be used to evaluate the climate of an area or tourism facilities, can calculate the duration of sunlight with or without the sky factor; estimating the average daily maximum or global total radiation, and determine the shaded area (shaded area).

Rayman allows us to enter the picture structure of an urban (i.e. Building, leaves, and trees), drawing freely Sky View Factor (SVF), also allows insert the picture of fish eye to calculate factors an area that can be expected flux of radiation. Rayman's interface can be seen in Figure 4.5.

The result of this model is a daily average of radiation that is needed for further calculations of Human-Biometeorological that the ultimate value of thermal comfort is issued in PMV, PET and the SET, such as Figure 4.6..

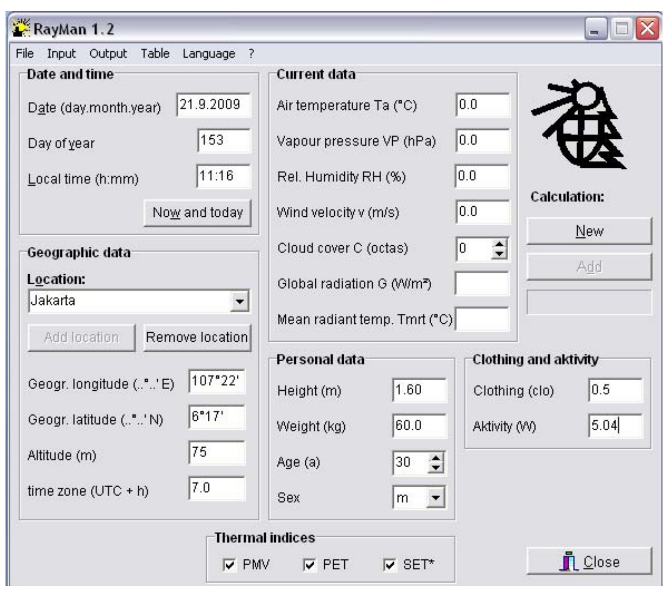
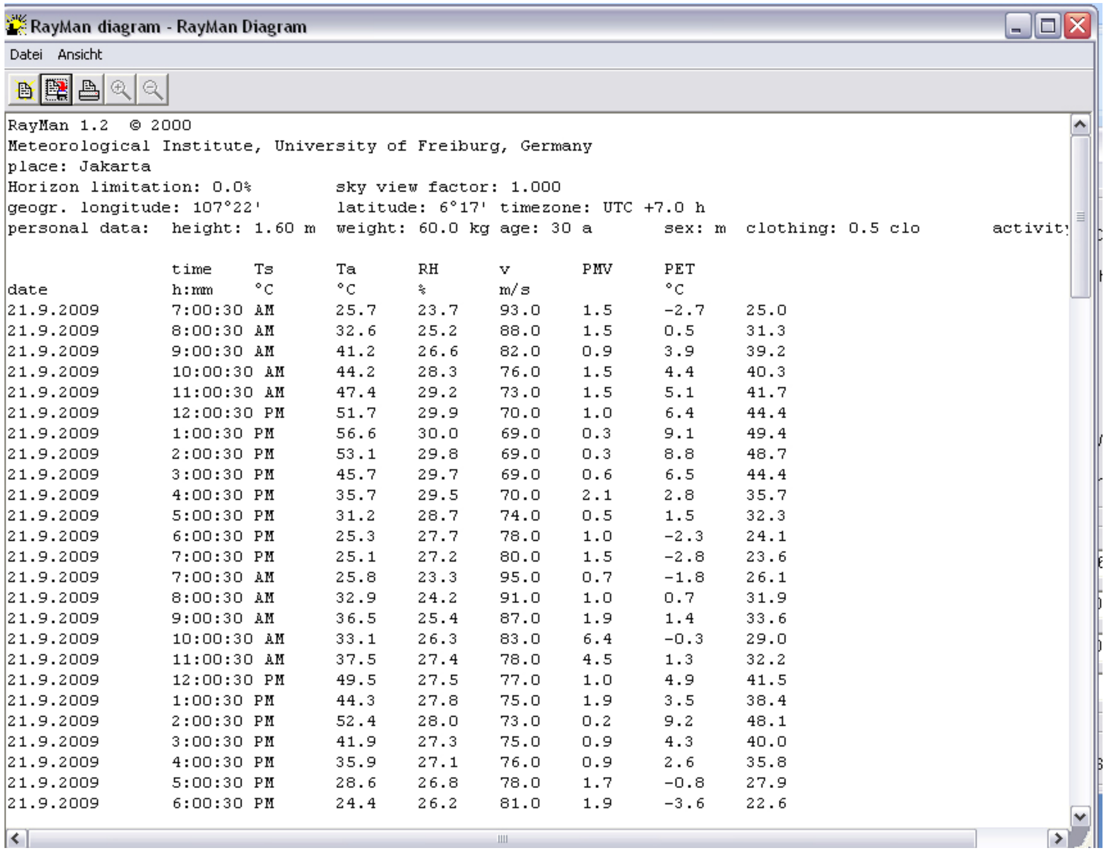


Figure 4.5. Rayman Interface



RayMan diagram - RayMan Diagram

Datei Ansicht

RayMan 1.2 © 2000
Meteorological Institute, University of Freiburg, Germany
place: Jakarta
Horizon limitation: 0.0% sky view factor: 1.000
geogr. longitude: 107°22' latitude: 6°17' timezone: UTC +7.0 h
personal data: height: 1.60 m weight: 60.0 kg age: 30 a sex: m clothing: 0.5 clo activit

date	time	Ts	Ta	RH	v	PMV	PET	
	h:mm	°C	°C	%	m/s		°C	
21.9.2009	7:00:30 AM		25.7	23.7	93.0	1.5	-2.7	25.0
21.9.2009	8:00:30 AM		32.6	25.2	88.0	1.5	0.5	31.3
21.9.2009	9:00:30 AM		41.2	26.6	82.0	0.9	3.9	39.2
21.9.2009	10:00:30 AM		44.2	28.3	76.0	1.5	4.4	40.3
21.9.2009	11:00:30 AM		47.4	29.2	73.0	1.5	5.1	41.7
21.9.2009	12:00:30 PM		51.7	29.9	70.0	1.0	6.4	44.4
21.9.2009	1:00:30 PM		56.6	30.0	69.0	0.3	9.1	49.4
21.9.2009	2:00:30 PM		53.1	29.8	69.0	0.3	8.8	48.7
21.9.2009	3:00:30 PM		45.7	29.7	69.0	0.6	6.5	44.4
21.9.2009	4:00:30 PM		35.7	29.5	70.0	2.1	2.8	35.7
21.9.2009	5:00:30 PM		31.2	28.7	74.0	0.5	1.5	32.3
21.9.2009	6:00:30 PM		25.3	27.7	78.0	1.0	-2.3	24.1
21.9.2009	7:00:30 PM		25.1	27.2	80.0	1.5	-2.8	23.6
21.9.2009	7:00:30 AM		25.8	23.3	95.0	0.7	-1.8	26.1
21.9.2009	8:00:30 AM		32.9	24.2	91.0	1.0	0.7	31.9
21.9.2009	9:00:30 AM		36.5	25.4	87.0	1.9	1.4	33.6
21.9.2009	10:00:30 AM		33.1	26.3	83.0	6.4	-0.3	29.0
21.9.2009	11:00:30 AM		37.5	27.4	78.0	4.5	1.3	32.2
21.9.2009	12:00:30 PM		49.5	27.5	77.0	1.0	4.9	41.5
21.9.2009	1:00:30 PM		44.3	27.8	75.0	1.9	3.5	38.4
21.9.2009	2:00:30 PM		52.4	28.0	73.0	0.2	9.2	48.1
21.9.2009	3:00:30 PM		41.9	27.3	75.0	0.9	4.3	40.0
21.9.2009	4:00:30 PM		35.9	27.1	76.0	0.9	2.6	35.8
21.9.2009	5:00:30 PM		28.6	26.8	78.0	1.7	-0.8	27.9
21.9.2009	6:00:30 PM		24.4	26.2	81.0	1.9	-3.6	22.6

Figure 4.6. The result of Rayma**n** simulation

4.3.2. . EnviMet Model

The Envi Met simulation begins to rise because of the early issues of the 21st century that the global trend of urbanization cannot be dammed with about 60% of the world population living in large urban areas (Bruse, 1998, Huttner, 2009).

The available space is limited not only leads to an increasingly dense urban areas, but also the urban sprawl into areas that are usually not intended for human settlements such as settlements in the desert or the occurrence of mega-cities in the tropics.

Build houses and open surface cause changes in environmental conditions in urban areas significantly, raising the question of how urban environments can be designed to offer the best climatic conditions for its citizens.

But not only extreme climate conditions in the region such as the desert can cause outdoor environment that is hostile, local conditions were not pleasant also be produced by the design of the urban poor as the effects of wind gusts caused by the effects of jet in the corner of the building, the accumulation of air pollution or discomfort thermal conditions outdoor.

Planers and architects who want to maintain or improve the quality of urban areas should be aware that the urban microclimate is a very complex system that consists of a nonlinear feedback loop of the many relationships between natural and artificial elements are different. A simulation of how the design of cities or buildings interact with the local climate is an essential tool to be able to describe the increase in the desired condition.

EnviMet model is a simulation model of the microclimate in the 3-dimensional shape (Bruse, 1998). EnviMet made to simulate vegetation, surface temperature and air flow in the urban environment, urban climate, as the thermal design of the building with the basic design, and environmental planning (Huttner, 2009). This model combines computation fluid dynamic parameters such as the flow of wind or turbulence the thermodynamic processes occurring in the soil surface, wall and roof structures or urban areas. With a typical resolution between 0.5 m and 10 m, this model can simulate geometric shapes and even complicated as a terrace, balcony or a complex. The EnviMet end the result is a color scale that shows the value of PMV, which corresponds to the value of thermal comfort.See Figure 4.7.

Color values which represent the value of PMV when linked with environmental characteristics can describe positions that cause the space into hot or cold in a thermal comfort scale. So that environmental characteristics can be assessed spatially using this EnviMet.

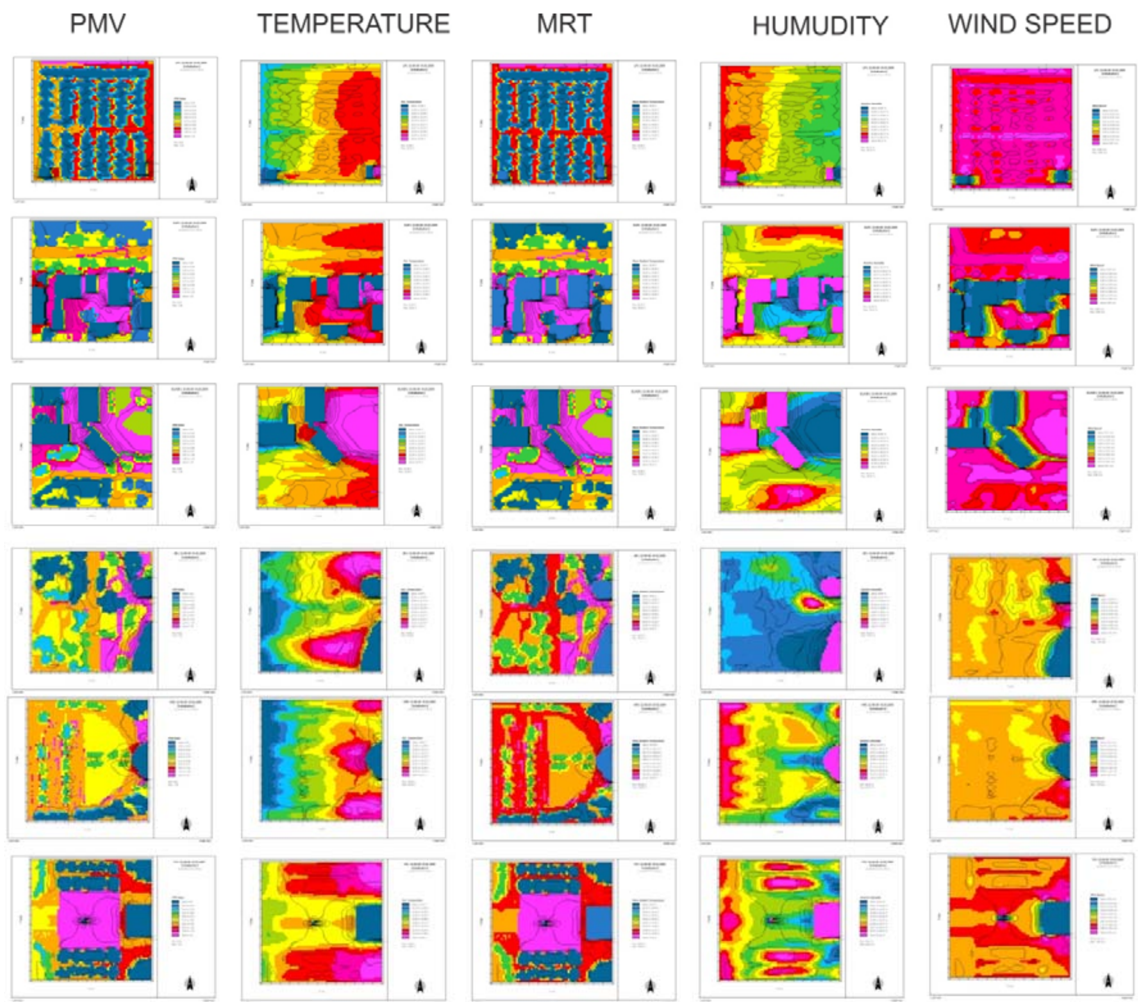


Figure 4.7. The Examples of EnviMet result

4.3.3. Sky View Factor Calculator Software

SVF Calculator is software to calculate the Sky View Factor . “SVF calculator is written in MATLAB computing language and is executed using the Matlab Compiler Runtime (MCR)” (Lindberg, 2010). The version 1.1. can calculate using two different methods. First the method that developed by Holmer (2001), using pixel-based method. Second produced by Johnson and Watson (1984), the method that developed using annulus. “The calculation procedure for annulus method make use of 45 annuli with a 5 degree azimuth interval resulting in that 3240 pixels in the hemispheric image is used in the calculation. The pixel method includes all pixels within the radius of the image. This result, for example, in approximately 404000 pixels that is examined in a 720x720 pixel image.” (Lindberg, 2010). For the process and results of the SVFCalculator can be seen in Figure 4.8.

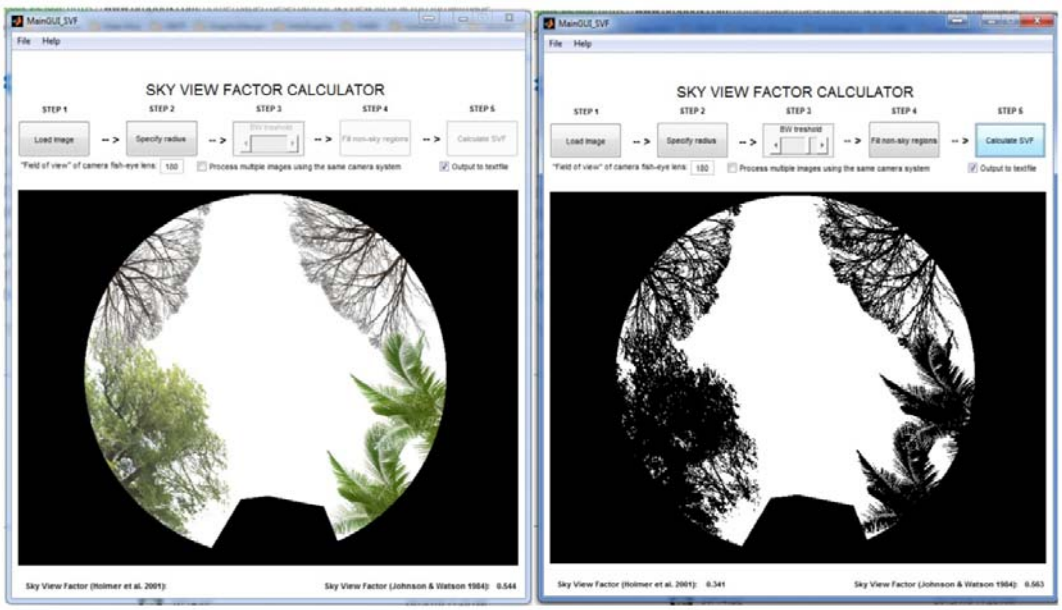


Figure 4.8. Process and the result of Sky View calculator

4.3.4. Statistical Model

In order to calculate and evaluate the urban structure affect the urban microclimate and thermal comfort, common urban structure and environmental characteristics, such as SVF (Sky View Factor), Building Height/Street Width, albedo, and Green Plot Ratio (GnPR) was compared with microclimate variables using the statistical package, R. Pierson's R coefficient (for normally distributed data) and Sperasman's rho coefficient (for skewed data) were used to analyze the correlation.

4.4. Methodology

4.4.1. . Research area

Indonesia is an archipelago country consist of about 17.000 islands, see Figure 4.9. Break-up by the equator, Indonesia is almost entirely in tropical climate. The coastal plains average temperature is 28°C, the inland and mountain 26°C, and the higher mountain regions 23°C. The east monsoon from June to September brings dry weather while the west monsoon from December to March is moisture laden bringing rain. The transitional period between these two is interposed by occasional rain showers, but even in the midst of the west monsoon seasons, temperatures range still from 21°C to 33°C except at higher altitudes, which are much cooler.

The seasons in Indonesia are divided into two distinct seasons, wet and dry. The climate is fairly even all year round. Heaviest rainfalls are recorded in December to January. Being in the tropical zone, Indonesia has an average humidity 80%, with a minimum of 70% and maximum of 90%. The main variable of Indonesia's climate is not temperature or air pressure, but rainfall. The equatorial air circulation and the meridian air circulation form the characteristic of climate and weather in Indonesia. The temperature of Java island, the main and populated island in Indonesia, throughout the year between 22° C to 29° C with humidity average 75%.

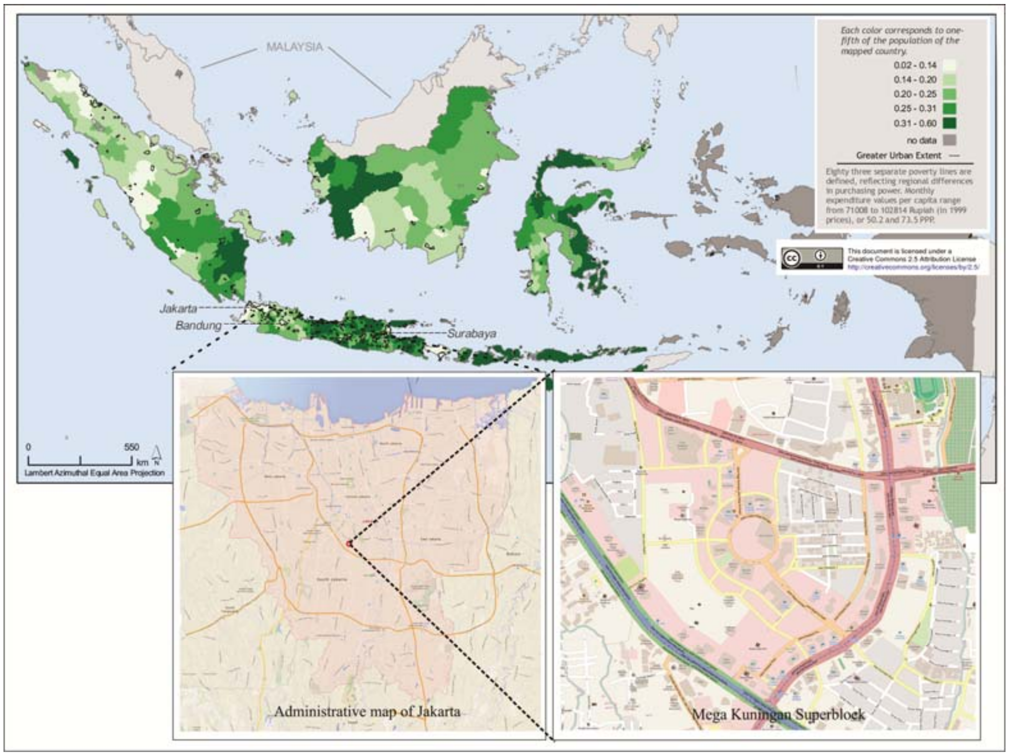


Figure 4.9. Location of research area

The wet season is from October to the end of April. North equator the heaviest rainfall is between November and April and dry seasons between May to October. In the south equator, the heaviest rainfall is between Decembers to February.

Winds are moderate and predictable, with monsoons, usually blowing in from the south and east in June through September and from the northwest in December through March. Prevailing wind patterns interact with local topographic conditions to produce significant variations in rainfall throughout the archipelago. In general, western and northern parts of Indonesia experience the most precipitation; from the north and westward-moving monsoon clouds are heavy with moisture, by the time they reach these more distant regions.

4.4.2. . Jakarta's Climate Condition

Jakarta located at 6° 13' S 106° 50' E on the northwest coast of Java, at the mouth of the Ciliwung River of Jakarta Bay, which is an inlet of the Java Sea. The city is a lowland area, average height is 7 meters above sea level. Officially, the area of the Jakarta is 662 km2 of land area and 6,977 km2 of the sea area. Rivers flow from the hilly southern parts of the city northwards towards the Java Sea. The most important river is the Ciliwung River, which divides the city into the western and eastern principalities.

Jakarta is a hot-humid tropical climate city that located in the western-part of Indonesia in South Equator. Jakarta's wet season rainfall peak is in January with average monthly rainfall 400 millimeters (16 in), and its dry season low point is in August with a monthly average 70 millimeters (2.8 in). The average daily temperatures range is from 25° to 36°C, which the hottest month is October and the coldest month is January. Jakarta area has an average wind speed 3ms^{-1} with south direction on May-October (wet/rainy season) and from east on November-April (dry season) annually Figure 4.10 and Figure 4.11.

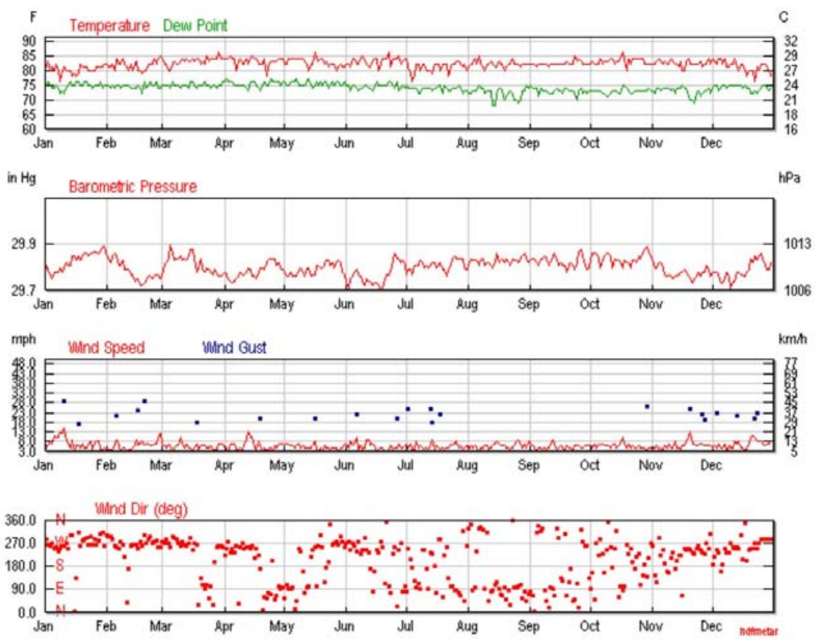


Figure 4.10. Seasonal pattern of temperature, air velocity, and relative humidity in Jakarta, 2013
(Source: Wunderground.com)

.

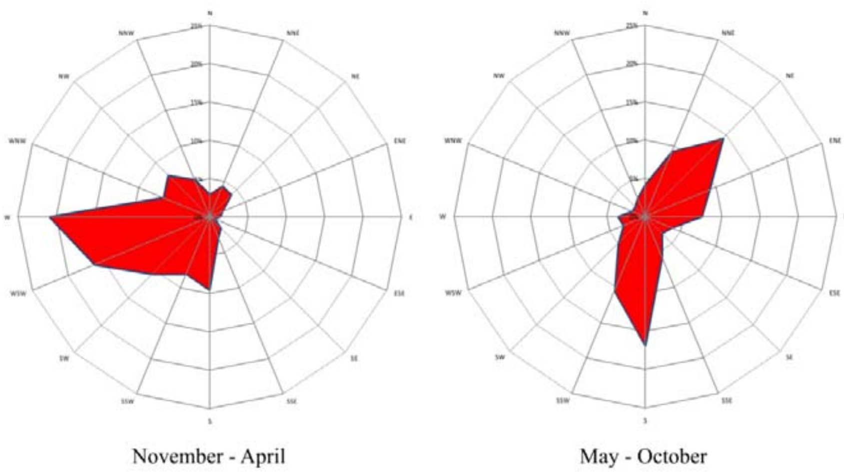


Figure 4.11. Wind direction at Jakarta on rainy season (November-April) and dry season (May-October), 2013

4.4.3. Location Study

The famous name of Jakarta is *Daerah Khusus Ibukota*-Special Capital City Region of Indonesia. Jakarta had become the capital city since 1945 when Indonesia proclaimed as an independent state. Since then apart as the state capital, Jakarta is also a center of economic growth in Indonesia. Jakarta has grown faster than Kuala Lumpur, Beijing and Bangkok leaped from ranking 171 to 17 in 2007 among the 200 largest cities in the world. Jakarta Megapolitan City's area is 662 square kilometers with almost 10.000.000 population in 2011. See in Figure 4.9.

4.4.4. . Thermal Comfort Measurement

A Sunny day without rain is an essential day to make field measurement in urban open space. Temperature (Ta), relative humidity (Rh %), and wind velocity (v, m/s) are measured based on the climate condition in Jakarta. The coldest month of the rainy season and hottest month of the dry season were the best periods to carry out the physical measurement. February and October are the best conditions. The weather in February and October in Jakarta are very stable, without rain and clouds, lower thermal oscillation and small variation of the relative humidity day by day.

The measurements were made on 3 February and 10 October 2013, in a clear sky, during 24 hours, from 1 am to 12 pm. The 8 points were chosen in the area include shaded, sunny and half-shade areas, to promote different possibilities of thermal conditions, see Fig.4. The eight points of measurement can be seen in Figure 3. The tools were used in the field measurement, i.e., Thermo Recorder RT 13 to measure temperature and relative humidity, LM 8000 to measure wind velocity, and EM 528A to measure Surface temperature. All sensors installed in 1.5 m above the ground and under factory calibrated. All data results were made into hourly means.

GIS data were used to obtain the urban structure data of Mega Kuningan Superblocks. The sky view factor (SVF) was made from Nikon DSLR and fisheye lens that captured from each measurement point. The RayMan 1.2 software is used to calculate SVF from the DSLR image (Matzarakis, Rutz, and Mayer 2007).

4.4.5. The most widely used thermal indices at present time

Mayer and Hoppe (1987) stated PET (Physiological Equivalent Temperature) was used to calculate the thermal comfort index. PET is widely known using °C in its unit. Therefore, PET has the advantage compared to other thermal comfort index (Hoppe 1999; Matzarakis, Mayer and Iziomon 1999). Base on the human energy balance of the human body PET is a very good match to the human biometeorological evaluation of the thermal component in any different climates. Therefore, it is suitable to thermal physiologically and reproducible.

The thermal comfort model prompts eight-point scale, from very cold to very hot, combining individual parameters (metabolism and clothing resistance) and environmental parameters (air temperature, air humidity, air temperature and radiant temperature). This research used the PET index stated by Lin and Matzarakis (2008), which suitable for tropical region like Indonesia, see Table 1.

PET index was suitable used for those theme parks where the level of comfort can be obtained from the features of the urban environment that already present in those theme parks. Matzarakis et al. (1999) stated PET has been well-defined as a thermal index that serves the thermal component in different climates.

Rayman model, developed by Matzarakis, Rutz, and Mayer (2007), was used as tools to calculate PET. This model enables estimate the mean radiant temperature, one of the most difficult parameters to calculate.

Gulyas et al. (2006); and Lin et al. (2006) reported that Rayman can predict the thermal environment. It has been used to calculate in several of outdoor thermal comfort with complex shading patterns. Lin et al., (2010) reported, PET can be estimated using Ta (temperature), RH (Relative Humidity), v (wind velocity), Tmrt (Mean Radian Temperature), human clothing and activity in the model. Moreover, several parameters can be added to calculate following analyses, i.e. the Tmrt (the most important factor during hot condition when calculating PET) can be also estimated by global radiation (Gr), cloud cover (Cd), fisheye photographs, albedo, the Bowen ratio of ground surface and the Link turbidity to include the shading effect while calculating short- and long-wave radiation fluxes. Besides variables above, the sky view factor (SVF) is another factor that affected the value of PET (Hwang et al. 2011).

Table 4.5. PET Index Source: Lin and Matzarakis (2008)

PET Tropical Region °C	Thermal Perception	Grade of Physiological Stress
> 42	Very Hot	Extreme Heat Stress
38–42	Hot	Strong Heat Stress
34–38	Warm	Moderate Heat Stress
30–34	Slightly Warm	Slight Heat Stress
26–30	Comfortable	No Thermal Stress
22–26	Slightly Cool	Slight Cold Stress
18–22	Cool	Moderate Cold Stress
14–18	Cold	Strong Cold Stress
< 14	Very Cold	Extreme Cold Stress

Gomez et al. (2013) reported the value of clothing and activity were assumed to be constant to set up the index. This model did not mean that the model has a limitation, if they vary equally outdoors and in the standard of the indoor situation, the PET does not significantly affected.

The following condition of this research had to be taken into account: the locations of the research; human-biometeorology; the factors of specific condition in the theme parks that affecting and distorting some meteorological component; the characteristic of each index regarding to their model and component.

The methodology of this research was to precisely measure the meteorology's variables, which became input data for the Rayman model, once the suitable locations had been chosen for this research and the different situation described for each of the objectives. This research objective is: Establish the comfort level of theme parks in different location and situation.

4.4.6. . Step-by-step walking comfort simulation

These step-by-step explain how to simulate walking comfort based on Matt deVau (2011, pp. 27), as follows:

1. Identify the study area and the time of year to collect the information of weather data.
2. Determined the four climate-based biometeorology inputs: use average field measurement to determine air temperature, relative humidity, and wind velocity on a typical day for three times of day – 7 am, 1 pm, and 5 pm. Used Rayman software to determine the mean radiant temperature ($T_{mrt)}$ value for three sample urban environments, shaded area, light shaded and unshaded area.
3. Used the established values in literature to determine the two behavioral biometeorology inputs, i.e.: clothing value (clo) for typical tropical business clothing for male, and metabolic rate for individual walking at speed 1.34 $m.s^{-1}$, or 80.4 meters per minute.
4. Identify the case study and determined the body surface area of the model, in this case, the model is Indonesian male.

5. Used de Dear's Human Heat Balance calculator to calculate skin temperature (T_{sk}) and evaporative heat loss through regulatory sweating (q_{sw}) minute-by-minute for every combination of urban environment and time of day.
6. Used the partitional calorimetry spreadsheet (Atkins and Thompson, 2000) to calculate the maximal evaporative capacity of the environment (q_{emax}) for every combination of urban environment and time of day. The partial water vapor pressure of ambient air (P_a) is calculated using the Visual basic interface in EnvironTab of the spreadsheet. The saturated water vapor pressure of skin surface (P_s) is determined from skin temperature (T_{sk}) values calculated by de Dear's calculator. All other calculation are made using equation 2-11.
7. Calculation skin wittedness (w) of the model in every environment, and the combination of time using equation 1 and q_{sw} and climax values determine from above methods. The values are calculated for each minute of the 30 minute period, and then every minute result values are compared with 0.3 wettedness values, which is the required value of comfort condition by (Gagge, et al. 1969); and 0.5 as the thermal comfort limitation by (Havenith, Holmer, and Parsons 2002).

Conclusions

The theoretical framework has to be structured in order to hold or support a theory of a research study. The framework of research is made not only to explain, forecast, and understand the phenomena, but also to challenge and extend existing knowledge within the restrictions of critical bouncing assumptions. The theoretical framework introduces and describes the theory that explains why the research problem under study exists.

Chapter 5

THERMAL COMFORT IN THREE THEME PARKS IN JAKARTA

Summary

This research presents the results of a study about thermal comfort measurement and evaluation in the theme parks. Physiological equivalent temperature (PET) is employed as a thermal index in this research. This research studied how climate impacts thermal comfort in the three biggest theme parks in Jakarta: Taman Mini Indonesia Indah (TMII), Kebun Binatang Ragunan (KBR), and Taman Impian Jaya Ancol (TIJA). Part of the large ongoing Urban Microclimate Space Research, this research that aims to investigate the influence of the microclimate on how urban public spaces are appreciated and used shown in a tropical humid climate thermal comfort is difficult to achieve with respect to open spaces. The results highlighted the need to expand the concept of comfort in the different concept of theme parks. This analysis shows that the location and the concept of theme park directly influence the formation of microclimate affected thermal comfort inside.

5.1. Jakarta's Bioclimatic Characterization

Jakarta located at 6° 13' S 106° 50' E, Figure 5.1., on the northwest coast of Java, at the mouth of the Ciliwung River of Jakarta Bay, which is an inlet of the Java Sea. The city is a lowland area averaging 7 meters above sea level. Officially, the area of the Jakarta Special District (Daerah Khusus Ibukota/DKI) is 662 km2 of land area and 6,977 km2 of the sea area. Rivers flow from the hilly southern parts of the city northwards towards the Java Sea. The most important river is the Ciliwung River, which divides the city into the western and eastern principalities.

Jakarta, the capital of Indonesia climatologically located between 060 06 '49 "S, 106 ° 37'59.08" E and 6 ° 18'2.38 "S, 107 ° 0'0.19" BT. As shown in Figure 5.2. Average the sun shines in Jakarta 12 hours in the sense that the long day and night in Jakarta is almost the same. See the solar chart of Jakarta on Figure 5.1.

The Köppen climate classification stated: Jakarta, located in the western-part of Indonesia in South-Equator, is a hot and humid equatorial/tropical climate (Af) city.

According to the meteorological data in 2012-2014, Jakarta's wet season rainfall peak is January with monthly average rainfall 400 millimeters (16 in), and reaches low-point in 70 millimeters (2.8 in) in its dry season in August. In whole years, Jakarta has an average wind speed is 3 m/s from 270° (west) with humidity (Rh) range 75-90, and average daily

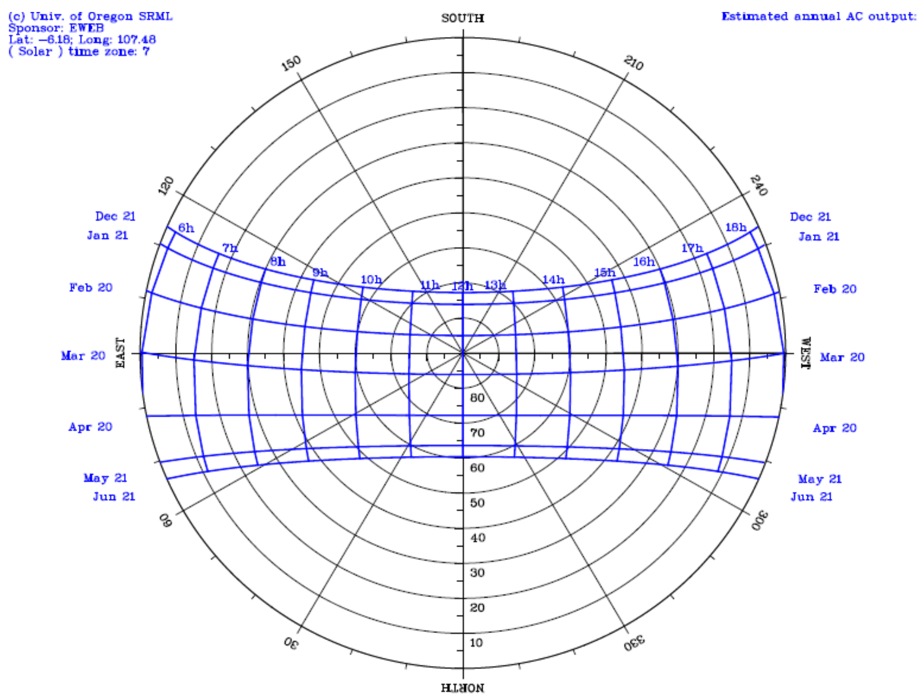


Figure 5.1. Solar Chart of Jakarta

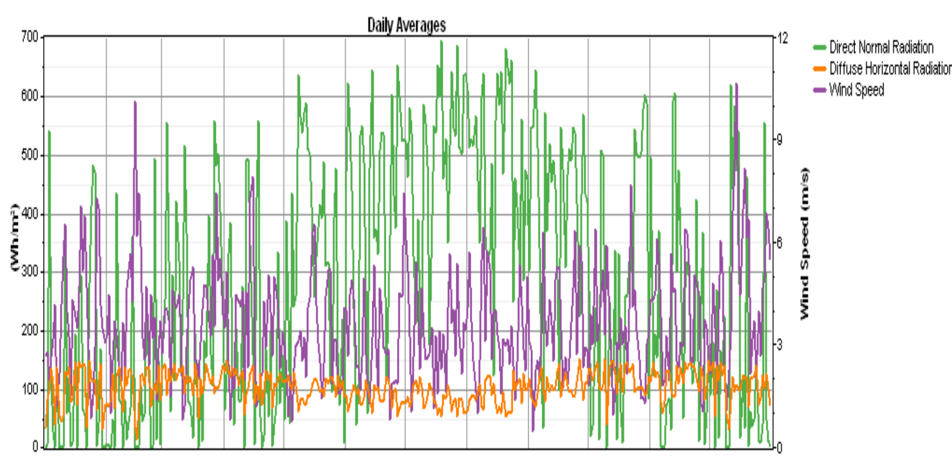


Figure 5.2. Seasonal pattern of daily radiation in Jakarta, 2013 (Source: Meteonorm,

2014)

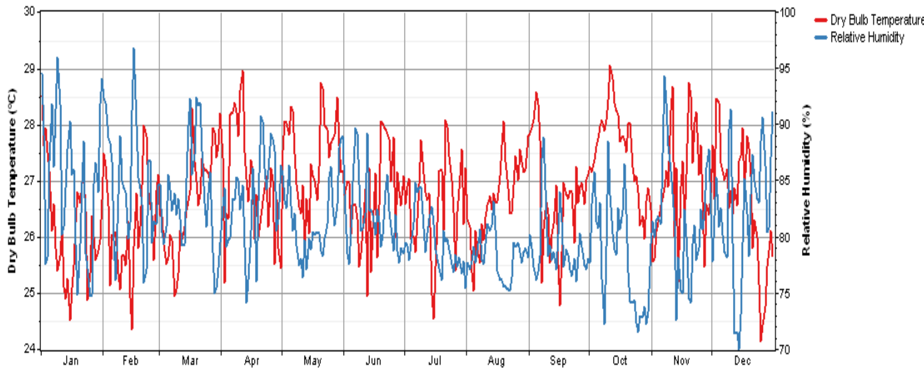


Figure 5.3. Seasonal pattern of temperature, air velocity, and relative humidity in Jakarta, 2013 (Source: Meteonorm, 2014)

temperatures range from 25° to 36°C. Thus Jakarta become hotter and the hottest month in Jakarta is September-October and the coldest month is in February-March, Figure 5.2 and Figure 5.3.

5.2. Case Study

A theme park is a type of protected area designated by some authorities. Theme Parks in Jakarta are administered by several different agencies. There are three big theme parks in Jakarta, see Figure 5.4, i.e.: a) Taman Mini Indonesia Indah (TMII); TMII is a recreation park that presents Indonesia Cultures divided into buildings, which every building represents Indonesia Cultures from East to West part of Indonesia; b) Ragunan Park (Kebun Binatang Ragunan/KBR) is a zoo, second largest zoo in Indonesia after Surabaya's zoo; c) Taman Impian Jaya Ancol (TIJA) administered by a private company is a modern theme park located at north beach of Jakarta.

The theme park is designed as a part of the city, which provided for recreational use. The design of a theme park may determine who is willing to use it. The most important elements of a theme park are attractions as they provide the main reason or motivation for tourists to visit. The aim of purpose-built attractions are to attract visitors and increase visitor numbers, but not all of the attraction in the theme park can be accessed because of the largeness of the theme park and the climatic condition.

5.2.1. Taman Impian Jaya Ancol (TIJA)

Taman Impian Jaya Ancol (TIJA), known as Ancol Dreamland, is an integral part of the Ancol Bay City, a resort destination located along Jakarta's waterfront (6°07'29.35"S, 106°50'35.45"E). Ancol Dreamland opened in 1966, and it is currently the largest integrated tourism area in South East Asia. TIJA with 552 Ha is boasting an international championship golf course, beach theme park, hotels and other recreational facilities. The concept of TIJA theme parks is modern theme parks with modern amusement facilities.

Measurement points in TIJA selected on the following points: see in Figure 5.5

5.2.2. Taman Mini Indonesia Indah (TMII)

Taman Mini Indonesia Indah (TMII) is an area of approximately 250 square kilometers, located in East Jakarta, Indonesia (6°18'6.8"S, 106°53'47.2"E). TMII is a culture-based recreational theme park. It is a representation of Indonesian culture captured in separate pavilions, with the collections of Indonesian architecture, clothing, dances and traditions. All are portrayed clearly all aspects of daily life in 26 provinces of Indonesia (1997). In the middle of the park, there is a lake with a miniature of the Indonesian archipelago and cable cars above. A part of the park there is a museum, Keong Mas Imax cinema, with theatre named My Homeland Theatre (Theater *Tanah Airku*) and other recreational facilities which make TMII one of the most popular for local tourist destinations in Jakarta. Culture, diversity in unity, is the theme brought to the visitors by TMII.

Measurement points in TMII selected on the following points, see in Figure 5.6

5.2.3. Ragunan Zoo (Kebun Binatang Ragunan/KBR)

Ragunan Park is a zoo located in the Ragunan area, South Jakarta, (6°18'42.45"S, 106°49'00.40"E). The zoo area of 140 hectares was established in 1864, also known Ragunan Zoological Park, Ragunan Zoo consist of Zoo and Park area. There are many attractions in KBR e.g.; the Schmutzer Primate Centre is a special enclosed house with various primates, including gorillas, chimpanzees and orangutans. The 13-hectares (32-acres) part of the KBR area are in the children's playground area include a Children's Zoo, playground and animal rides, along with the Sunday events of elephant ride, pony cart and boat rides on Ragunan Lake, and the orangutans watching deck on their daily tour of the zoo grounds in a pony cart. Restaurant facilities and picnic shelters are available for visitors' convenience as well as stands for purchasing souvenirs of the zoo.

Measurement points in TIJA selected on the following points, see Figure 5.7.

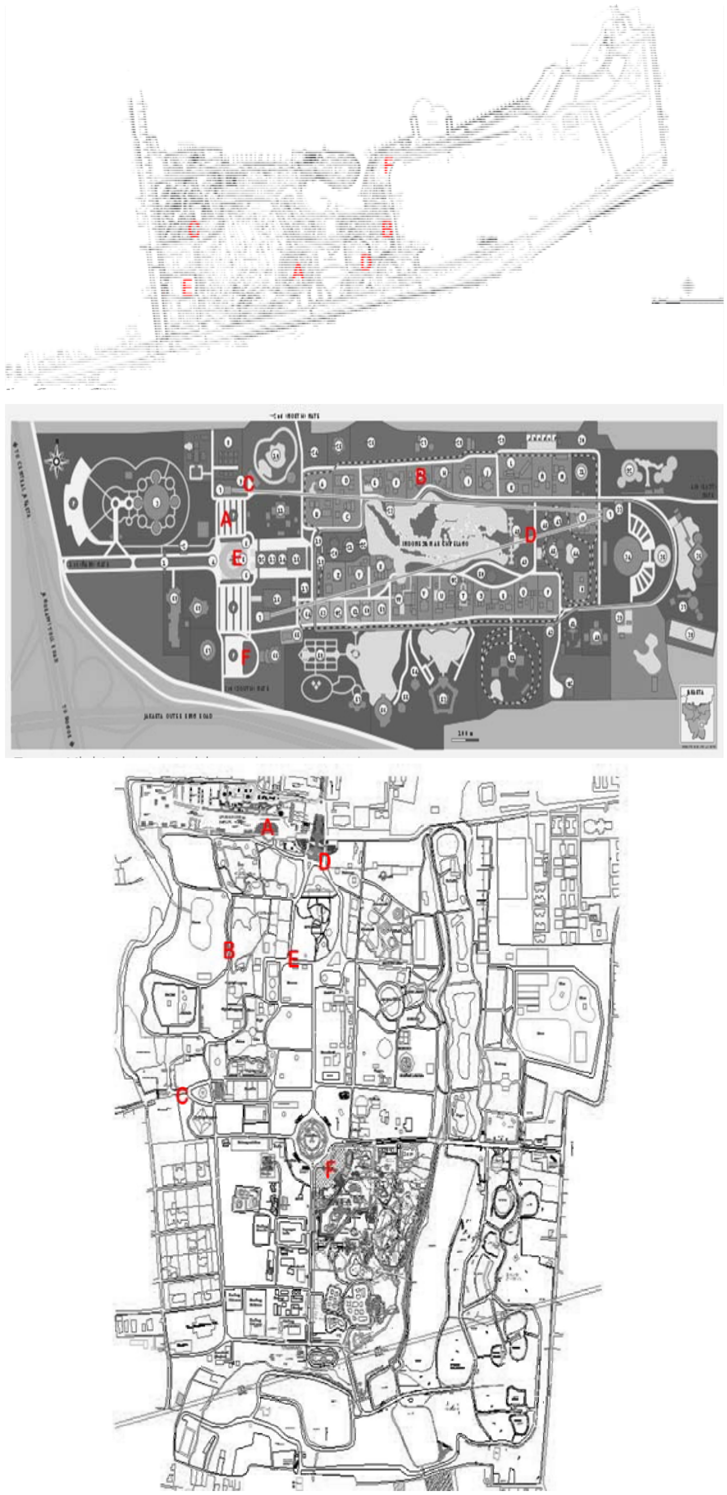


Figure 5.4. Map of TIJA, TMII and KBR, and the points of measurement

A	B	C	D	E	F
Art Market	Main Entramce of DUFAN	Galanggang Samudra	Entrance of Sea World	Dufan’s Parking area	Main Entrance of TI.

Figure 5.5. Environmental characteristics of TIJA at the measurement point

A	B	C	D	E	F
Main Parking Park	North Sumatra Pavilion	The Entrance of Snow Bay Water Park	The Entrance of Gelanggang Remaja	Pancasila Fire Sculpture	Keong Mas Park

Figure 5.6. Environmental characteristics of TMII at the measurement point.

					
					
					
A	B	C	D	E	F
Main Entrance of KBR	Elephant and Giraffe area	East Entrance	Flamingo area	The Entrance Picnic Park	The entrance of Prim area

Figure 5.7. Environmental characteristics of KBR at the measurement point

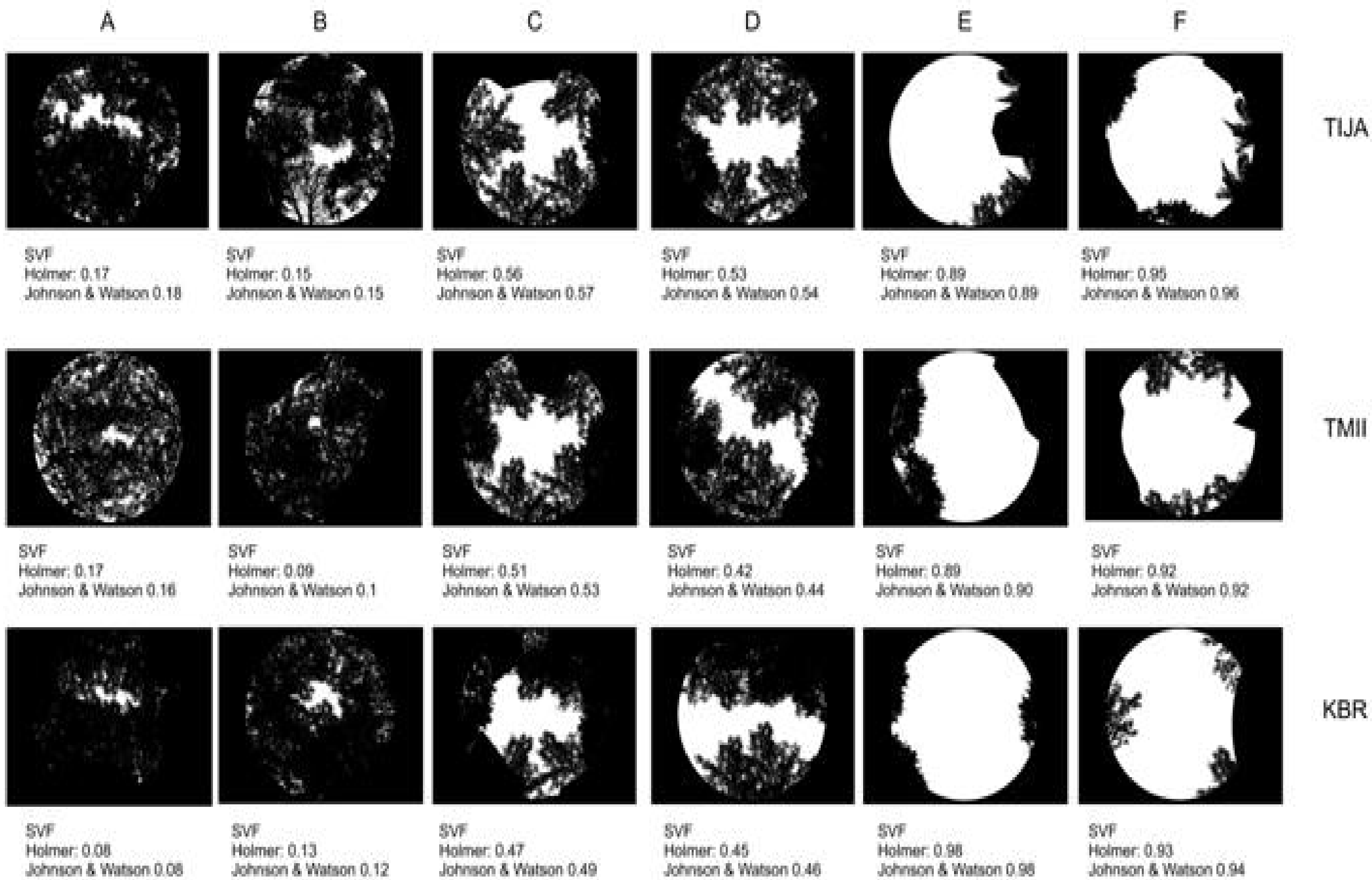


Figure 5.8. Value of sky view factor calculated by Sky View Factor Calculator by Lindberg and Holmer (2006).

5.2.4. Field Measurement

Data was collected on two consecutive years (2013-2014). The measurements were made on 21 March and 19 September, during 10 hours, between 7.00 AM to 17.00, regarding theme parks were opened.

The following equipment to measure, as follows: LM 8000, the surface temperature measuring device, and EM 528A are used during field measurements. All sensors installed in 1.5 m above the ground and under factory calibrated. All Data results were made every 10 minutes.

The six point measurement was conducted in each park and divided into 3 groups with respect to their different shaded area conditions based on Sky View Factor (SVF) value, Figure 5.8. The first group is the dense greenery (DG, SVF=0-0.33), the second group is Light greenery (LG, SVF=0.34-0.66), and the third group is sparse dense greenery (SG, SVF=0.67-1.0), see figure 4.5.

In this research SVF, Figure 5.8, was measured using images taken with one set of photographic equipment: a conventional camera (Nikon D80) with a fisheye hemispheric lens (Tokina 10 mm f4). The image from the camera was transferred to the Sky View Factor Calculator. Brown et al. (2001) stated that Sky View Factor Calculator is able to calculate the Sky View Factor (SVF) value on hemispherical photographs using a Graphical User interface (GUI).

Lindberg and Holmer (2006) reported in Manual Book of Sky View Factor Calculator version 1.1, the method of calculation in Sky View Factor Calculator based on two methods, first is the annulus method as presented in Johnson and Watson (1984) and the second is pixel-based method developed by Holmer (2004) and. Based on two methods the results of SVF value were similar in this measurement.

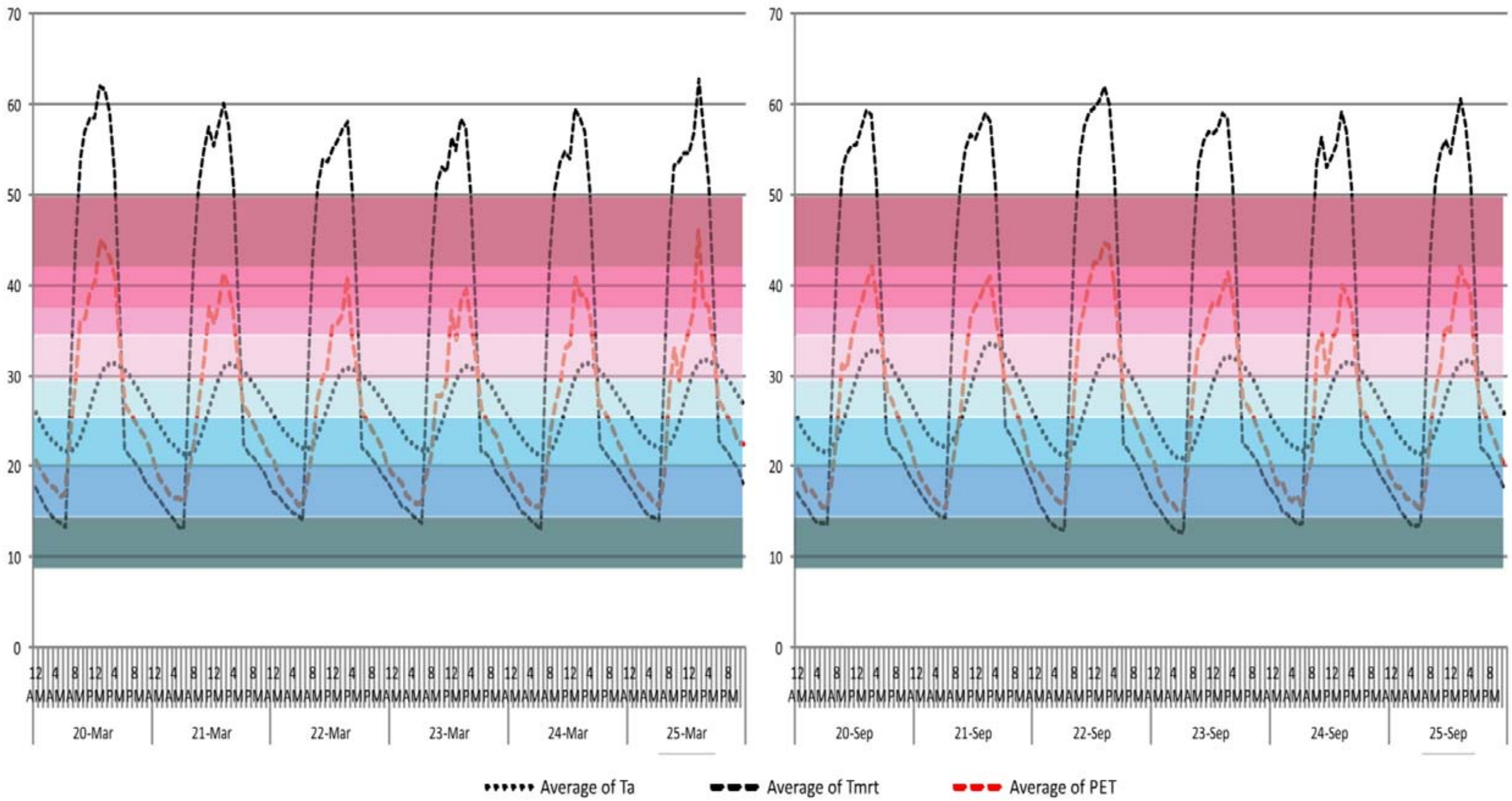


Figure 5.9. Average Ta, Tmrt and PET of Jakarta calculated by Rayman software based on weather data 2012-2014 show the results at the day of field measurement (March 20-25th and September 20-25th).

5.3. Measurement Results

Figure 5.9 shows during the days of measurement in March and September, Jakarta's thermal comfort was affected by macroclimate condition which shown uncomfortable. The data of Jakarta's macroclimate were accepted from two big weather stations from 2012-2014, Soekarno-Hatta International Airport weather station and Halim Perdana Kusuma Airpot.

Average PET values in Jakarta were above 30 °C starts from 11 AM and reached 45 °C at 3 PM, although in the morning at 7am was still in a comfortable condition, 22 °C PET, these conditions change quickly became uncomfortable in the afternoon.

Every district in Jakarta is affected by Macroclimate condition of Jakarta. Macroclimate on 19 September and 21 March, shows that the average temperature was at 28 °C varied from .24 °C to 32 °C. The morning temperature started at 24 °C where the temperature is the influence of the previous day with 95% humidity and wind speed 0 m/s.

5.3.1. Result of Taman Impian Jaya Ancol (TIJA)

From the measurement on March 21, shaded area with SVF 0.2 at TIJA A (Art Market) and SVF 0.25 in TIJA B at the site entrance of Fantasy World was still very satisfying in thermal comfort with the value of PET 24 °C, but this value continues rise due to the circulation of the sun that penetrate into the area. Temperature value continued rise from 0.2 to 0.5 °C. The peak temperature at this location occurred in 1pm which was 28.7°C and declined steadily until 5pm. See Figure 5.10. Assessment Result in TIJA on March and September of PET, Ta, Rh, and wind speed.

The value of humidity was starting with 90% in the morning because of the a bit overcast in the day before. The wind influence on thermal comfort at this location because the average speed is almost 4 m/s at the time of measurement, Figure 5.10.

Material Zone of the art market and the main entrance of DUFAN is made mostly from soft material and a little asphalt of the driveway at the main entrance of DUFAN. This was actually a slight disadvantage in the value of the albedo because this material much has a heat reflective. Besides this location, there are many standing buildings that gave diffuse radiation to this area.

Overall the location is still in the thermal comfort zone that can be tolerated, even though during the day the value of thermal comfort was at the pea0k uncomfortable with the value 32.9 °C PET occurred at 11am and in DUFAN the PET value was 35.6 °C, can be seen in Figure 5.10.

Peak hour discomfort between the art market and the main entrance DUFAN is not the same because of differences in environmental characteristics. The main entrance of DUFAN is asphalt slightly more dominant and made permanent building with material wall concrete and brick building with a height of two floors, this will reduce the wind speed and increase the reflection of radiation around the location, Figure 5.10.

On 19 September, the location of the art market becomes more uncomfortable, this was happening because of the higher humidity values 90% from the morning and the very low wind speeds 2.7 m/s on average. The peak uncomfortable value in Art Market occurred at 13:00 at a temperature 35.2 °C PET. The rain on the previous day in the Art Market thermal the thermal comfort condition is worsening, Figure 5.10.

The SVF in the main entrance of DUFAN is larger than the Art Market, The direct sunlight that penetrates in the area has advantage reducing the humidity. Additionally the cold air came into the area from the east that slightly open area. With an average wind speed of 3 m/s and a humidity of 80%. The peak uncomfortable in this location occurred at 12pm at 38 °C. The thermal comfort simulation on September 19th, can be seen in Figure 5.10.

On-site measurements of TIJA C that located at the Sea Worlds entrance has SVF value 0.44 and TIJA D that located at entrance of Gelanggang Samudara have SVF value 0,47, can be seen in the second picture, Figure 5.10. The temperature at that location is almost equal to the rate of the average wind speed 3.2 m/s and the humidity is at 87%.

Environmental characteristics of these two locations are dominated by paving and not so shaded by trees. The existing buildings surrounding is more likely to be open not filled by a high wall. At the location of the entrance of Sea World large building located on the west side.

With similar characteristics to the physical location of this site has the same value of thermal comfort in the morning at 07am the value of thermal comfort has been started with a warm, comfortable at position 24 °C PET and kept going to the peak at about 11am to 13pmx and dropping back after that, but impairment thermal comfort was not achieved the expected value of thermal comfort in a comfortable condition.

The second peak of discomfort at these locations is different a little bit at the entrance Sea Worlds discomfort peak occurs at 11am at 36.6 °C PET. Meanwhile, at the entrance of Arena Samudra discomfort peak occurred in 1pm at 36.7 °C. See Figure 5.10.

In September slightly different conditions on the measurement of March. At Sea Worlds locations more convenient conditions other than the SVF values lower than Arena Samudra many trees and buildings scattered around the influence of location will influence this value.

Peak discomfort at this location slightly shifted in September, at the location of discomfort Sea World peak occurred at 2pm hours at 35 °C and the ocean location rink at 12pm hours at 38.9 °C. The peak of discomfort occurs due to the shift of the wind speed has changed both direction and speed. With conditions slightly open on the southwest side of The Sea Worlds favorable wind can enter in September which tends from the west. Unlike the Arena Samudra location in southwest more positions covered by buildings and trees that significantly inhibit the rate of the incoming wind speed within the premises. See the chart of PET in Figure 5.10

With an average wind speed of 3 m/s at the location of Sea World with an average humidity of 78% make Sea Worlds is at 7am remained at comfortable limits. While the ocean location rink in the morning at 7am with a wind speed of 2.1 m/s and high humidity tends to 85% and the temperature has reached 25 °C make this location the morning already started with a warm comfortable position, see Figure 5.10. Suggests that thermal comfort tendency to rise in line with increasing time, also in tandem with the rise in temperature, and the declining value of moisture. A more open area with little paving impact more comfortable, Sea Worlds with little buildings that surround it can reduce the value temperature on the location of the measurement, the measurement location can be seen in Figure 4.9.

Both are almost the same characteristics of the environment, only met by paving and asphalt as ground cover without many around the buildings, with conditions very open without any trees and buildings blocking. For the measurement location in TIJA E and F, so it tends to get a rate that is relatively high wind speeds, an average of 1.3 m/s for DUFAN parking area and 2.1 m/s from the location in Round About with the evaporation speed humidity for two locations tends to be low at an average of 84%, see Figure 5.10 .

Thorough analysis, Ancol area illustrates that the trend in September thermal comfort in TIJA ride along with the hot temperatures and low wind speed in the region. TIJA shaded area in the region provides comfort a little better than the area that is not shaded. At 7am (7 am) all measurement points are still in comfortable circumstances and will likely begin to heat at 9am and the peak of heat occurs between the hours of 11am to 13:00.

Average winds in not shaded areas are larger than in a shaded area so not shaded areas have excess thermal comfort in the morning, but will be faster rise than in the shaded area as quickly receive direct solar heat.

Change the direction and wind speed have an impact on each measurement location, locations that covered by many trees and in the surrounding buildings will be less receive higher temperatures, so it still tends thermal comfort rise to heat, even though it is slower compared to open area.

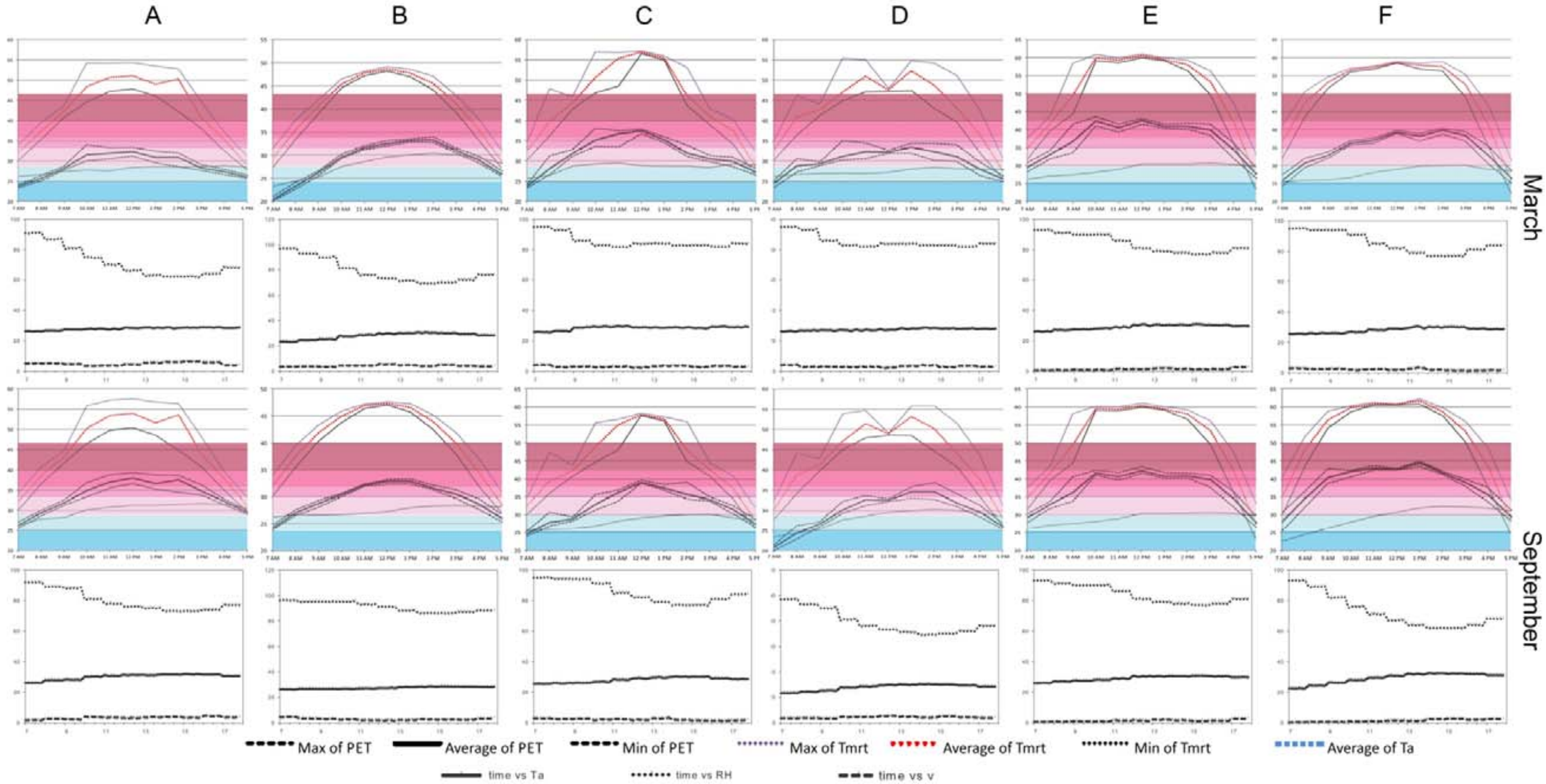


Figure 5.10. Assessment Result in TIJA on March and September of PET, Ta, Rh, and wind speed

5.3.2. Thermal Comfort in Taman Mini Indonesia Indah

Measurements on the field in March and in September in TMII produce some analysis as follows, see Figure 5.11.:

In the month of March in the location of measurement in TMII A (Main Parking Park), SVF 0.21 and B (North Sumatra Pavilion), SVF 0.37, with each illustrates that this location exists at the level of thermal comfort in the morning at 7am with warm cozy conditions.

At the main parking area which has a more dense tree with SVF 0.21 in the first two hours the temperature measured at that location is stable without any significant increase in the impact on the first two measurements of thermal comfort tend to rise slowed down, see Figure 5.11. Although this parking area is fully covered by asphalt. The closure of the trees tends to slow down the increasing of surface temperature. Average temperatures in March at this location is 27 °C with 82% humidity and wind speed of 4 m/s. While in September the average wind speed at 2.7 m/s with 75% humidity and temperature at 27 °C, see Figure 5.11.

Thermal comfort in the main parking area is likely to be cozy in the morning at 7am. The shadowing give the benefit at this location due to thermal comfort headed by slowing to peak at 12.00 in March and September. In March peak of thermal discomfort occurs at 32.4°C PET and September tend to rise to 32.7°C PET. While the performance of an average day rate of thermal comfort of this location is 28°C in March and 28.5 °C in September. See Figure 5.11.

At the location TMII B in North Sumatra Pavilion area when compared to the main parking area a little more heat. Environmental characteristics, that have many buildings around the measurement and ground cover a wider range of parking area temperatures bring a higher level and reduce the rate of the incoming wind speed in this area.

Figure 5.11 shows that measurement results that the average wind speed in this area is 2.6 m/s in March and 2.5 in September. Humidity is on average 66% in March and September 71%, this location is hotter than the main parking of TMII with an average of 28 °C on March and 26 °C on September.

The average of thermal comfort level is at 32 °C PET in March and 28 °C PET in September. Mornings tend to be still comfortable, heat peaks occurred at 13:00 hours at 34°C in March and in 12.00 at 36.3°C PET in September. Can be seen in the graph in Figure 5.11.

The measurement locations at A and B, with different levels of the shaded area, had a different result. Although the value of SVF in the location of A which tend to be smaller than B area, but the main parking area (A) to be more comfortable. The environment characteristic is different. The building shadowing has not been a lot of means to make conditions more comfortable than a location with a lot of tree cover.

The results of measurements at the Main Entrance Snow Bay Water Park (TMII C) and the entrance to Arena teenagers (TMII D) shows similarities in March, this is shown in the Figure 5.11. Seen from the measurement of microclimatic variables, both these locations have the same temperature level with an average humidity and wind speed are almost equal.

With environmental characteristics similar to the shade of a few trees and cover most of the surface of the paving and asphalt, the thermal comfort value of the two locations almost same. Location Snow Bar Water Park is dominated by paving and building one-story, parking location is for four-wheeled vehicles that will enter the water park. While the Entrance Arena of Teen dominated by paving and asphalt, but at the back of the garden there are several parks with grass covering the surface. In the eastern part there is existing building with a height of 4 floors of a game castle.

In March at Snow Bay Water Park average rate of temperature is 28°C with a wind speed 0.4 m/s and humidity 73%. While the youth center at the entrance level the average temperature was 27.5 °C and Rh 82% with a wind speed 0.4 m/s. So in March of this second location average of microclimate that thermal comfort chart have the same pattern.

Thermal comfort that can be seen in Figure 5.11, illustrates that thermal comfort in September at both these locations tend to rise. At the location of the entrance of Snow Bay Water Park is more likely to be hot, although not significant when compared with youth center areas. Heat peaks at the entrance of Snow Bay Water Park occurred at 12pm, while the area of the peak summer youth center was at 3pm. The heat peak at Snow Bay Water Park occurs at a temperature 40.2 °C PET and in the area of youth centers at 37.9 °C PET.

When you see the elements of microclimate that affects both locations can be understood that the average temperature in both locations at 27 °C with low wind speeds the rate at 0.6 °C and 1.5 °C in the youth center. Humidity in both places have an average that is almost the same at 77%. While the wind direction does not remain tend to vary with dominance comes from the southwest.

With characteristics very open environment, Figure 5.11. SVF 0.86 (TMII E), Pancasila Monument area and 0.74 for Keong Mas Park, with a few trees that shaded in both this area and the material tends to radiate heat makes thermal comfort in both locations is far from comfortable even though in area Keong Mas park on the morning at 7am still get a comfortable 19.3 °C PET, but the temperature rapid rise in in this area causes the thermal comfort level moving very fast-moving heat from a comfortable position of being comfortable warm (24.4 °C PET) in just over an hour. Likewise, in Monument of Fire heat very fast move from the comfortable conditions 21 °C to 26.2 °C PET in just over an hour. This illustrates that the elements of microclimate that moves in this area experiencing rapid changes both temperature conditions, humidity and wind speed rating. See Figure 5.11.

Temperatures in the area Pancasila Monument were changed from 23.2 °C to 24.9 °C while the humidity was changed from 91% to 85% at a rate of wind speed of 0.7 m/s to 0.6 m/s. This shows the indications of changes in temperature very quickly that the area is experiencing a warming temperature, due to the materials that reflect the heat quickly like granite, asphalt and no trees that resist sunlight coming in the environment. So it is with Keong Mas parking garden. See chart of thermal comfort in the Figure 5.11

The overall condition of TMII region can be described as follows, in fact shaded area with small SVF in TMII have far more comfortable conditions than areas not shaded at all.

The condition is not shaded or large SVF values tend to be more comfortable in the morning due to the amount of wind that blew unhindered in the morning can be seen from the table amount of wind in the annex, but tends to be faster uncomfortable over time, due to direct sunlight penetrate in the area, In the area of discomfort TMII peak occurs between the hours of 11am to 2pm in March and September where temperatures PET reaches an average of 39 °C.

In circumstances where the rate is far below the wind speed of 1 m/s thermal comfort conditions can be very hot above 40 °C PET. This occurs in an area that is not shaded like Ancol E (area Parking Keong Mas Park) and TMII F (Fire monument area) so quite vary as a recreational area, this condition into consideration to be improved, although that uncomfortable condition only happens in 1 hour from 1pm to 2pm.

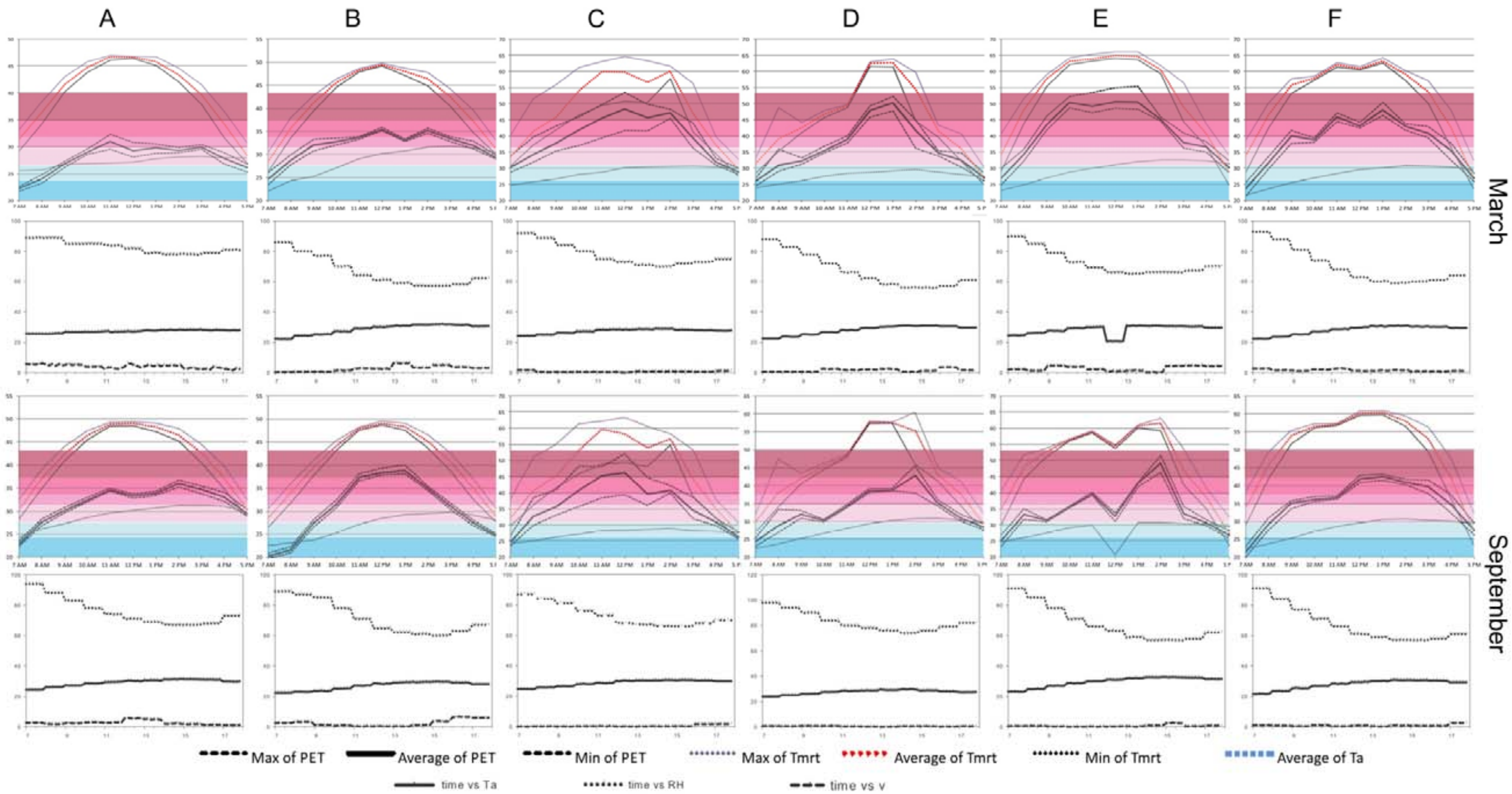


Figure 5.11. Assessment Result in TMII on March and September of PET, Ta, Rh, and wind speed

5.3.3. Thermal Comfort in Ragunan Zoo

Measurements on the ground in March and in September at Ragunan Zoo (KBR) produced some analysis as follows, see Figure 5.12.:

A KBR measuring point in the location of the main entrance (SVF 0.1) in the morning, starting at 7am temperature of 25.9 °C with 97% humidity and wind speed of 2.1 m/s produces thermal comfort at 22.9 °C PET, see Figure 5.12. With environmental characteristics that many large and shaded by vegetation and covering material conditions grasslands and little paving, this area is ideal as the main entrance into the zoo. See Figure 5.7.

Over time thermal comfort in this area increased to heat, although not extreme. Judging from the Figure 5.12 flatness of this graph illustrates that this area tends to be comfortable. Peak summer this area occurred at 11am at the time of measurement, because of low wind speed of 0.4 m/s and an increase in air temperature of 30.5 °C, while the air temperature peaks occur at 15:00 hours with wind speeds of 3.5 m/s.

KBR and around the park elephants and giraffes (B) with SVF 0.13 with state environmental characteristics similar to the main entrance have the same result. Figure 5.12 shows the flatness of the thermal comfort chart significant thermal comfort conditions in fully shaded areas in KBR is still in a comfortable condition in March. In the morning the temperature in this area at 25.8 °C with a humidity of 90% and the rate of wind speed of 1.5 m/s produces thermal comfort at 22.6 °C PET.

This comfortable condition happens for almost 4 hours until 11am hours convenient conditions, turn out to be hot at 30.7 °C PET. Peak discomfort in this area occurred in 13:00 with the degree of PET at 33 °C. This condition occurs as the summer peak wind downs to 0.1 m/s and a temperature rising to 27.3 °C areas. This situation illustrates that with a wind speed of 0.1 m/s are not able to block the incoming hot air in this area, and cannot afford anyway wind speed it brings cool air into the area, noticed that the moisture conditions at 13:00 still high 80%.

In September of thermal comfort conditions in both locations, seen from Figure 5.12 thermal comfort is generally not much different than in March. In September where the air is drier causing a shift in thermal comfort in the morning. At 7am thermal comfort state is in a position comfortably warm in both areas. At the main entrance, KBR A, at the beginning of the measurement of these conditions reaches 24°C PET and Elephant and Giraffe Park (KBR B the position is a 24.7 °C PET.

Thermal comfort conditions in two locations in September is rising rapidly because of discomfort shifting at 12pm PM at the main door entrance KBR and at 10:00 AM at the park elephants and giraffes. But continued to decline, but still in hot conditions and are back in a comfortable position warming at 17.00 at the end of the measurement.

In the graph of Figure 5.12 depicted a state of thermal comfort from two locations KBR C, Park East door, and KBR D, Flamingo Park. In the Measurement on March shows that both these locations on the morning begins with a comfortable condition and move up to the peak of thermal discomfort occurred at 11am to 2pm.

The flatness of the graph shown in the KBR C park east door that has SVF 0.58, with environmental characteristics more trees and a bit of the surrounding buildings, see Figure 5.12. Compared with KBR D, parks pelicans north, with SVF 0.

Peak thermal discomfort at KBR C, park east door, occurred at 2pm hours at 39 °C PET while North Flamingo Park occurred at 11am at 35.2 °C PET. The average temperature in KBR C is at 28.4 °C with a humidity of 75.7% and air speed of 1.7 m/s. KBR D has an average temperature of 28 °C with a humidity of 75.8% and a wind speed of 0.8 m/s. Conditions in March are almost 6 hours from 9:00 to 2:00 p.m. in hot conditions.

In September the situation in these two locations are not much different, just heat more rapidly achieved because in the morning, at 7am, the condition of thermal comfort has reached comfortably warm i.e. at 25.6 °C PET position in KBR C and 24.7 °C PET in KBR D. Peak thermal discomfort more quickly achieved at 11am on KBR C and 12.00 at KBR D.

A Long area in hot conditions in September has been started from 08.00 and almost 7 hours to 16.00 hours we will feel the heat with the heat peak at 38.1 °C PET in KBR C and 39.6 °C in KBR D. See Figure 5.12

The measurement results in the condition is not-shaded area in KBR, represented by E, in the Picnic Area entrance and KBR F entrance area of Primates. In March, the conditions in the morning the temperature in KBR 7am E at position 22.9 °C with thermal comfort position are still in a comfortable position. While at the entrance of the primates, KBR F, thermal comfort has entered into a warm comfort at 24.1 °C of PET with the temperature at 25.4 °C.

Environmental characteristics, see Figure 5.7, in KBR E and F dominated by paving impact thermal comfort. Picnic Area is better because located in amongst the buildings, while at the entrance of the primates there are two floors of the building on the east side to the fence that surrounds the south.

Peak thermal comfort in hot conditions, in two locations in March this happened in 1pm with 39.1 °C PET at KBR E and 40 °C at KBR F. The state of thermal comfort on two locations is almost the same as having the characteristics of the environment that is almost similar.

Similarly, in September, see Figure 5.12, state charts tend to be the same thermal comfort. In this chart tends to be hotter than March that showed higher heat levels. Interestingly, these two locations with SVF 0.78 for KBR E and SVF 0.82 which tend to be open to incoming sunlight in the region, thermal comfort is not much different than in March. Characteristic environment with many trees are still helping lower the temperature of the environment, see Figure 5.7.

Thoroughly region Ragunan Zoo is an area with many large and old trees located in the city center of Jakarta. Feels comfortable in shaded areas, especially in March, where high winds can enter the area.

In the morning, the value of the average thermal comfort is the comfort zone. Over time it will feel hot and peaked at 13:00 to 2pm hours. The graph shows the flatness of the thermal comfort in a sense, the value of thermal comfort tends to rise slowly toward the heat and after 13.30 hours decreased significantly, which means that the value of thermal comfort dropped drastically from the heat became uncomfortably warm at about 5pm.

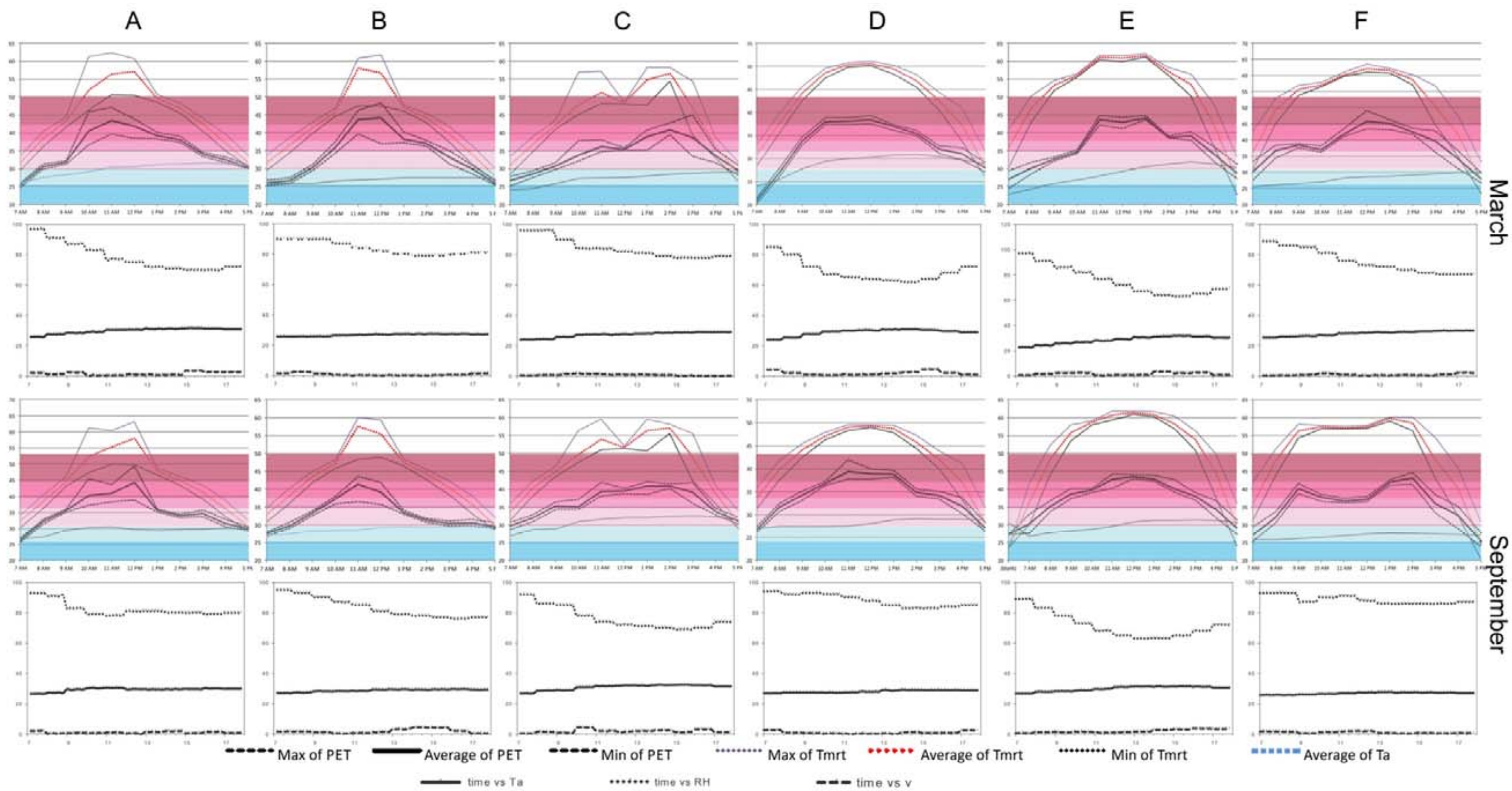


Figure 5.12. Assessment Result in KBR on March and September of PET, Ta, Rh, and wind speed

5.4. Urban Park Simulation of Thermal Comfort

In addition to measuring the microclimate variables, environmental characteristics measurement has to be performed. This measurement is done in two ways: direct measurement in the field and through the measurement scale images in this case wearing a CAD drawing.

Environmental characteristics were measured to assess the albedo, building orientation, the orientation of the open space and the Green Plot Ratio (GnPR) and Sky View Factor (SVF). Figure 5.5, Figure 5.6, and Figure 5.7 shows how the environmental characteristics assessed in an outdoor environment. Determination of the measured area is the area that coverage of 100m x 100m (Okay, 2006).

5.4.1. Validation of Simuation

This simulation in the theme parks use the initial condition as seen in Table 5.1. Boundary of the simulation is 100x100m as the border of microclimate that affect the area of measurement. Using the same grids to calculate the area of microclimate parameters. The parameters of microclimate that are used in this simulation were the average condition that taken from the field measurement.

The validation of simulation are the comparison between the average condition of thermal comfort (PET) from the field measurement and the result of simulation, the validation result can be seen in Figure 5.13. The R square is 0.6, shows there is strong correlation between the field measurement and the simulation.

Table 5.1. Initial Condition of Theme Parks Simulation

Boundary Model	100m x 100m	[SOLARADJUST]	
Grids	100x100	Factor of shortwave adjustment (0.5 to 1.5)	1
Start Simulation at Time (HH:MM:SS):	6:00:00		
Total Simulation Time in Hours:	24	[BUILDING] Building properties	
Save Model State each ? min	30	Inside Temperature [K]	293
Wind Speed in 10 m ab. Ground [m/s]	3	Heat Transmission Walls [W/m²K]	1.94
Wind Direction (0:N..90:E..180:S..270:W..)	180	Heat Transmission Roofs [W/m²K]	6
Roughness Length z0 at Reference Point	3	Albedo Walls	0.65
Initial Temperature Atmosphere [K]	296	Albedo Roofs	0.75
Specific Humidity in 2500 m [g Water/kg air]	16.5		
Relative Humidity in 2m [%]	80	[SOILDATA] Settings for Soil	
		Initial Temperature Upper Layer (0-20 cm) [K]	301
[PMV] Settings for PMV-Calculation		Initial Temperature Middle Layer (20-50 cm) [K]	301
Walking Speed (m/s)	0.9	Initial Temperature Deep Layer (below 50 cm)[K]	301
Energy-Exchange (Col. 2 M/A)	116	Relative Humidity Upper Layer (0-20 cm)	60
Mech. Factor	0	Relative Humidity Middle Layer (20-50 cm)	70
Heattransfer resistance cloths	1	Relative Humidity Deep Layer (below 50 cm)	70

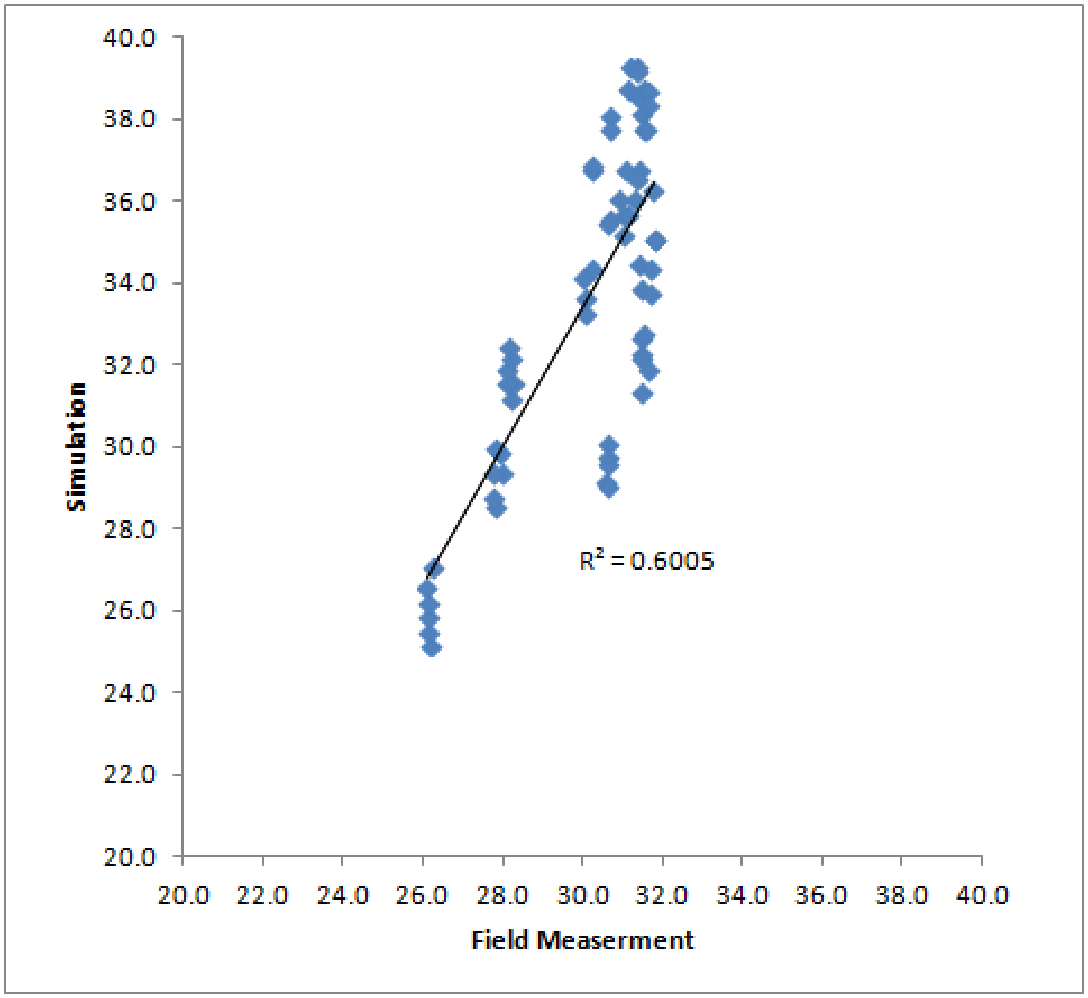


Figure 5.13. R square of average thermal comfort (PET) between field measurement and result of simulation

5.4.2. Simulation and analysis at Taman Impian Jaya Ancol Theme Park (TIJA)

In accordance with field measurements following is a description of the location for TIJA A (Art Market) and TIJA B (Fantasy World entrance). These two locations are included in the shaded group that filled with SVF 0.20 and 0.25.

In the area of art market, SVF is low because of the large trees that scattered in the location. 3.65 GnPR value has still lower than the scale of 10, but many scattered buildings surrounded on the first floor with the total wall 2539. 75m2 and the area covered by paving 30.7% total area. See Figure 5.14.

.

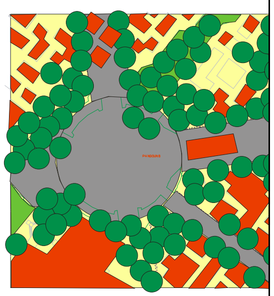
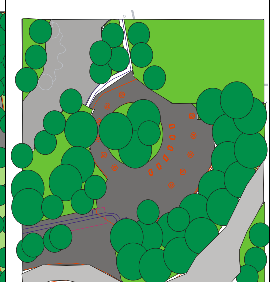
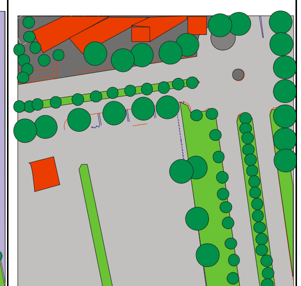
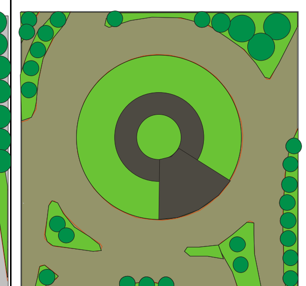
A	B	C	D	E	F
Art Market	Main Entramce of DUFAN	Galanggang Samudra	Entrance of Sea World	Dufan's Parking area	Main Entrance of TIJA
					
					
Paved area 30.7 GnPR 3.65 SVF 0.20	Paved area 63.01 GnPR 2.25 SVF 0.25	Paved area 50.04 GnPR 3.12 SVF 0.44	Paved area 12.87 GnPR 2.37 SVF 0.47	Paved area 72.27 GnPR 0.50 SVF 0.82	Paved area 65.16 GnPR 1.09 SVF 0.82

Figure 5.14. Paved area, GnPR, and SVF comparison of Environmental Characteristics at TIJA

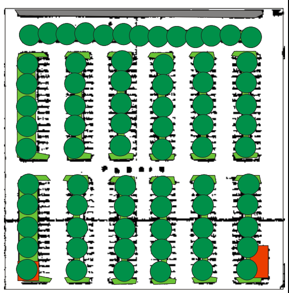
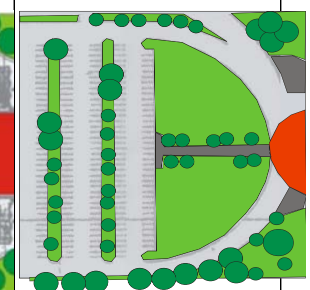
A	B	C	D	E	F
Main Parking Park	North Sumatra Pavillion Pavilion	The Entrance of Snow Bay Water Park	The Entrance of Gelanggang Remaja	Pancasila Fire Sculpture	Keong Mas Park
					
					
Paved area 82.17 GnPR 3..60 SVF 0.1	Paved area 42.46 GnPR 1.87 SVF 0.37	Paved area 56.45 GnPR 0.89 SVF 0.50	Paved area 53.17 GnPR 2.15 SVF 0.53	Paved area 56.19 GnPR 0.99 SVF 0.74	Paved area 70.06 GnPR 1.28 SVF 0.86

Figure 5.15. Paved area, GnPR, and SVF comparison Environmental Characteristics of TMII

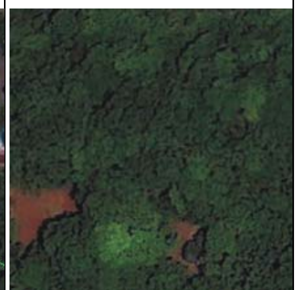
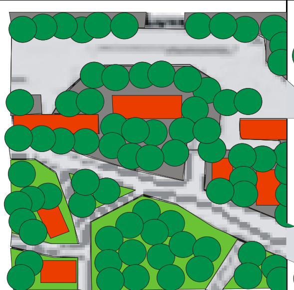
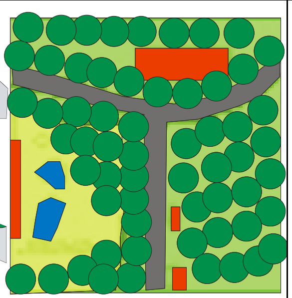
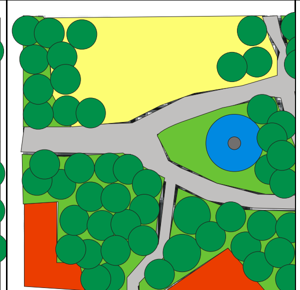
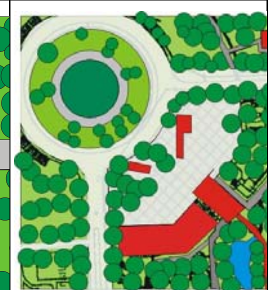
A	B	C	D	E	F
Main Entrance of KBR	Elephant and Giraffe area	East Entrance	Flamingo area	The Entrance Picnic Park	The entrance of Primate area
					
					
Paved area 67.58 GnPR 4.18 SVF 0.10	Paved area 11.99 GnPR 6.08 SVF 0.18	Paved area 19.32 GnPR 4.17 SVF 0.58	Paved area 49.92 GnPR 4.05 SVF 0.62	Paved area 21.24 GnPR 2.88 SVF 0.78	Paved area 35.13 GnPR 2.78 SVF 0.82

Figure 5.16. Environmental Characteristics of KBR

Figure 5.17 shows that the paved area is potentially being an uncomfortable area while the area under the tree is the area with the most comfortable thermal comfort, with the wind potential move from the northwest wind disadvantaged by their rate of building both in the art market as well as at the entrance of DUFAN. More complete simulation can be seen Figure 5.27.

In the simulation, it is clear that the potential wind speed and wind direction impact to create a comfortable thermal comfort. In the simulation means the color pink with PMV above 1.28 means there is heat stress, while dark blue is the PMV with a value below 0.5 mean comfortable. The pink color dominates the art market in the middle of the area where there are the most paving areas.

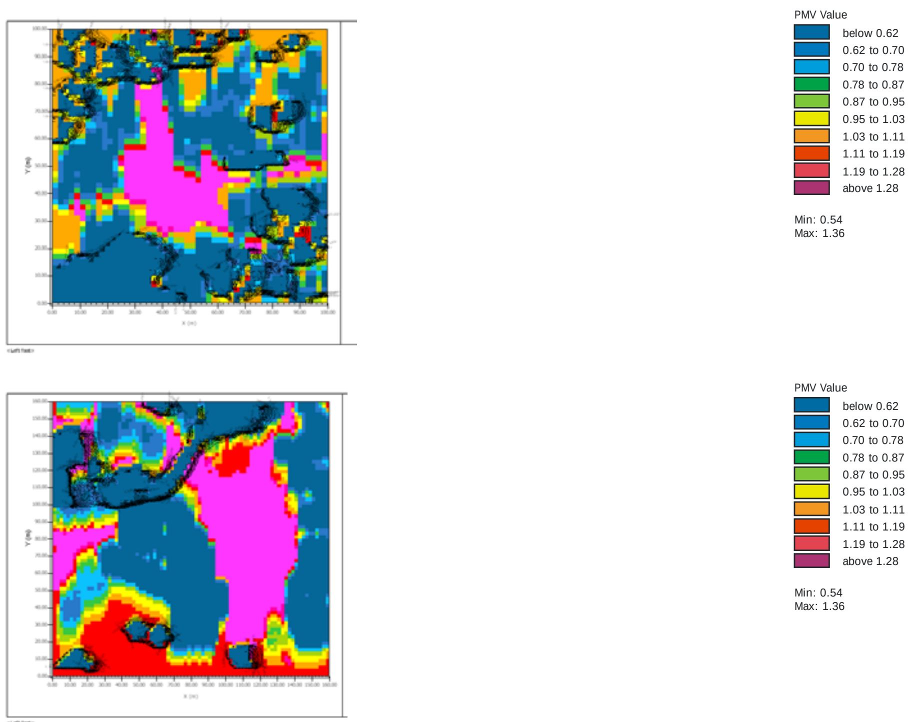


Figure 5.17. EnviMet simulation of Art Market (TIJA A) and Entrance of Dufan (TIJA B)

While in the Dufan entrance area with many paving had potential discomfort. The simulation Figure 5.17 shows the land is covered with the grass, but it still has the red color in which PMV value between 1.11 to 1.9 means that was in hot condition. In the art market where the wind speed come from the northwest have an impact on the building, where the wind speed is hindered by the two-storey building and a single storey. With this building barriers, wind speed can not enter into the area that affect this area increasingly uncomfortable because it cannot release the heat. The area under the trees to be convenient, but because the wind speed is too small,l comfort can not be taken to bring the area to be more comfortable.

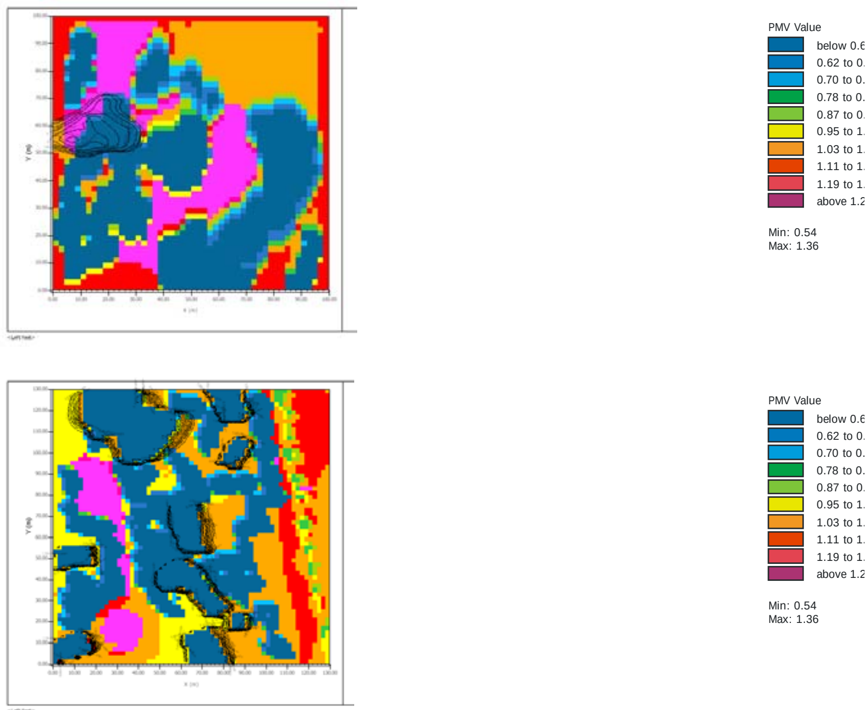


Figure 5.18. EnviMet Simulation of Entrance of Sea Worlds (TIJA C) and Entrance Gelanggang Samudra (TIJA D)

Characteristics the entrance of Sea Worlds has been paved area with 50.04% of the total area measured, with 3.12 GnPR no buildings around it and with SVF 0.44. Disclosure of these areas has an impact on the variation of thermal comfort, see simulations PMV in the Figure 5.18. Paving triggers discomfort in this area. Almost the entire area with paving has PMV above 1 where the thermal comfort was in the hot position. Orange color found on the grass in the northeast part of this area, where its value of PMV 1.03 to 1.11. Under vegetation area becomes more comfortable.

In contrast with the entrance of the Sea Worlds, the entrance of Arena Samudra surrounded by buildings. Wind resistance is very big in this area. With environmental characteristics with paving 12.87%, 2.37 GnPR, wall area 1886.7 m2, and SVF 0.47 has a variety of thermal comfort. Buildings that surrounded in this area affects the radiation penetration so the area is more cooling because of shadowing. In the simulation the higher buildings provide shade in the area to cool the area. At the same time they contribute hinder the wind. When the building is placed in the right position can provide better comfort.

The locations without shading such as a parking place, a Fantasy World, and Main Entrance thermal comfort tend uniformly hot, at 5.3 PMV. The PMV simulation area is colored in yellow where PMV between 1.03 to 1.11 which means it is still in the hot region. In the area without shading and open space on the other hand has advantage can bring the wind speed into the area to release the heat. But that should be considered how fast the wind speed can release the heat to change the temperatures in the area.

At the main parking of a Fantasy World the paving dominated nearly 73%, GnPR 0.50, and 0.82 SVF. 1st floor of the building as a security building that stood in this area, coupled with the building manager at the north of this region.

In the main Round About, asphalt and paving dominance reached 65.16%, 1.09 GnPR themselves with SVF 0.96. From the simulation image obtained figure 6.6 that asphalt can absorb more heat in comparison with other surface as the cover face of the land in this case granite or cement.

In the Figure 5.19 the simulation shows that the difference in shaded areas with no shaded area is 0.5 PMV scale, which means that if we move from under the tree that feels comfortable on a scale of 0.1 PMV and moved to the area with paving that has a scale of 1 scale PMV we will feel excessive heat, thermally feel discomfort, due to differences in the degree of comfort that is too large.

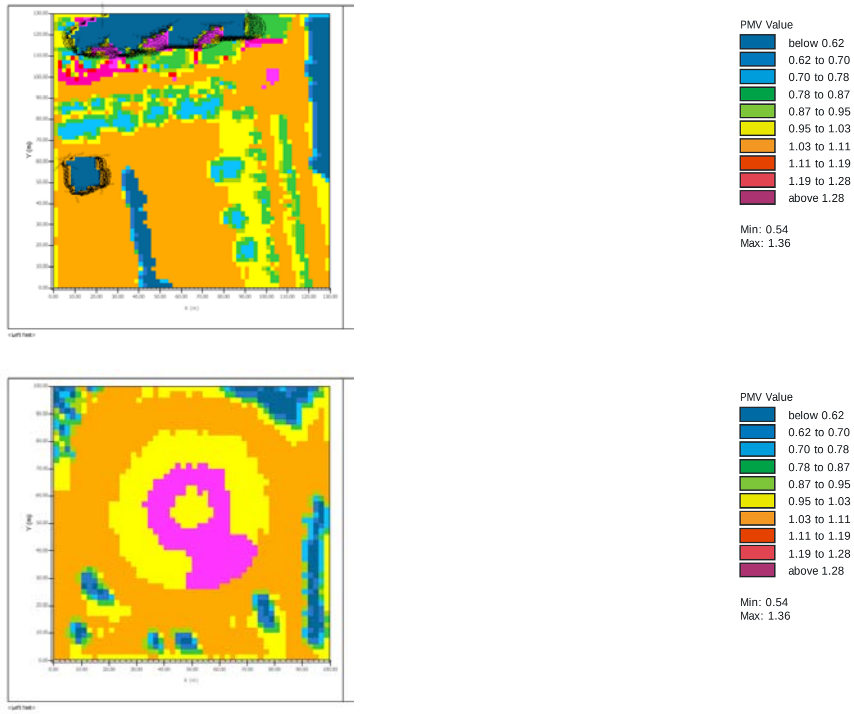


Figure 5.19. EnviMet Simulation of DUFAN park (TIJA E) and Main Entrance of TIJA (TIJA F)

5.4.3. Simulation and analysis at Taman Mini Indonesia Indah

The main parking field located at the north entrance of TMII in full shaded location. This location has the following characteristics SVF 0.1, GnPR 3.6, only 2% of buildings surrounding the area with a height of one floor have an area of 32 m2 the total building’s wall.

Existing buildings are not much affecting the general condition of the region, which is spatially still within the limits of comfort. Asphalt paving material dominated the land cover affect the comfort of their own, which in part under a trees comfort PMV scale was hot with an average of 0.95 to 1.11with the red color can be seen in Figure 5.20.

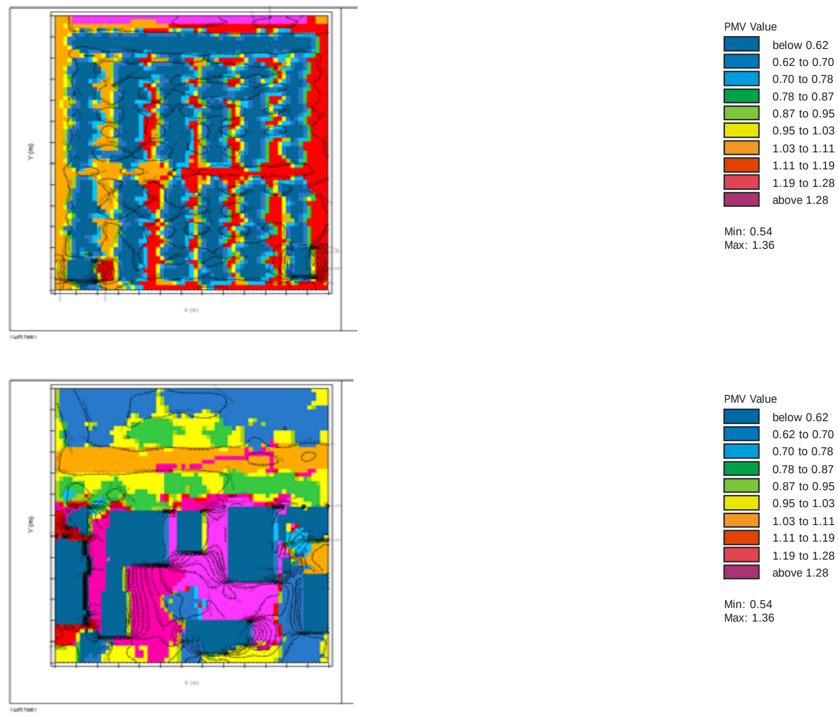


Figure 5.20. EnviMet Simulation of the Main Parking Park TMII (TMII A) and North Sumatra Pavillion Pavillion (TMII B)

While in North Sumatra Pavillion, although SVF Pavilion 0.37 but because it is dominated by buildings 21.8% and 42.46% paving the thermal comfort conditions showed more than 1 PMV. Figure 5.21 simulated that wind has disadvantage by the buildings and affected the reflected solar radiation trapped amongst the buildings, so the thermal environment around the building can not be released.

The entrance to the location of the Snow Bay Water Park, a half-open condition with SVF 0.50, GnPR 0.99, 56.45 paving and building of only 1.8% remained in a condition fit with the dominant scale of more than 1 PMV. Some parts under the tree fell on a scale of 0.5 PMV. Predominant wind coming from the northwest hampered by one storey building located on the western part of the area measured, so made the wind speed, lower in the area. The wind much stuck between buildings.

Some parts of the region such as swimming pools watery contribute to lower the ambient temperature even if the radius of the decline is not so high, about 1 m.

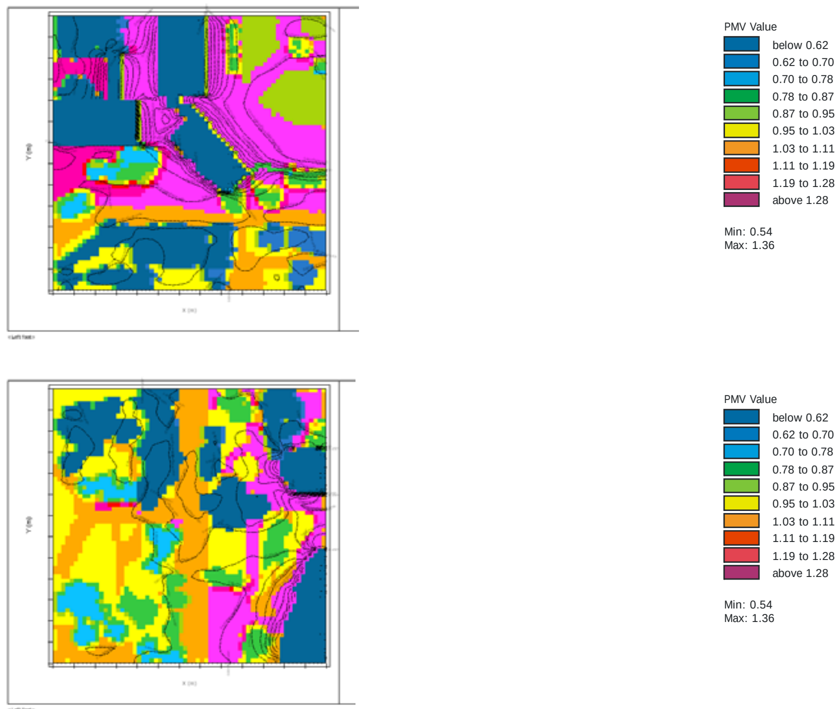


Figure 5.21. EnviMet Simulation of Entrance Snow Bay Water Park (TMII C) and Gelannggang Remaja (TMII D)

While in the arena entrance teen winds from the northwest have a significant impact on lowering the temperature of the thermal comfort of the western part of the region, the color yellow in figure 6.8. PMV simulations, suggests that thermal comfort in the paved area can descend on a scale of less than 1 PMV. But does not occur in the eastern part of this region because of the resistance rate of wind speed by the trees in western side impacts are paving the west side become uncomfortable at all on a scale of 1 PMV.

Under the trees still feels comfortable and only a few feel warm comfortable conditions. SVF location with large shadowing not at all like Keong Mas Park and Pancasila Fire Monument got the hot thermal comfort on a scale above 1 PMV that occurs almost throughout the region. The absence of trees that shaded cause the sun beam directly get into the area and speed up the process of heating material land cover. See Figure 5.22.

The rate of wind speed in those areas quite high, but not fast enough pace dispels the heat propagation into the region. The absence of sufficient moisture to cause regional cooling of this region is not fast enough to be comfortable. The average humidity was at 65% see more in the attachment.

The existence of grass cover on the park area of the Keong Mas Parking area is not strong enough to chase away the heat of the region.

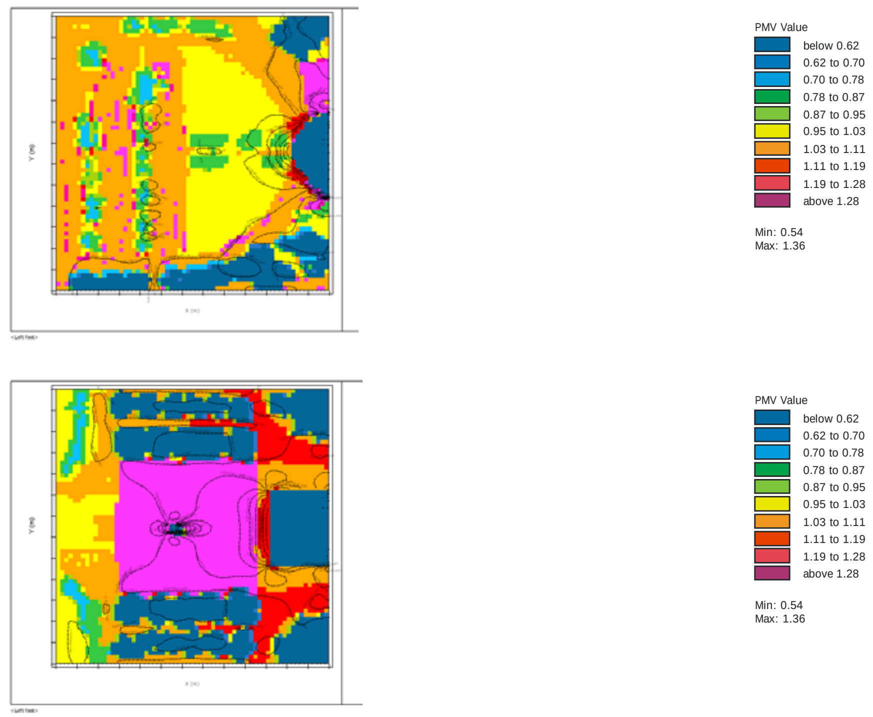


Figure 5.22. EnviMet Simulation of the Keong Mas Park (TMII E) and Pancasila Fire Monument (TMII F)

Overall thermal comfort TMII spatially in this region tend to be uncomfortable or in the hot position with a scale of 1 PMV. Thermally convenience only occurs in shaded areas. In areas with a large paving area becomes hot quickly and affect the region as a whole.

The rate of wind speed necessary to dispel the heat in the area, but the wind speed and direction changing is not strong enough and quick to dispel the hot temperatures that fall into the area in the form of solar radiation.

5.4.4. Region Spatial Analysis Ragunan Zoo (KBR)

At Ragunan Zoo thermal comfort patterns look not so varied. The Main Entrance doors as fully shaded areas, SVF 0.1, with 4.18 GnPR and buildings in the area occupy an area of 9. 21% with 61.8% paving area, including the area which is very convenient. In the spatial simulation, see Figure 5.23. Blue color dominates the area while the maximum PMV scale paving only be at 1.19 PMV.

Thus extents of GnPR influence in the region to relieve the temperature reaches thermal comfort. Domination of wind from the north can enter in the area because the north of the region was slightly open. Can be seen in Figure 5.23 where the wind contour covers the whole area. Wind speed of 0.77m/s to 0.9m/sec dominate the area throughout the region.

SVF little help relieve the region by reducing the temperature of the incoming sunlight in the region.

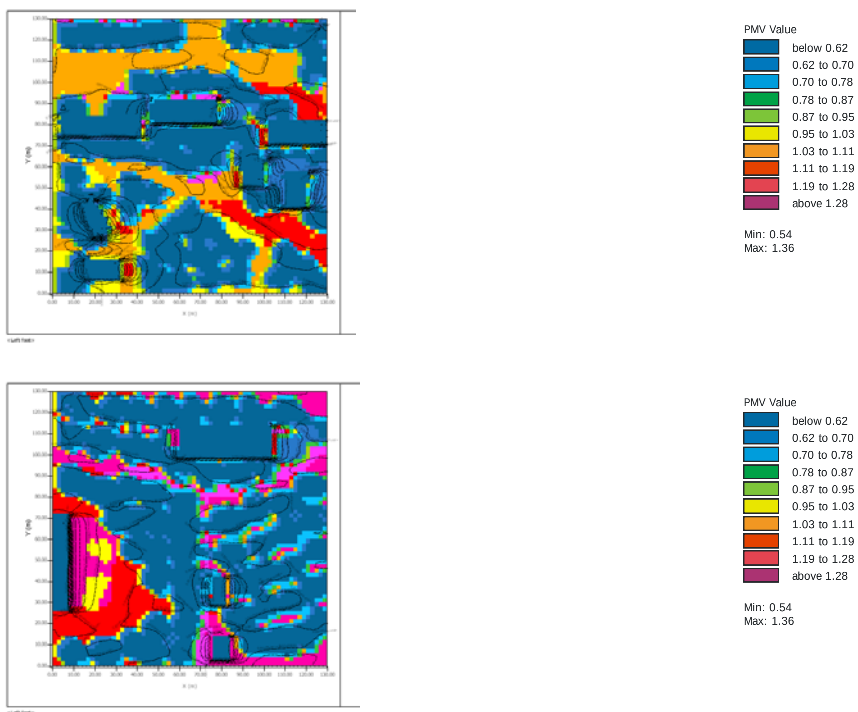


Figure 5.23. EnviMet Simulation of the Main Entrance (KBR A) and cage elephant-giraffe (KBR B)

While in the Elephant and Giraffe Cage area thermal comfort level is hot in some parts there are more than 1 PMV. GnPR area here is not so influential in relieving thermal comfort in the paving and open parts of the area. The dominance of the region covered by trees still has cracks to sunlight that heats some parts of the region.

The wind speed of 0.72m/sec is not strong enough to chase away the ambient temperature that propagate rapidly as the circulation of the sun. The pace of wind from the southwest that dominates is also not strong enough to bring moisture to dissipate heat under a tree on the parts open to the region. Figure 5.24.

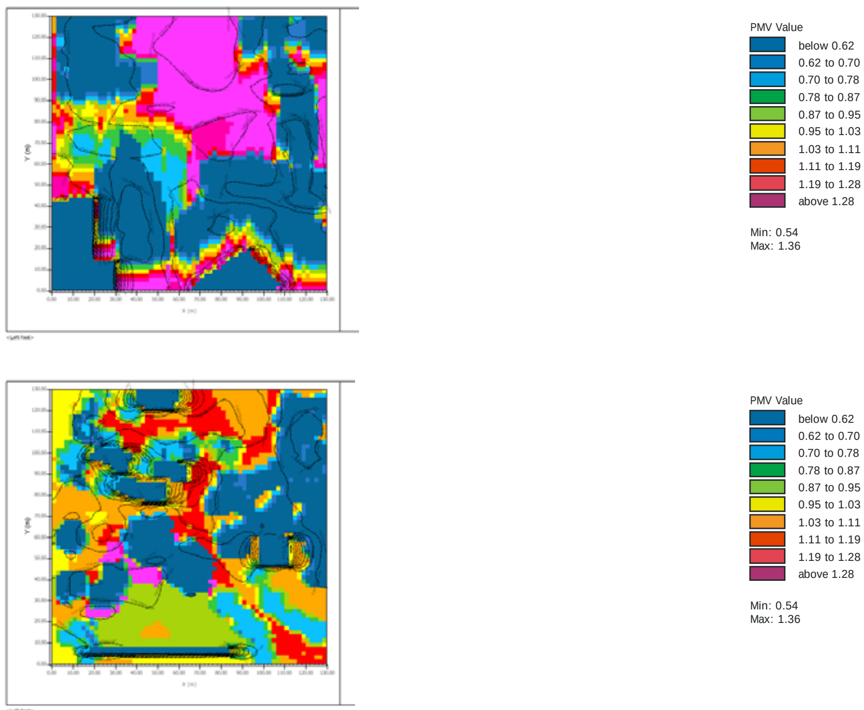


Figure 5.24. EnviMet Simulation of The Entrance of Picnic Park(KBR C) and Flamingo area(KBR D)

In the Figure 5.24, at the east entrance of the park and North Pelican Park, where both these locations have half the level of shaded, SVF values of 0.58 and 0.62 in the area of thermal comfort in open places. Hordes of trees in one hand bring good thermal comfort underneath, but cannot bring comfort to the whole region on the microclimate of the area (100m x 100m) this can be seen in the simulation PMV to Park East door.

While the trees are spread out better impact on the region, in the Pelikan Park North, PMV scale conditions over 1 less than the Park East door. Hordes of big trees also inhibit the rate of speed of the wind while the spreads tree in a better neighborhood in distributing wind speed and wind direction. With the distribution of wind speed and direction are good overall region can achieve thermal comfort expected.

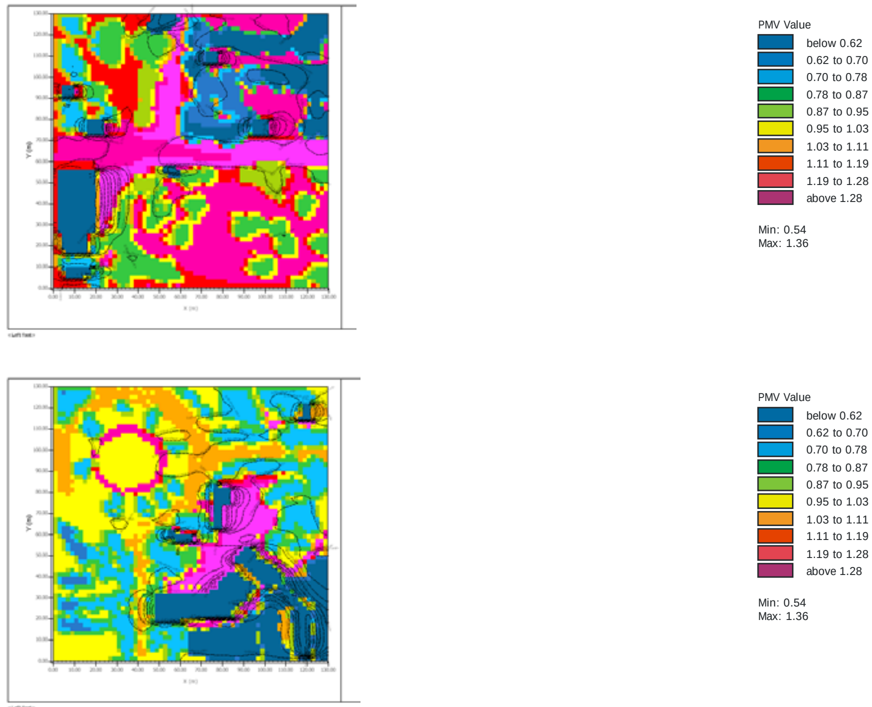


Figure 5.25. EnviMet Simulation of The Entrance of Picnic Park (KBR E) and The entrance of the primate area (KBR F)

At the entrance to the picnic area and the entrance Primate Center different patterns of thermal comfort even though these two locations have a shaded level with almost the same SVF 0.78 and 0.82. In the entrance area of Primate Center hot thermal comfort only felt in the paving area right at the entrance, while in the open area, around the roundabout, scale of PMV has the lowest thermal comfort. See Figure 5.25.

At the entrance of the thermal comfort picnic area perceived to be above 1 PMV value with paving dominance in the middle of the area and the area surrounding GnPR not be able to lower the temperatures are entered directly in the center of the region. Likewise the rate of wind pressure from the west hampered by the presence of a large building on the southwest side, so that the wind cannot penetrate into the region to be able to lower the temperature of the region.

Wind plays a role in lowering the rate of heat in this area, which is dominated by the wind speed from the southwest bring speed at 0.84 m/sec. See Figure 5.25.

5.5. Overall Analysis of the Theme Parks Simulation.

Overall thermal comfort simulation, Ta, Tmrt, Rh and wind speed of TIJA, KBR, and TMII can be seen in Figure 5.27, Figure 5.28, and Figure 5.29. Disclosure of the region on one hand brings advantages can include the rate of wind speed in the region. Changes in wind direction also play a major role in lowering the temperature of the comfort in the region.

Tree on one side of a regional benefit in lowering the temperature of the region on the other hand inhibits tree wind into the region. Regions with large SVF tend to be able to enter the wind into the region, otherwise the area with small SVF inhibiting the wind direction and wind speed the pace of entering into the area. Besides, the copse only a small role in the scope of the swarm the tree alone, more spreading trees will give a better impact on the regional scale in lowering temperatures are thermal comfort.

In lowering the temperature of an area of wind speed and direction will race over time with the entry of sunlight into the surrounding area causing radiation. Closure of an area would hamper the speed of rising temperatures in the region so that the pattern of increase in thermal comfort will be slowed down, if it is followed by the entry of the winds in the area with both the temperature of thermal comfort can be maintained in a state of comfortable throughout the day.

The pattern of PET value between Jakarta and the theme parks are similar. The macroclimate condition of Jakarta more over affected the microclimate condition in the theme parks. The three big theme parks did not achieve the expected thermal comfort during the measurement, average comfort condition only occurs 2 hours in the morning at 7 AM to 9 AM, after 9 AM the areas grew up to be hotter, start from 29 °C and reached the peak uncomfortable condition at 2 PM, 45 °C.

As we had predicted in Figure 5.26, the PET values in September are higher than in March. The reason of this is that in September the temperature increased, and the rainfall season started in Jakarta, humidity increased respectively. PET values in the three big parks illustrates that thermal comfort tends to increase along with the hot temperatures, high humidity and low wind velocity in Jakarta. In March, the condition is more comfortable and the condition just little bit more comfort than in September.

From the Figure 5.26 shows PET inside the parks still lower than the PET condition in Jakarta, Figure 5.9 was taken from the Soekarna-Hatta Airport Weather Station and Halim Perdana Kusuma Airport Weather Station during the 2 years from 2012-2014. In whole years thermal comfort condition is not much different in Jakarta.

The field measurement indicated that the average air temperature between 7 AM and 5 PM was above the required comfort level of air temperatures, whereas the neutral air temperature needs to be maintained at 28.2°C to reach the thermal comfort (Humphreys, M.A, Nicol, J.F. 2001).

Average Relative Humidity was about 90% at 7 AM, 65% at 2 PM and went up to 80% in 5 PM. At 7 AM averages Rh almost same, Rh difference between SG and DG are about 20% at 3 PM. The results emphasized the highest relative humidity in DG area. The air velocity fluctuated from 1m/s to 6m/s. DG area air velocity can reach 6m/s at 4 PM, in the DG average air velocity from 7 AM to 3 PM is stable about 3m/s, in SG; air velocity at 7 AM is lowest 0.5m/s.

Conclusion

The results of the thermal comfort analysis of this research have proven that comfort is mainly affected by exposure of solar radiation. The comparison of all orientations shows that the best thermal comfort conditions occur in dense greenery. The best conditions occur in KBR, which area with more greenery than TIJA and TMII.

The PET values of Less Greenery (LG) are higher than Dense Greenery (DG). The reason of this is that in LG there is greater capacity of heat accumulation, in the surface and the ambient, because of the openness area. In this case LG areas have little bit benefit of the wind velocity at least can refresh the area from the heat. Otherwise DG areas are closer to the wind, thus the wind velocity is slower, but giving rise to a lower radiation value.

The wide range of microclimatic conditions in TIJA, TMII and KBR strengthens the point that a purely physiological approach is inadequate to characterize thermal comfort conditions outdoors, whereas the issue of adaptation becomes increasingly important.

Shaded areas in the region provide comfort slightly better than areas that are not shaded. At 7 AM all measurement points were in comfortable circumstances. Trees provide shadowing can be considered not only as an element of design, but also provide thermal comfort in the whole year.

Architects and landscape designers usually do not consider designing innovative element and soft surface to reduce heat in hot areas, such as in Jakarta. They design hard surface material which can lead to great reflectivity and higher heat load. The case can be seen in area E and F in the theme parks, especially in the hot season, due to the enormous amount of heat accumulated by the surface element. They have to be creative design the materials which can create a specific condition in outdoor spaces.

By researching these case studies, it has been concluded that PET index mostly stable, because it can clearly depict the variety of human-biometeorological parameters in different image of hot-humid tropical country.

This result is very important for an architect, urban planner, and landscape designer, who concerned to find better design, especially for theme parks and generally for open space in the cities.

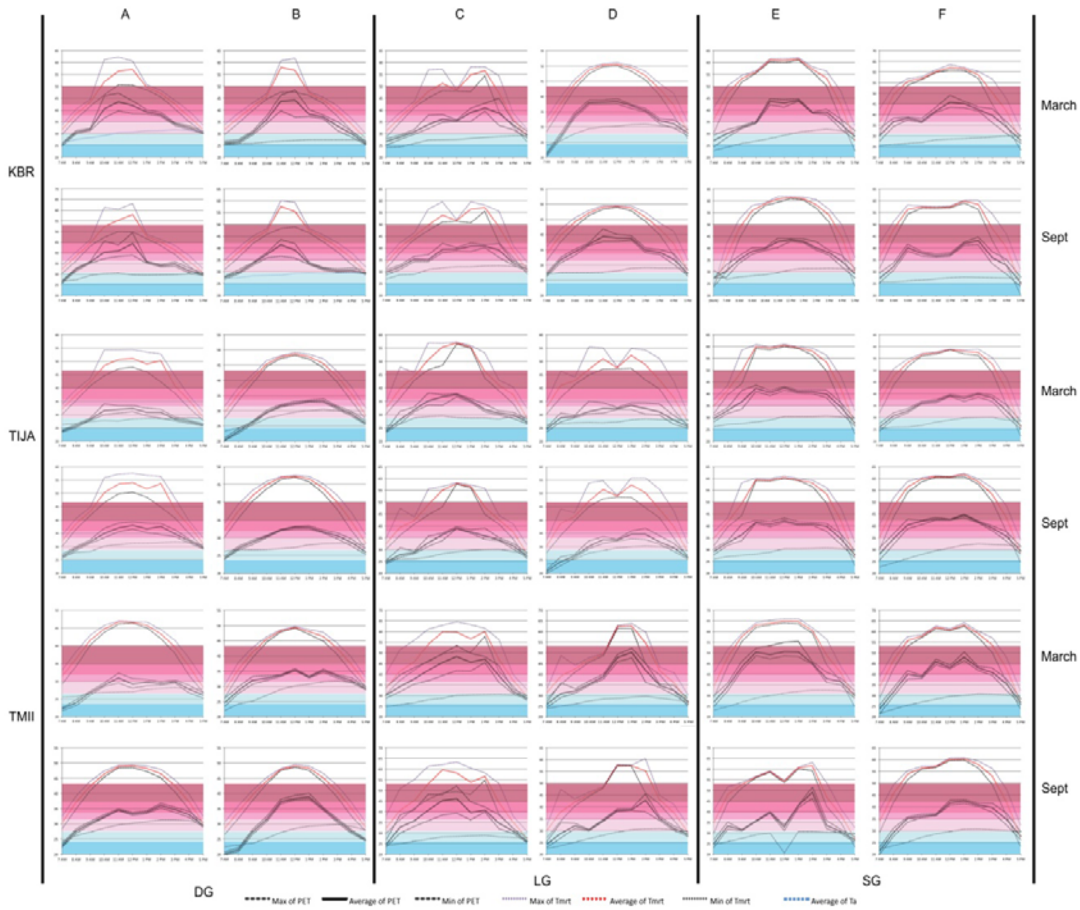


Figure 5.26. PET comparison values, average Tmrt, and Ta of measurement result of three big theme parks (TIJA, TMII, KBR) at March 21st and September 19th from 7 AM to 5 PM

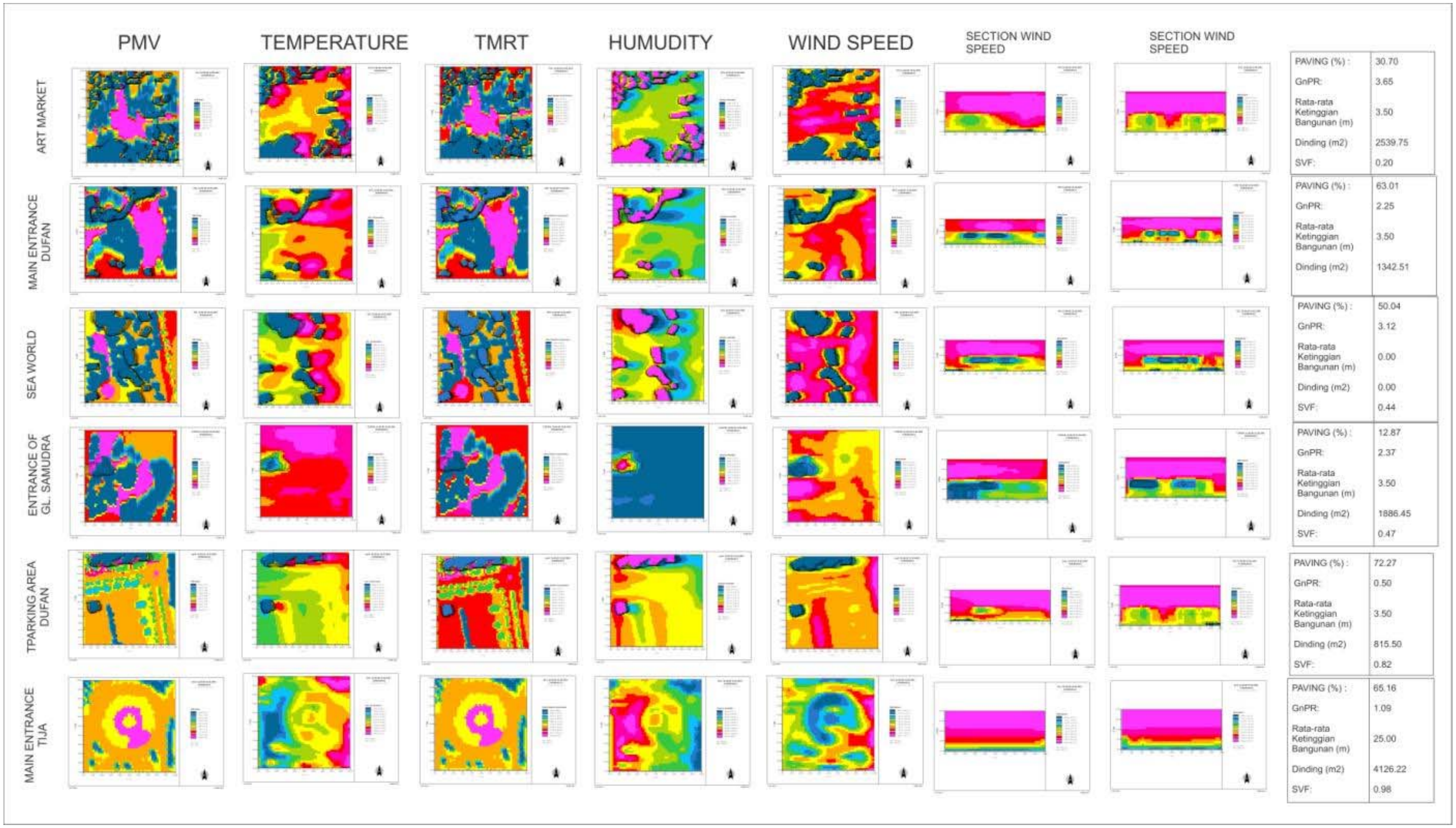


Figure 5.27. Overall of EnviMet Simulation of TIJA

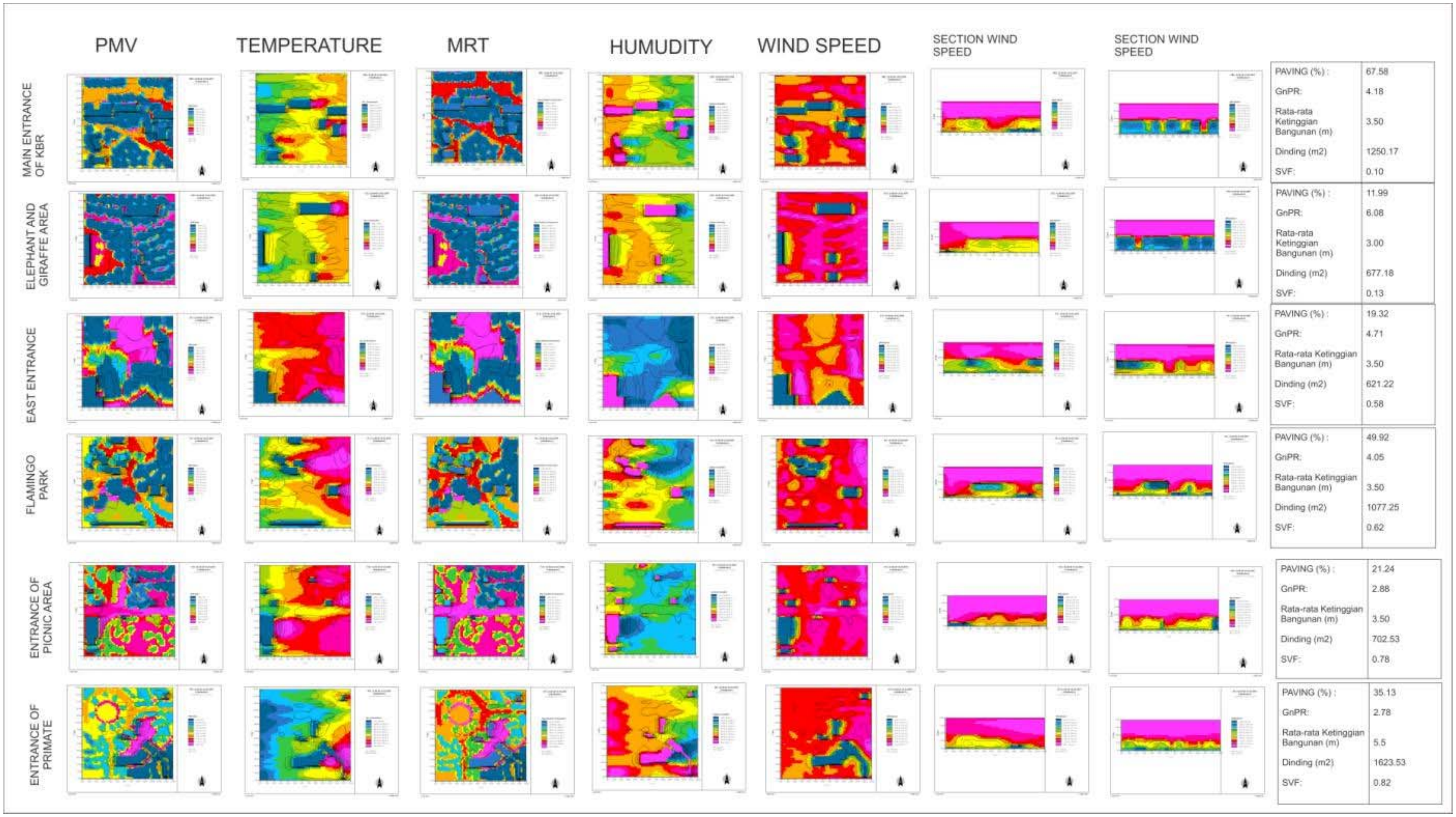


Figure 5.28. Overall of EnviMet Simulation of KBR

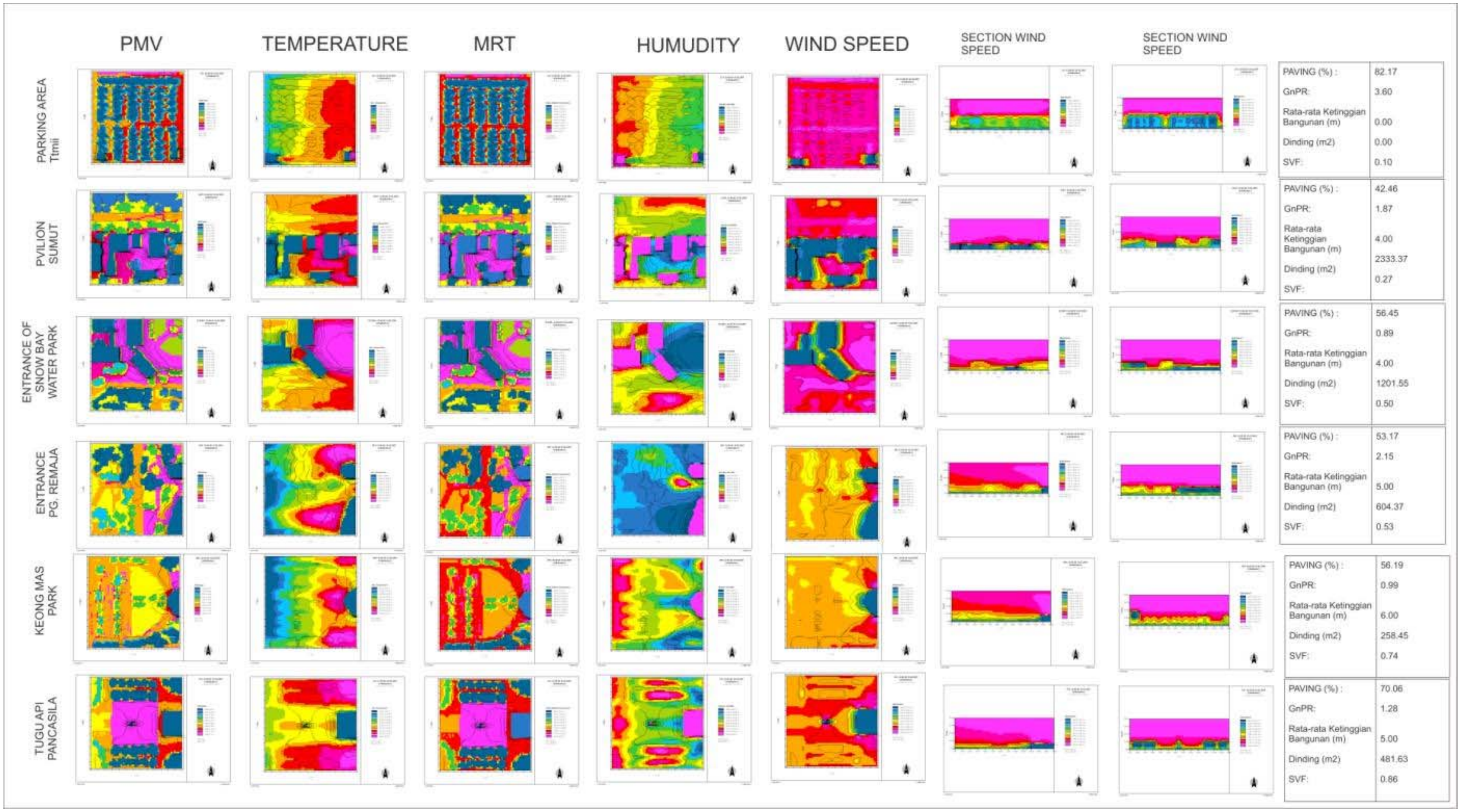


Figure 5.29. Overall of EnviMet Simulation of KBR

Chapter 6

THERMAL COMFORT AND WALKING COMFORT INVESTIGATION AND EVALUATION IN THE CITY'S SUPERBLOCK OF JAKARTA CASE STUDY OPEN SPACES IN MEGA KUNINGAN

Summary

This chapter investigated and evaluated outdoor thermal comfort and walking comfort in the hot-humid city of Jakarta. This research was built through two approaches, showing the result of field measurement and simulation of the walking comfort. The simulation was used to calculate how far an individual might be able to walk before experiencing discomfort in an outdoor setting. This research was carried out in Mega Kuningan-superblock in Jakarta. From microclimatic measurement data and thermal comfort analysis the effect of natural and build environment on ambient temperature and a daytime walking at pedestrian comfort levels was evaluated using Rayman Software and skin wettedness methodology. The Physiologically Equivalent Temperature (PET) was utilized to assess the thermal comfort condition of selected area. Thermal comfort was difficult to achieve during the day. The heat trapped amongst the buildings in the night time affect the temperature in the morning, thus made Tmrt rise significantly during the daytime. Tmrt did not only affect the thermal comfort in open space, but also affect the walking. The simulation showed that the walking distance are affected by Tmrt. Shadowing are needed regarding thermal comfort and walking comfort in the open space in a hot humid city like Jakarta.

This research focused in the Mega Kuningan superblock in Jakarta which discussed about the thermal comfort condition of outdoor space and walking comfort in a context of hot-humid climate city. This research conducted field measurement investigated the outdoor thermal comfort and walking comfort simulation regarding to environmental condition and human level.

6.1. Mega Kuningan Superblock in Jakarta

Located on 55 ha land, Mega Kuningan superblock is one of the famous superblock in Jakarta. This superblock is at the south east of Jakarta city on the site of Golden Triangle of the business district. Circular is the main form of the Mega Kuningan superblock, every block of the building is facing the main circular road in the center of the site. The business function is located in the center of the superblock as the main focus as it is also the main entrance of the superblocks (Bruse, 2007). The main entrance accesses are from. Jl. Satrio and Jl. Rasuna Said. See Figure 6.1.

Mega Kuningan superblock, one of the famous and oldest superblock in Jakarta, is located in the southeast of Jakarta's Golden Triangle district sited on 55 ha land Figure 6.1. The Mega Kuningan superblock has a concept split the land into small groups of buildings to make interlink easily among them. The groups of buildings integrate with circulation systems for pedestrians and vehicles. The form of the Mega Kuningan superblock is circular, each block at the center are facing the main circular road named Jalan Mega Kuningan. In the center of the superblock is the blocks in the business area, where hotels, malls, apartments, and hospitals are located (*Pengelola Mega Kuningan,* 2013). There are two main entrance to enter the Mega Kuningan superblock; north entrance is from Prof. Dr. Satrio street, and the south entrance from Jalan Rasuna Said. See Figure 6.1.

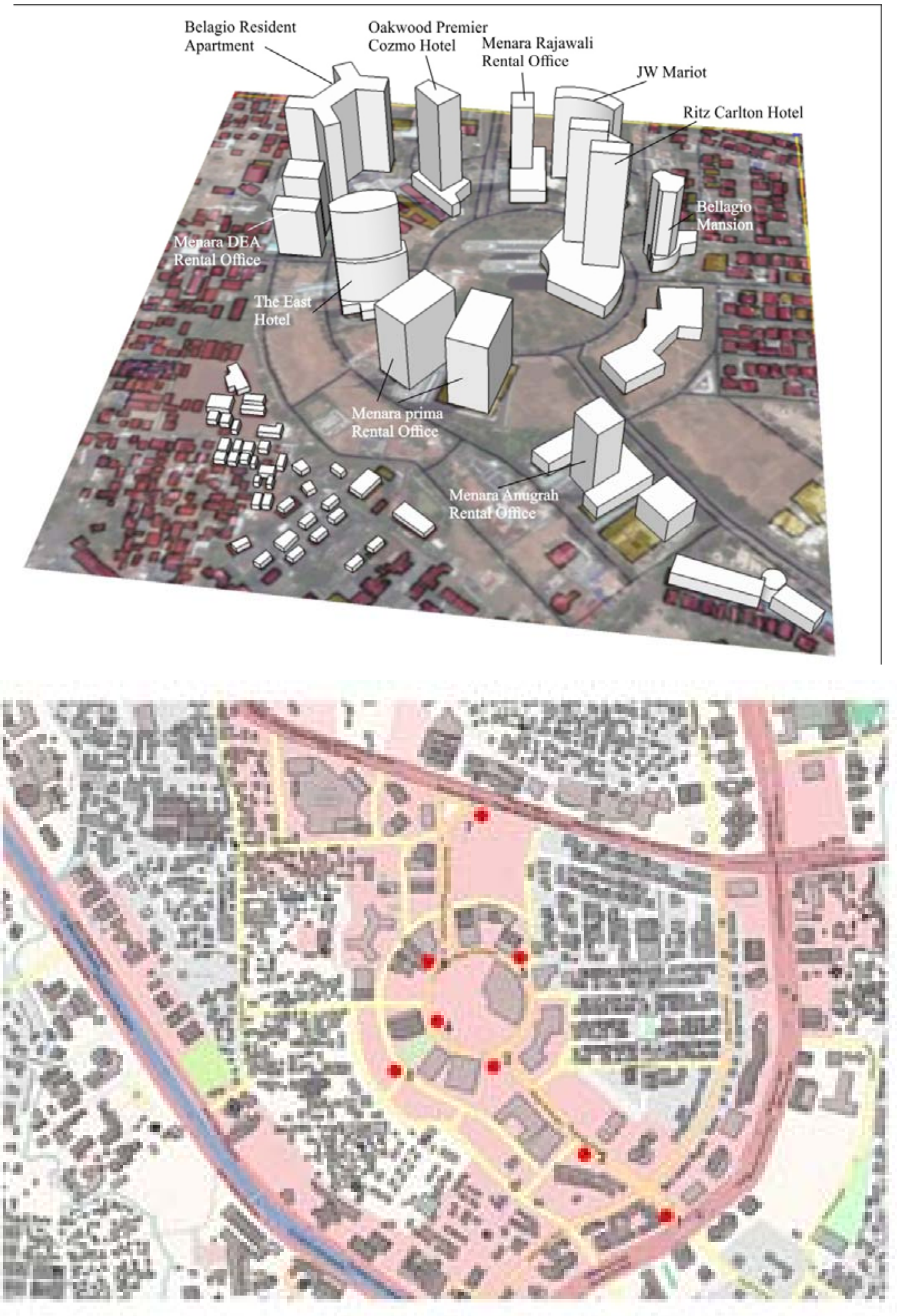


Figure 6.1. 3D and map of Mega Kuningan Superblock

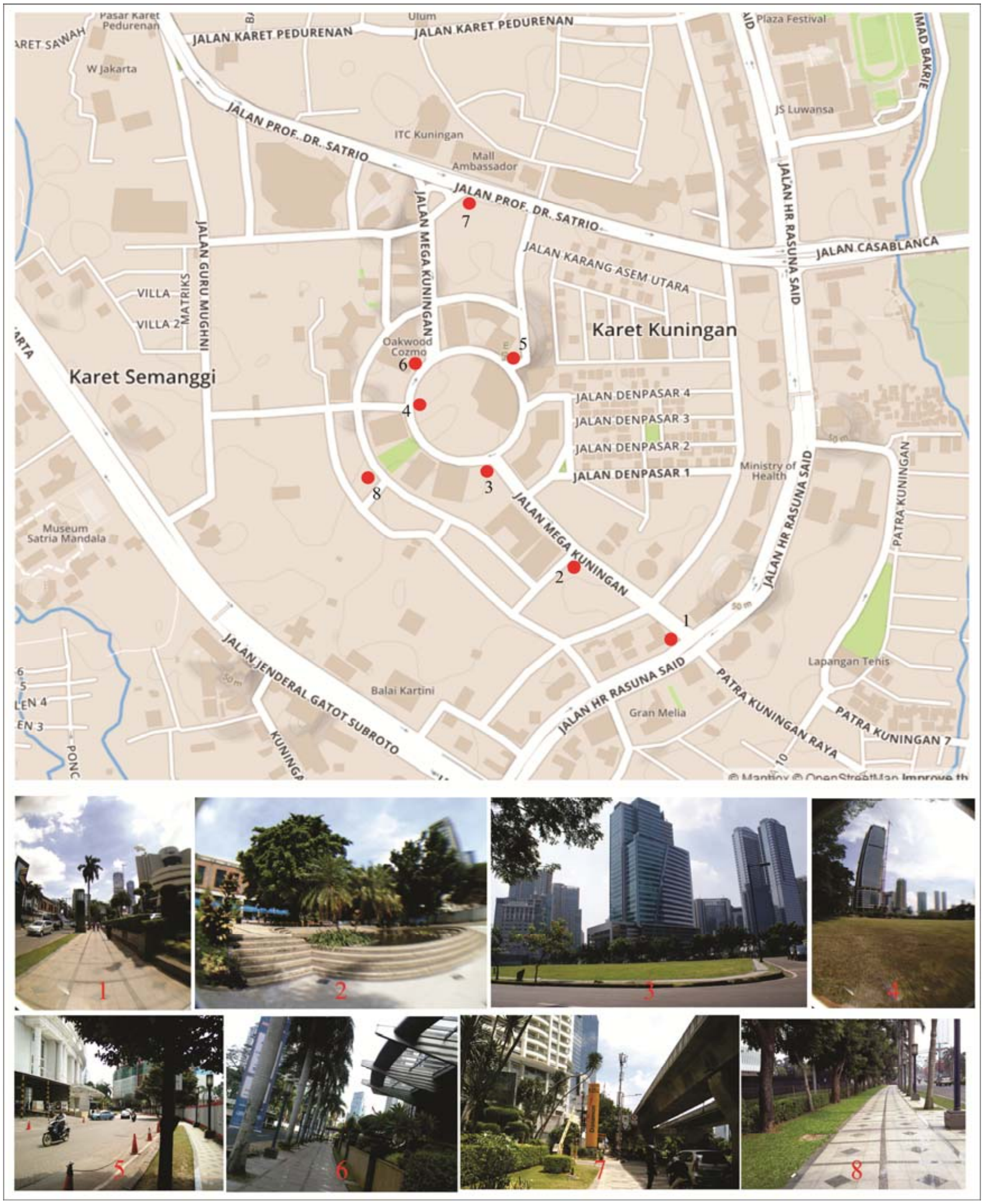


Figure 6.2. Mega Kuningan Superblock and selected survey zones. Number represent zones.

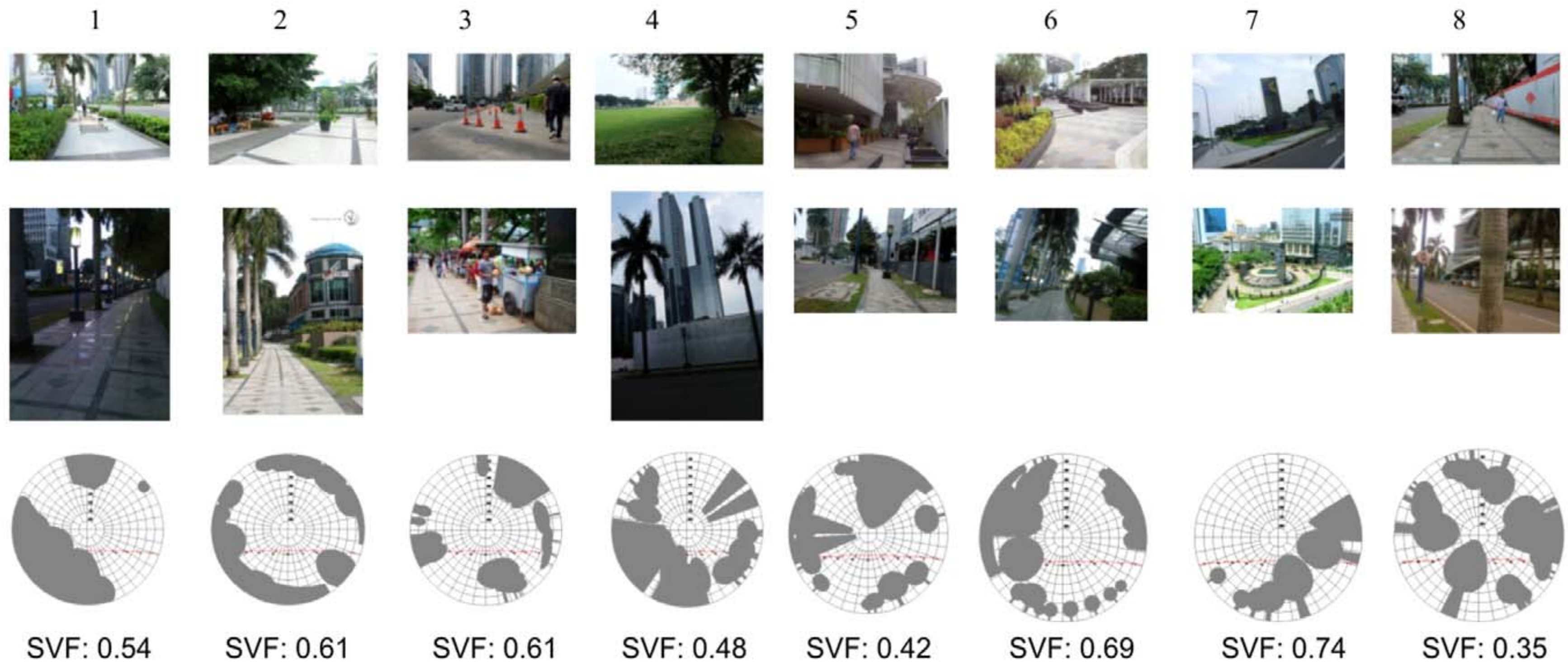


Figure 6.3. Environmental Characteristic at point measurement.

Heat island is one of phenomenon of Urban Climate when the temperature is appeared higher in the urban than its surround. The temperature in the urban increases gradually, (Shudo at a, 1997). Shudo, H, 1997, proved that the temperature in urban higher 2^{o}C than in cropland and forest. It happens because of transformation surface covered from natural to be artificial environment such as concrete and asphalt (Lee, H.Y., 1993).

Mega Kuningan superblock integrates of high-rise buildings located in the middle, and two stories landed houses in its surrounding area. The highest building is the Ritz Carlton Hotel, 180 m high, located in the middle of the superblock. Besides high rise buildings, there is a park located in the middle of the superblock as well where people usually use to hang out Figure 6.1.

The build environment such as apartment, residences, road, and industrial facilities in the cities changed because of buildings and facilities development from the past to the present, increasing change the albedo of the cities from the natural environment to be concrete and asphalt, and generates new climate condition in the cities called Urban Climate (Landsberg, 1981), see Figure 6.3.

This research proposes a computational approach to model the urban microclimate and assess the thermal comfort of open space in existing superblocks in Jakarta that can change how outdoor space use to make better space.

6.2. Thermal Comfort

6.2.1. Thermal Comfort

Three observation times were selected in this research at 7am, 13pm, and 5pm. These times reflected typical times of morning and evening commutes, and time close to the midday when the radiation is the highest, according to the field measurement shown in Figure 6.2.

The 8 points of measurement in the site were conducted on 3 February and 10 October, 2014, in the condition of clear sky, during 24 hours, from 0.00 to 23.00. The field measurement conducted using the following equipment: Thermo Recorder RT 13 to measure temperature, LM 8000 to measure temperature and wind speed; and EM 528A to measure Surface temperature. All sensors installed at 1.5 m above the ground.

The points of measurement were chosen on the condition of the shaded area, half-shade areas, and openness, to promote different possibilities of thermal conditions. The points of measurement can be seen in Figure 6.2 and Figure 6.3.

Regarding to the condition of the chosen area, Sky View Factor was used to calculate the position of point measurement. Using Rayman software the shaded area, half-shaded area, and openness area can be determined.

Figure 6.6 shows all points measured were uncomfortable either in the dry season in October or rainy season in February. During the daytime, the PET values of measurement of 8 points are uncomfortable, started at 9 am PET values tend to be in a slight warm situation, 32 ^{o}C, and reach its peak value at 1 pm, 40 ^{o}C.

The Tmrt value has begun to rise since 9 am and reached its peak at 1 pm. Tmrt value was rapidly rising due to the ambient temperature at night time still remain high, 24 ^{o}C. The wind velocity were not strong enough to drive away the hot air around the areas at the night time. Meanwhile the humidity was still high as well.

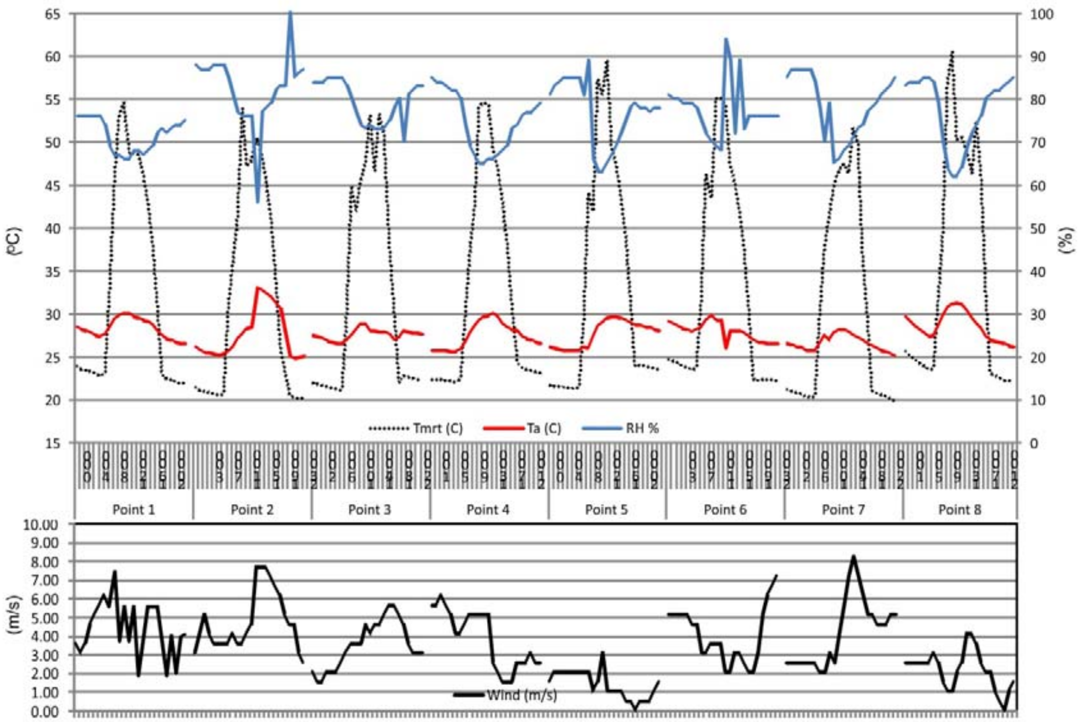


Figure 6.4. Graphic of Tmrt, Ta, RH and Wind speed measurement data obtained from 8 points on 2 February

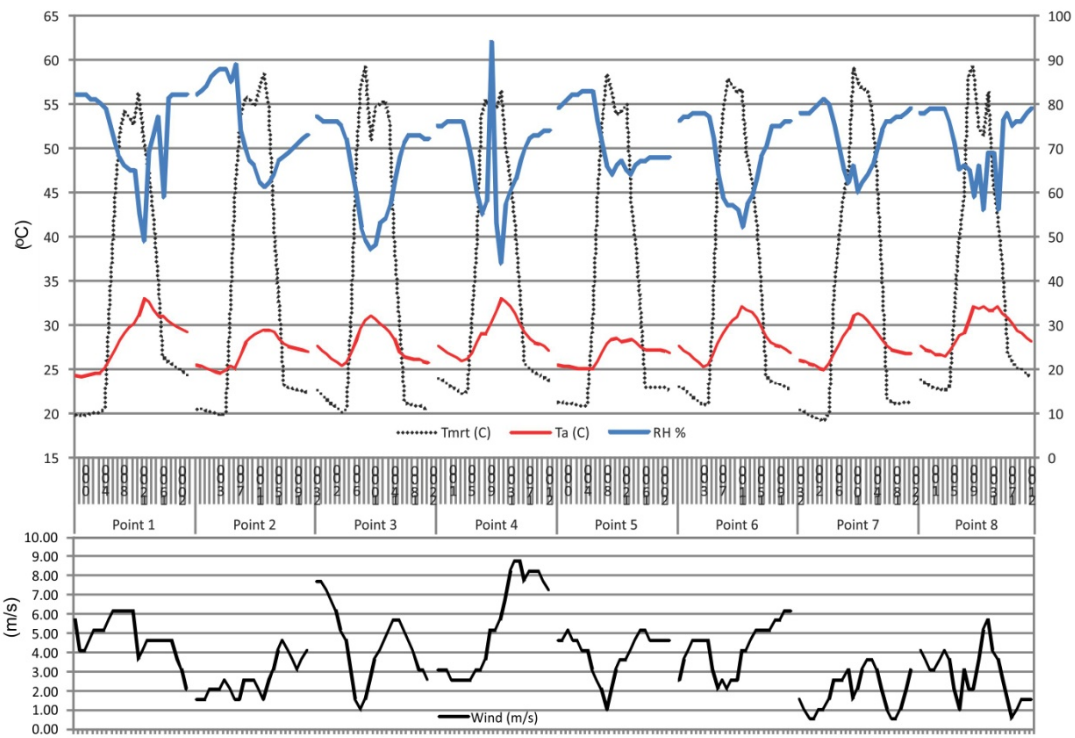


Figure 6.5. Graphic of Tmrt, Ta, RH and Wind speed measurement obtained from 8 points on 10 October

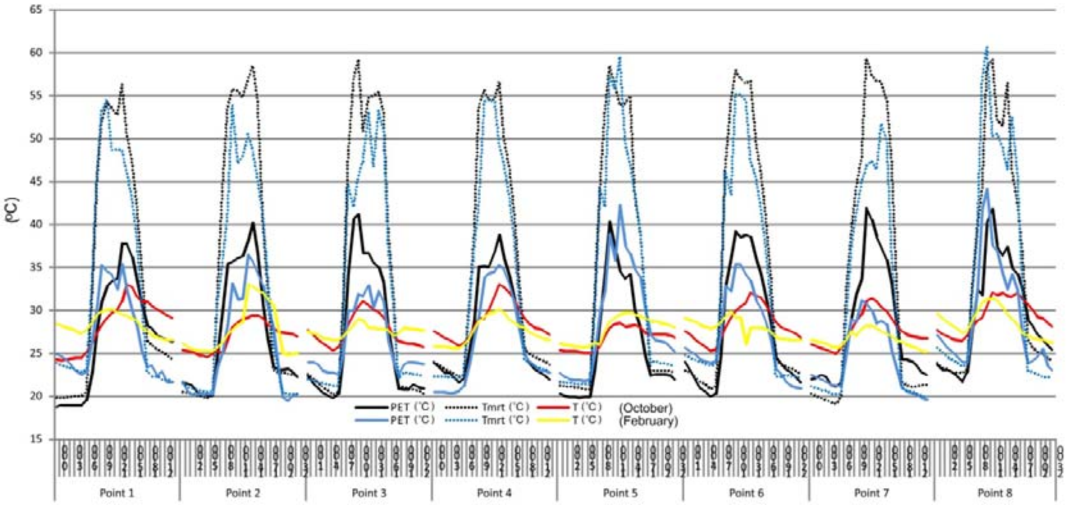


Figure 6.6. PET result on February and October

Point7 shows the significant difference PET value in October and February, the location of point 7 is located in the open space area where on the north side of the area is the highway road and a row of high density commercial buildings, south and east side is open space, west side is sparse density commercial buildings. In October the PET value of point 7 reached 42 ^{o}C at the peak point at 1 pm and 31 ^{o}C in February at the peak point at 12 am. Wind speed in October tends to be low and come from the northeast side that carries the heat from the highway road and a row of high-density commercial buildings (Figure 6.2). Meanwhile, in February wind speed is high, 5 ms^{-1} average, carrying cold air tends to come from West South where the buildings are rarer and has many parks (Figure 6.3).

According to the overall evaluation of the thermal condition of the selected areas showed the PET value of open space and the spaces amongst buildings is not significantly different, as shown at point 2, 3, 4, 7, and 8 and point 1, 5, and 6. Point1, 5, and 6 shows that the temperature during the night time trapped between the buildings, but in the day time the advantage of this point is the buildings can block the sun's radiation through that area, accordingly the temperature at that point is not significantly rose in the daytime. But the wind speed at that point is less than at open space. The solar radiation directly made open space fast to be hot, the advantage of open space is the wind speed is higher than the space amongst buildings.

The findings also illustrate that the use of natural and artificial shading lead to reduction of PET values of area of protection from direct solar radiation. Shading is the important characteristic that leads to a moderate reduction in Ta value while Tmrt value is strongly reduced. Accordingly, the shaded area that's covered by buildings and vegetation show tends to be slightly cooler than the others areas due to their lower exposures from the direct solar radiation. Hence, the high shading level is needed in outdoor environments to increase thermal comfort and extend the stability of the acceptable thermal condition during the day.

Overall measurement and analysis of the thermal comfort condition showed that an acceptable range of thermal comfort (<34 ^{o}C) only happened during the early morning (7-10 am) and late afternoon (4-5 pm). At the location with a high level shading area the duration of thermal comfort can be accepted more than 5 hours in the morning (7-12 am). The research also found that almost 6 hours a day, from 11 am – 4 pm is considered having the uncomfortable condition due to the high amount of solar radiation.

PET mostly affected by the Tmrt rather than by Ta. It can be proved during the measurement of ambient temperature (Ta) show very small differences between the selected areas (with maximum value 4 ^{O}C) whereas the PET values show significantly different between the selected location (with maximum values of about 15 ^{o}C). These results show the same result with previous studies (Mayer et al., 2008; Ali-Toudert and Mayer, 2007) that indicated air temperature alone is not significantly affect the thermal comfort in an outdoor environment. The stronger affect the thermal comfort values are radiant temperature than air temperature in an outdoor environment. It also should be noted that, air velocity can decrease the PET values, although, solar radiation is more the important key factor calculating the thermal comfort index (PET).

6.3. Walking comfort

6.3.1. Object Study of Walking Comfort

This research simulates an average of Indonesian people which met on site, i.e. male; tall 170 cm; and weights 70 kg, Clo (Clothing value) is 0.49 (typical tropical business cloth, trouser short-sleeved shirt) for all simulations, and activity (metabolic rate) is walking/light activity (150w/m^{2}) equals to 134 ms^{-1} according to de Dear's calculator. Use the data assumed by average Indonesian people and the variability of weather data, the distance of walking comfort in the superblock's open space can be calculated.

The surface area of the subject is calculated using the formula as follows (Atkins and Thompson 2000):

$$surface\ area\ (m^2) = 0.00718 \times weight^{0.425} \times height^{0.725} \quad (12)$$

The result of surface area of the average Indonesian male is 1.81 m^2.

The walking comfort was calculated in 3 different times; (1) in the morning at 7 am; (2) in the highest value of Tmrt at 1 pm; (3) and in the evening at 5 pm. The simulation data use the subject of Indonesia male 1.70 m height, 70 kg weight (surface area of the body 1.81 m^2 according to formulae 2), wearing common clothing with Clo value is 0.5 and walking is the activity in the simulation (the metabolic rate is 150 W/m^2). The Tmrt, temperature, relative humidity, and wind speed used the data which are combined with the data of environment treatment, and time is shown in Table 6.1.

To provide an accurate assessment of climate effect on walking comfort, it was important to select the hours when people typically travel during the day in which weather condition were the most extreme. According to Hyodo et. al. (2005), Urban travel behavior characteristic of 13 cities based on household interview survey data, 30% of all trips in Jakarta begins around 7 am to go work, at 13 pm to go business outside and lunch, and at 5 pm to go back home.

Table 6.1. Climate data which are used in walking comfort simulation

	Shaded Area				Light Shaded				Open Area			
	Tmrt °C	Ta °C	RH %	v m/s	Tmrt °C	Ta °C	RH %	v m/s	Tmrt °C	Ta °C	RH %	v m/s
7 am	30.5	23.9	85	4.2	58.7	24.1	96	0.5	57.1	22.9	97	0.7
1 pm	57.7	30.7	63	1.7	62.9	27.9	81	0.2	61.8	30.6	85	1
5 pm	50.7	28.9	72	1	60.7	29	79	0.7	58.9	30.4	75	0.9

The result of walking comfort simulation shown in Table 6.1. Climate data which are used in walking comfort simulation. The shortest distance of walking in this simulation is found at 1 am, where the people walk in the Open Area with the mileage of people can walk before they feel uncomfortable is 241.2 m (3 minutes).

In the morning time (7 am), people can walk more than 1 km in the shaded area before they feel discomfort. Meanwhile, in the light shaded and open space, in the morning, the distance people could walk is similar, about 320 m.

Table 6.2. The result of Walkability simulation (w = skin wettedness)

7 am walking distance threshold values			
	Minutes where w < 0.33	Approximate walking distance in "comfort" w < 0.33 (m)	w value at 5 minutes
Shaded Area Light Shaded Open Area	13 4 4	1045.2 321.6 321.6	0.252748357 0.349315888 0.351612304
1 pm walking distance threshold values			
Shaded Area Light Shaded Open Area	6 4 3	482.4 321.6 241.2	0.285632914 0.335885597 0.39096984
5 pm walking distance threshold values			
Shaded Area Light Shaded Open Area	5 4 4	402 321.6 321.6	0.285632914 0.327659274 0.322438126

At 5 pm people could walk no more than 405 m, they feel uncomfortable after 5 minute walking. In the term of climate in the hot-humid tropical country like Jakarta, all day is almost similar, the significant differences are the temperature and the Tmrt see Table 6.2. The average mileage of people could walk in the tropic is 350 m in the day time.

Shading area is the main factor make the walking more comfortable, all the shaded areas in every hour simulation show the longest distance of walking. Meanwhile the light shaded area and open space almost have the same result.

The calculation of the skin wettedness shows that the relative humidity and the wind speed are the significant factor affect the walking distance. The relative humidity and wind speed can affect the heat evaporation in the body (Eves, et al. 2008, Murakami, et al. 1999).

6.4. Thermal Comfort Simulation at Mega Kuningan Superblock in Jakarta

6.4.1. The initial condition of Simulation

We divided The initial condition of Simulation into 4: general condition; PMV setting; Solar adjusting; temperature condition inside the building; and temperature of the soil. General condition is the basic need of the simulation contain basic information on location. The indoor temperature, that is kept constant during a model run, represent the temperature of the building. In addition, the albedo of the walls and the roofs are needed to calculate the heat transmission through the walls and the roof. Solar adjustment is a new feature of ENVI-met 3.1. That allows to adjust the shortwave solar radiation calculated based on real situations, when the solar energy fluxes estimated by the internal methods of ENVI-met are systematically too high or too low. Besides of calculating pure meteorological data, ENVI-met also includes a simple biometeorological model to predict the thermal comfort inside the model area. The PMV (predicted mean vote) model -known as biomet model- is thermal comfort model based on Fangers (1972) model. It relates the energy balance of the human body to the personal comfort feeling of persons exposed to the corresponding climates. The soil data set the initial temperature and humidity profile for the soil and the surfaces in the model (Michael Bruse, 2003). The initial condition of the simulation can be seen in Table 6.3. The validation of simulation can be seen in the Figure 6.7. The R square shows there is strong correlation between the thermal comfort (PET) from the fiels measurement and the result of simulation.

Table 6.3. The initial Condition of Simulation

Boundary Model	800m x 800m	[SOLARADJUST]	
Grids	200x200	Factor of shortwave adjustment (0.5 to 1.5)	1
Start Simulation at Time (HH:MM:SS):	6:00:00		
Total Simulation Time in Hours:	24	[BUILDING] Building properties	
Save Model State each ? min	30	Inside Temperature [K]	293
Wind Speed in 10 m ab. Ground [m/s]	3	Heat Transmission Walls [W/m²K]	1.94
Wind Direction (0:N..90:E..180:S..270:W..)	180	Heat Transmission Roofs [W/m²K]	6
Roughness Length z0 at Reference Point	3	Albedo Walls	0.65
Initial Temperature Atmosphere [K]	296	Albedo Roofs	0.75
Specific Humidity in 2500 m [g Water/kg air]	16.5		
Relative Humidity in 2m [%]	80	[SOILDATA] Settings for Soil	
		Initial Temperature Upper Layer (0-20 cm) [K]	301
[PMV] Settings for PMV-Calculation		Initial Temperature Middle Layer (20-50 cm) [K]	301
Walking Speed (m/s)	0.9	Initial Temperature Deep Layer (below 50 cm)[K]	301
Energy-Exchange (Col. 2 M/A)	116	Relative Humidity Upper Layer (0-20 cm)	60
Mech. Factor	0	Relative Humidity Middle Layer (20-50 cm)	70
Heattransfer resistance cloths	1	Relative Humidity Deep Layer (below 50 cm)	70

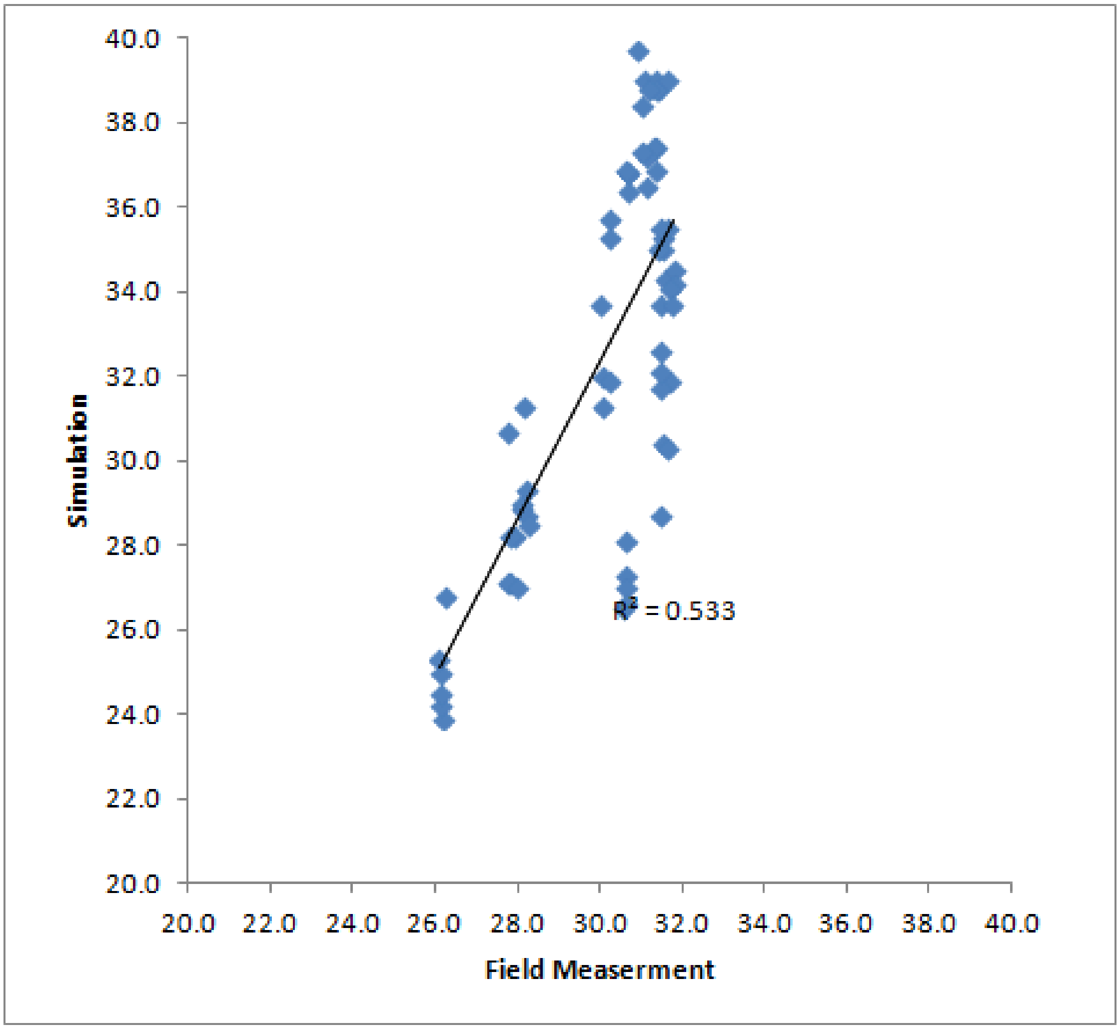


Figure 6.7. The R square of thermal comfort (PET) between field measurement and the result of simulation

6.4.2. The result of Simulation

Figure 6.8 shows the 3d simulation result of Mega Kuningan Superblock of Jakarta from EnviMet and how the map divided in XY axis, and Figure 6.9 shows the result of PMV in X axis and Y axis in graphic. Some axis in X and Y were chosen to distinguish the result among urban structure in the Super Block. The selected axis were based on the area which represent of residential area, open space, and the environment around the high rise building.

Each axis is represented by 3 axis: X axis are represented by axis no. 40 represents a residential area on the west side, axis no. 420 as area of Open space and high rise building, and axis no 780 as a residential area at the west part; Y axis, by axis no.60 as a residential area in the south part, no.480 open space area and high rise building in the middle part, and no.720 residential and commercial area on the north part.

Figure 6.10 shows the data of PMV at 7am, 9am, 11am, 1pm, 15.00, and 17.00 o'clock. Those hours chosen represent the condition of working hour in a day. Figure 6.16 shows residential area more comfortable than surrounding area of high rise building. In the morning time (7am -11am), PMV of residents is 1.2 while around the High rise building is 1.8 on average. South area of the superblock is more uncomfortable than the north part area of study. West area of study is more comfortable than east area of study. The thermal comfort around high rise building does not change significantly, especially in the Centre park. Thermal comfort in residential area changes significantly, especially in south and east part of

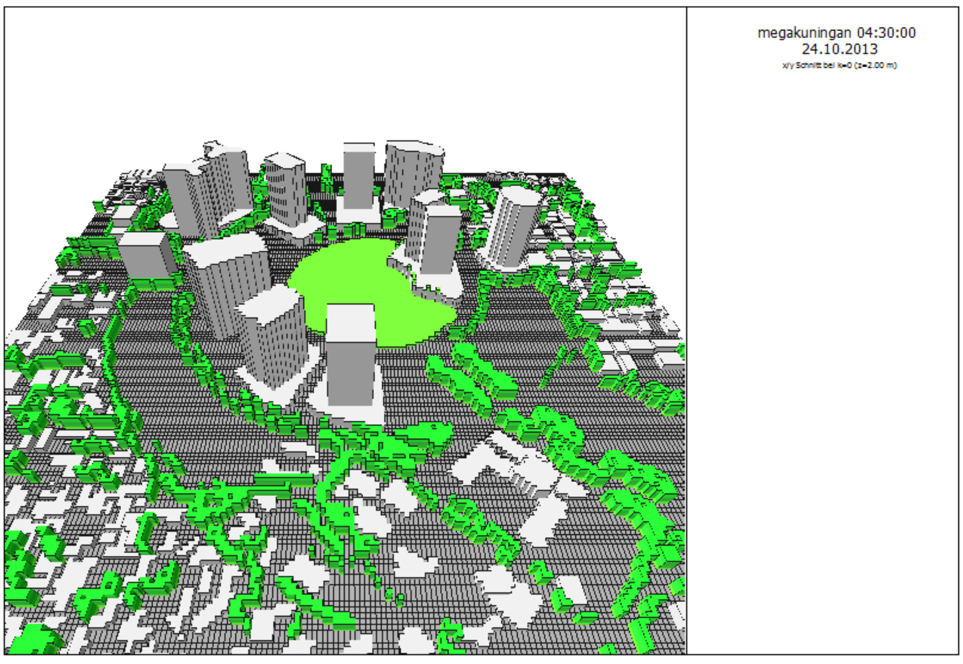


Figure 6.8. Simulation Model

the study area.

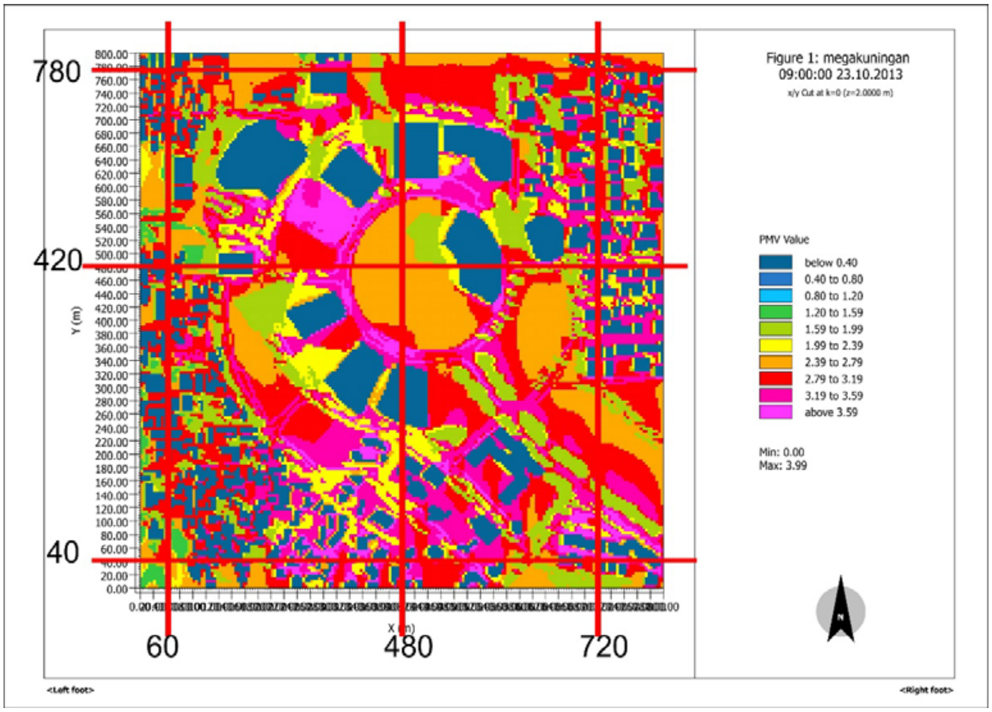


Figure 6.9. Simulation Result and XY axis division

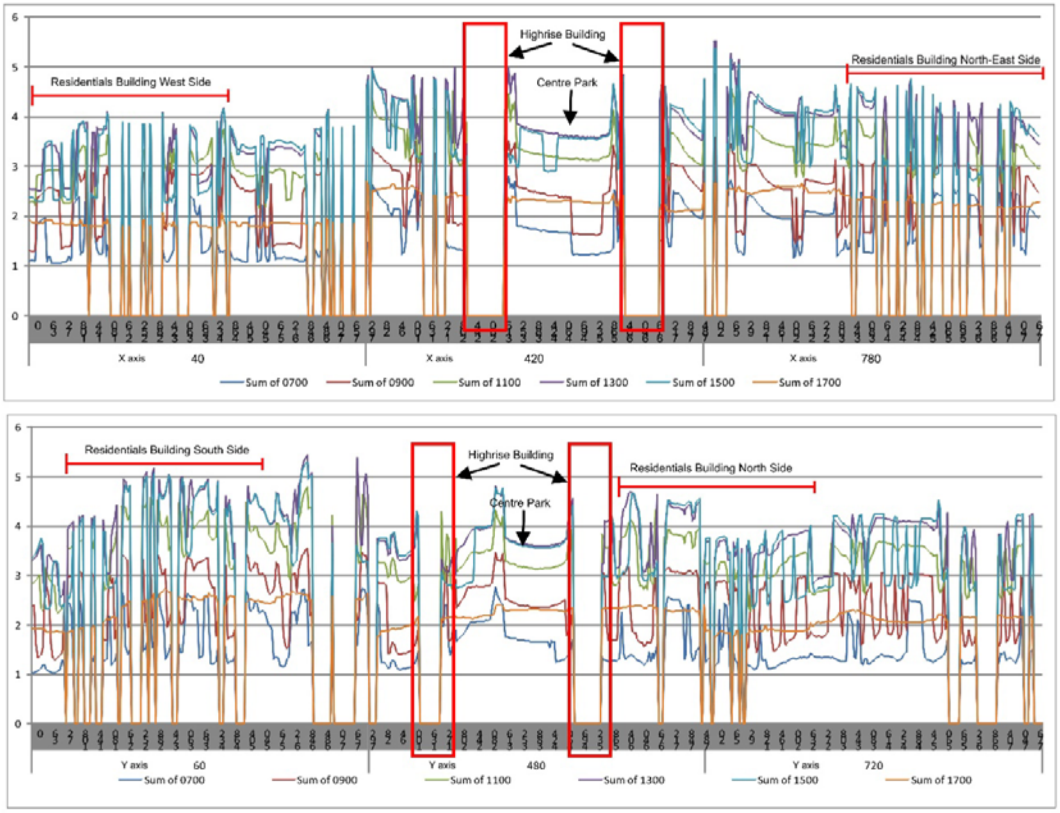


Figure 6.10. PMV result of Simulation

Figure 6.11 shows the simulation result of wind speed and Tmrt. Wind speed in residential area has variation while in the open space between high rise building more stable. On general condition on October, the wind came from the south, 5 m/s, that affect the condition of residential area in the south part, but when wind flow through the high rise building the wind became average 1.5 m/s. From 7am – 17.00 o'clock the average wind speed is 1.5 m/s.

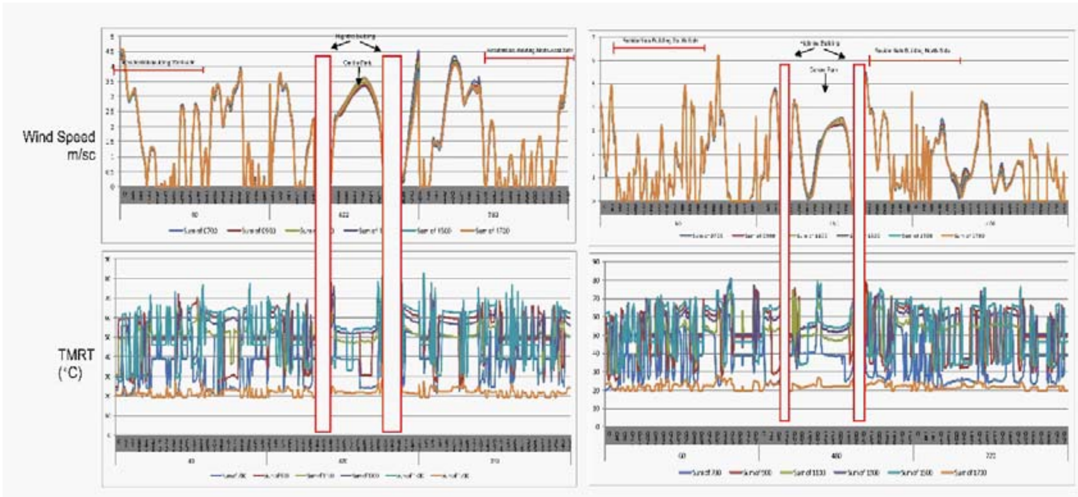


Figure 6.11. Wind Speed and Tmrt result of Simulation

Beside wind speed figure 6.17 shows Tmrt (^{0}C). Average Tmrt is 48 ^{0}C, the highest around a high rise building is 80 ^{0}C, Figure 6.11. Average Tmrt in open space is 42 ^{0}C lower than in residential areas, 49 ^{0}C. The south part and the north part area get the same value of Tmrt, 48 ^{0}C in average. At fifteen o'clock the Tmrt has the lowest value, 22 ^{0}C in average. The highest Tmrt yields at 15.00 o'clock.

6.5. Conclusion

This research presented a negative result of satisfaction/uncomfortable in some of the places in 3 biggest parks in Jakarta. A method that simulates the conditions previewed in the project must be taken into consideration, or that permit its calculations, making it possible to predict the conditions of thermal comfort of the future users.

The evaluation here presented was performed in only one day, with the objective of testing the PMV and PET method, we can notice the importance of this research, comprehending observations, and measurements, that when correlated may lead to the quality analysis of the thermal comfort conditions of the urban space.

Vegetation can be shown to be a prime factor, especially in hot climates in providing shade and reducing solar radiation.

High rise building affects thermal comfort, high rise building can make an uncomfortable condition surrounding and stabilize thermal comfort in a whole day as well. In contrast, thermal comfort in residential area changes quickly from morning to afternoon.

The addition of a building in an area in the region, if placed in the wrong place will inhibit the rate of wind speed and wind direction, which will be included in the region.

Besides building give more radiation in an area that does not degrade the thermal comfort but give effect to raise the temperature of the environment.

The comfortable distance of walking in a hot-humid city like Jakarta is 350 m average. It can be reached more than 350 m distance if the city can reduce the Tmrt value and the humidity, therefor the shading area has to be considered by the urban planner and architect. Buildings can be designed as the shading area, therefor the designer should pay attention to the solar movement, and building orientation.

PET and skin wettedness can be used as tools to help urban designers and architects before making design decisions. The simulation and the result from the field measurement are important information related to the climate and outdoor urban environment design. In conclusion, the final results present the thermal condition of open spaces together with walking comfort can be integrated in design guidelines to enhance the quality of livable and walkable outdoor spaces for human life in the tropical areas.

This research shows precious information in term of the thermal comfort in outdoor spaces and walking comfort in the hot-humid city of Jakarta. In the tropical hot-humid climate, outdoor spaces are used during the year, and they must provide proper levels of thermal comfort.

The findings of the field measurement depicted that the average values of PET in the selected points were uncomfortable (PET > 34 ^{o}C). However, the comfort condition occurred in 8 am-10 am and 4 pm-5 pm. The open area with the shaded of the plantation is the location can be tolerated as the location most comfortable because the high wind speed was not hindered by the buildings and had the longer thermal acceptable period.

The uncomfortable condition occurred in 1 am when the PET value reached its peak in 42 ^{O}C while, the location amongst the buildings with the high Tmrt occurred from the heat trapped amongst the buildings in the night time and made the temperature rise quickly in the morning (9 am-10 am).

Chapter 7

STRATEGY ADDRESSING THE CLIMATE BARRIER IN URBAN DEVELOPMENT IN HOT HUMID COUNTRY

Summary

Research in concerning of the relationship of urban microclimate, thermal comfort and walking comfort with an urban structure in developing countries, like Indonesia, shows a high importance not only there is not many researchers involve but also an important part of the region's of the urban development base. Monthly mean air temperature, relative humidity, precipitation, vapor pressure, wind velocity, and cloud cover for the period 2009–20014 data collected from two meteorological stations Jakarta was selected. The principle of this study is to conclude the most suitable urban structure to achieve human thermal comfort and walking comfort in urban development in Jakarta.

At several cities, climate represents a natural resource on which the urban climate department is predicated. Usually, geographical location, topography, landscape, vegetation, and fauna are factors that influence decisions regarding areas to be planned. Weather and climate are two additional factors (Abegg 1996). It is a fact that the weather / climate and urban structure are interconnected in diverse ways. In order to contribute to the sustainability of open space the knowledge about the urban thermal comfort and walking comfort should be transferred into climatic guidelines for urban structure planning. The general framework of this study responds to the need of analyzing thermal comfort and walking comfort in Hot-Humid climate regions and its influence in urban structure design factor.

7.1. Data usability

This section evaluates the background of the urban microclimate conditions in the hot, humid climate of Jakarta, based on the effects of urban structural modifications. Using the concept from Algeciras and Matzarakis (2015) "the simulation effects were quantified in terms of shading and variation of wind speed". "Using climate data from meteorological stations, the following setups were performed: without modifications from the original data of meteorology station, wind speed reduction of -1.0 m/sec., wind speed increase of +1.0m/sec., reduction of shade where Tmrt is equal to two, and finally combinations of shading and variation of wind speed" (Algecira and Matzarakis, 2015). Thermal comfort zone from tropical regions (Matzarakis and Lin, 1998) are used as the criteria of assessment. See Table 3.4.

This research climatic data were used with 1h resolution in the period from January 1, 2009 to January 1, 2014. Meteorological data of air temperature, relative humidity, and wind speed were collected at an urban automatic meteorological station (see Figure 7.1.) at Halim Perdana Kusuma Airport, Soekarno Hatta Airport, and Tanjung Priok Seaport in Jakarta, and some data from the internet such as www.wunderground.com, www.weatherspark.com, and www.weatheranalytics.com/wa.

CTIS (Climate, Tourism/Transfer-Information Scheme) from Matzarakis, 2014, is used to represent the result of the diurnal data of PET value from original Climate stations and simulation. The result is easy to understand and to visualize (Lin and Matzarakis, 2008; Matzarakis, 2014). 10 day period of data are presented to give more precise information on climate condition. Despite of present the data using CTIS, frequency data of PET value are used to draw the 10 day period or monthly time scale using Excel software. "A software module (CTIS program) that operated with data files containing frequencies of PET values can represent customizable diagrams for all simulations performed" (Matzarakis 2014).

Figure 7.1. The three Weather Station location in Jakarta, Soekarno-Hatta Airport, Halim Perdana Kusuma Airport, and Tanjung Priok Seaport.

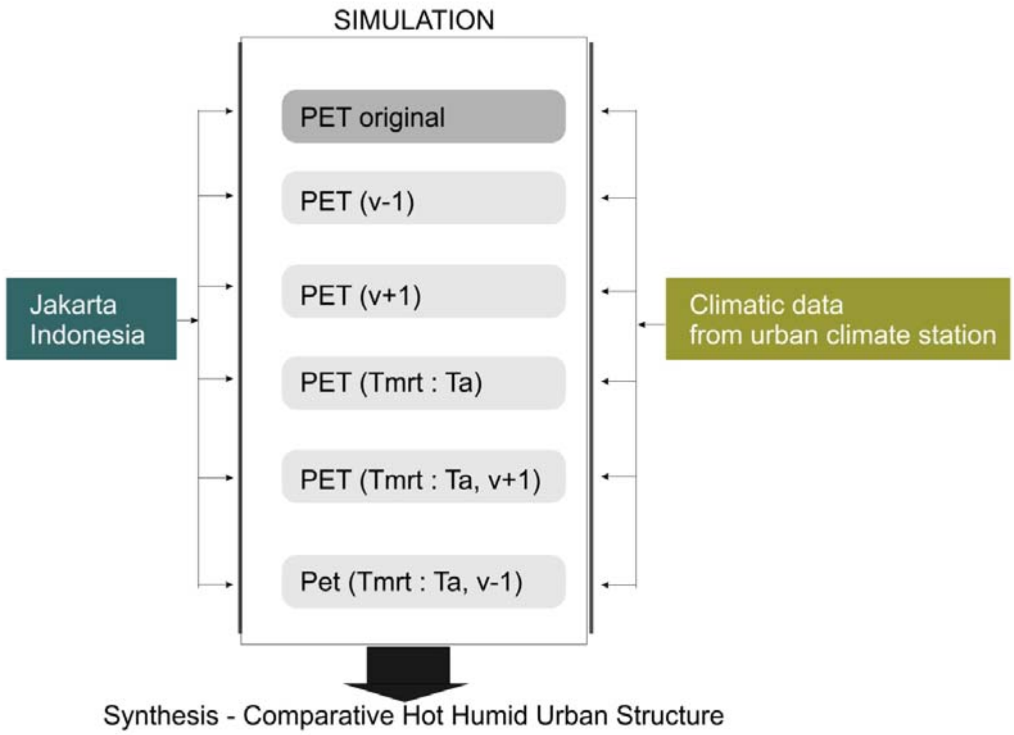


Figure 7.2. Simulation framework of urban structure comparison (modified from Algeciras and Matzarakis, 2015)

Table 7.1. PET value *Source:* Lin and Matzarakis (2008)

PET (Sub) Tropical Region (°C)	Thermal Perception	Grade of Physiological Stress
	Very Cold	Extreme Cold Stress
14		
	Cold	Strong Cold Stress
18		
	Cool	Moderate Cold Stress
22		
	Slightly Cool	Slight Cold Stress
26		
	Comfortable	No Thermal Stress
30		
	Slightly Warm	Slight Heat Stress
34		
	Warm	Moderate Heat Stress
38		
	Hot	Strong Heat Stress
42		
	Very Hot	Extreme Heat Stress

Table 7.2. Monthly frequency distribution of PET

Configuration	Cold Stress	Comfortable	Heat Stress
	PET < 22°C	22<PET<34°C	PET> 34°C
PET (Original)	37.86%	36.51%	24.87%
v + 1	35.31%	35.14%	29.32%
v - 1	35.74%	28.02%	29.32%
Tmrt = Ta	40.93%	58.71%	0.35%
Tmrt = Ta (v + 1)	33.17%	66.38%	0.45%
Tmrt = Ta (v - 1)	44.26%	55.36%	0.35%

7.2. The Simulation of Urban Structure in Jakarta

For the quantification of the background urban climate conditions of Jakarta, PET classes have been calculated from 2009 to 2014 of meteorology station. Figure 7.3 represent of the PET value of Jakarta from original data from meteorological stations, 9.5% of hours are in the slightly warm classes (PET >30 °C), 11% warm, and 14% hot-very hot. 12 % of hours are considered as comfortable (26 °C < PET <30 °C). However, frequencies of feeling cold-cool (PET <22 °C) are about 21.8 % happened in the night time Figure 7.4. Therefore, Jakarta is in a warm and hot climate region during the morning to evening.

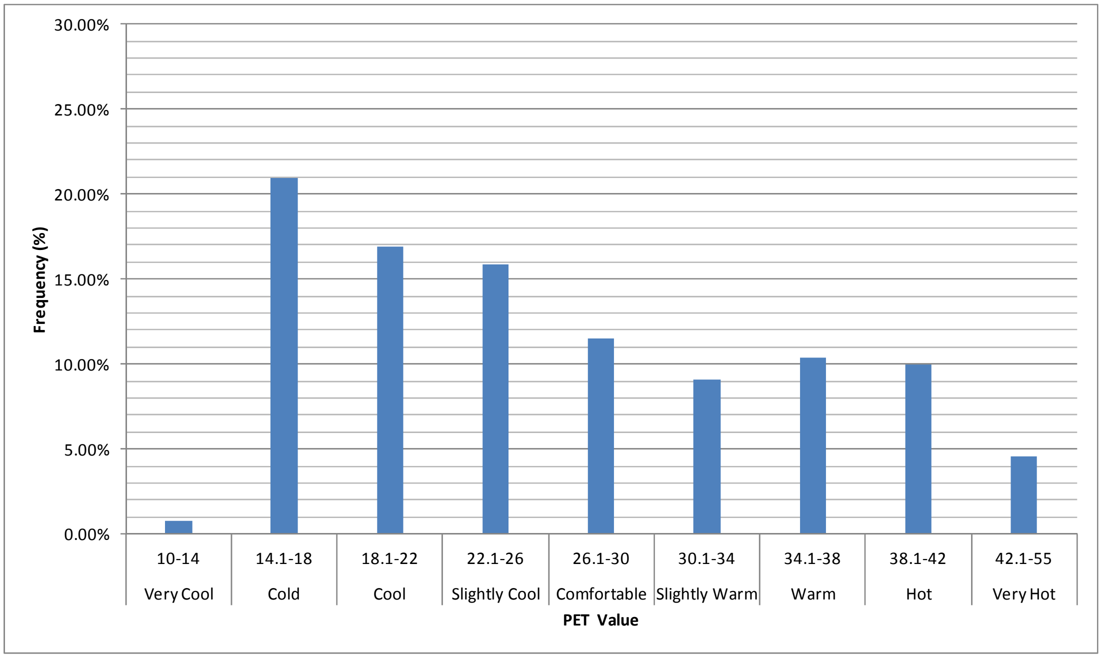


Figure 7.3. PET classes based on Urban station in Jakarta 2009-2014

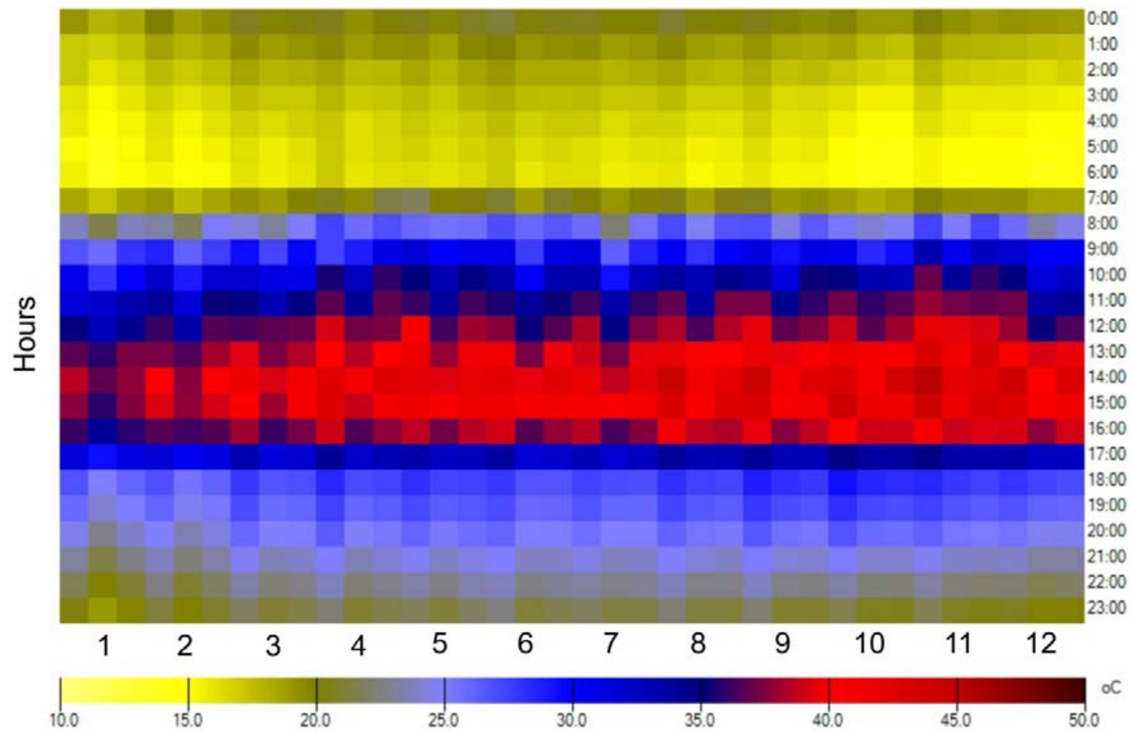


Figure 7.4. Mean Monthly diurnal of PET based on original data from an urban climate station in Jakarta, 2009-2014

Figure 7.5. shows the distribution of PET value in mean monthly average based on the original data and simulation from the climate station. The thermal stress can be depicted from the diagram and the Table 7.2. The PET value of original show the acceptable level of thermal comfort 22<PET<34^{o}C occurs through the years with 36.51% of the time especially from May to August. Coll level PET < 22^{o}C occurs approximately from January to April. Heat stress PET> 34^{o}C occurs from mid August to November when in Indonesia gets the dry season. Table 7.2 shows the simple way of the frequency of cold Stress, Comfortable, and Heat Stress.

Table 7.2 shows the climate station shows the PET original value as cold 37.86% of the time, neutral 36.51% of the time, and it was above 34^{o}C for 24.87% of the study period. For the urban structure when the shading area occurs (Tmrt=Ta) the comfortable become higher 22% than the original one, and there was no heat stress occurred (0.35% of the time); however, the heat stress increases 5% than the original when the wind speed decrease 1m/sec. There is much more effective when there is the combination of shadowing and wind speed increase almost 66.38% (more than 30% than original ones) of the time in the comfort level. It is said that the heat stress can mitigate when there is shadowing or increasing the wind speed in the level of urban structure. The frequency of cold can increase when there is more shadowing

PET < 22^{o}C, 3% than increasing of wind speed. The increasing wind speed almost do not have the effect the comfort level in the hot humid city, but decreasing the wind speed effect decreasing 8% of comfortable.

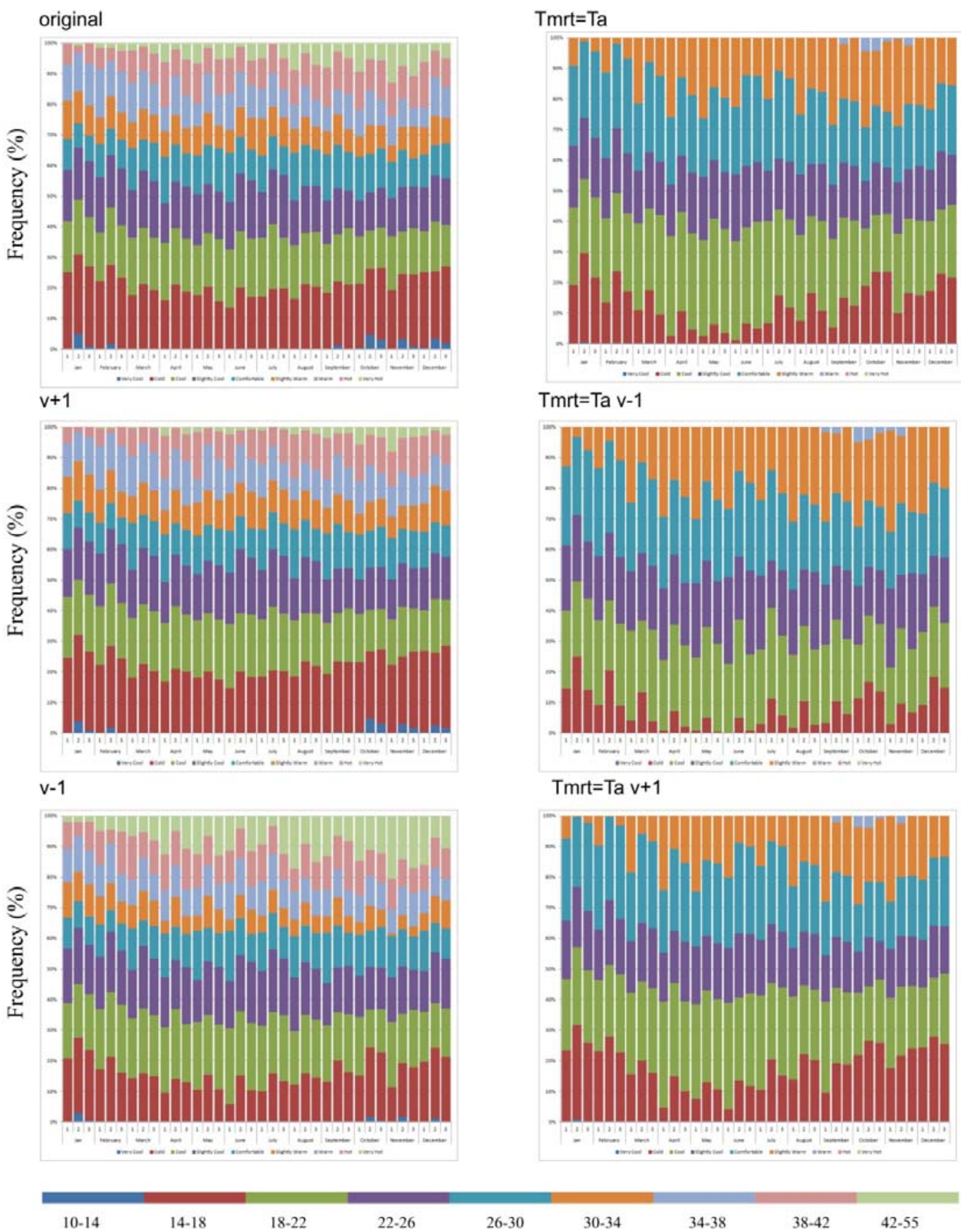


Figure 7.5. Mean Monthly diurnal variation of simulated PET based on the data of urban climate station in Jakarta, 2009-2014.

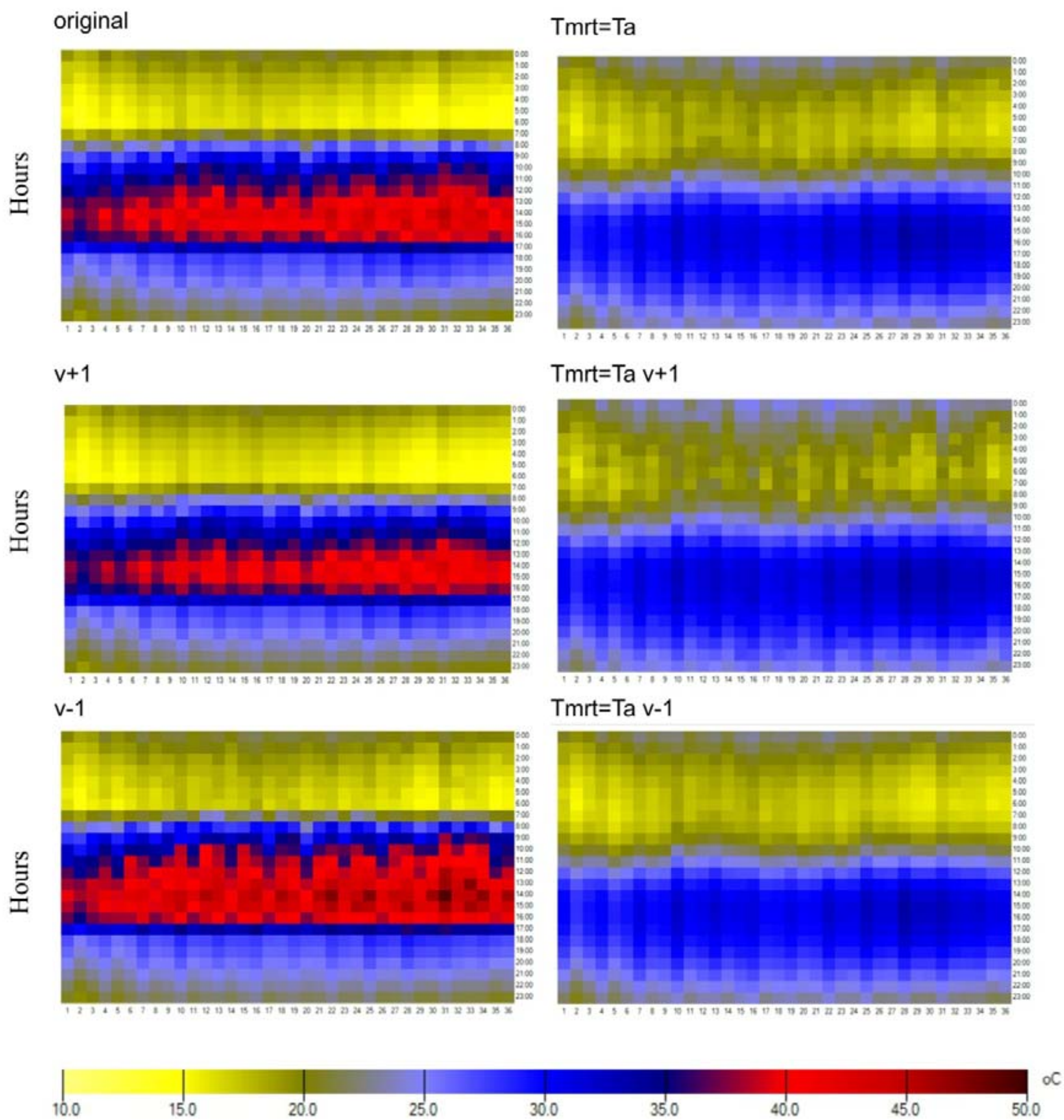


Figure 7.6. The PET variation of mean monthly diurnal for simulations performed based on the data of the urban climate station in Jakarta. Period: 2009–2014

Figure 7.6 shows the mean monthly diurnal variation of PET. Based on the data of PET from the original data the performance of comfortable occurs in the morning (9 am) and evening (4 pm). During the summer season September to November the uncomfortable condition increase.

In the night time the cold occurs and the frequency of comfortable improved because of the absence of solar radiation. In summer, during daytime hours, for shade conditions (Tmrt = Ta), there were no records of PET above 34 °C. However, in the wet season, PET becomes cooler than that of the urban station. This result clearly shows the influence of solar radiation on thermal comfort in comparison with the diurnal variation of PET obtained from the urban station. During summer days, the levels of thermal comfort improve because of the increase in wind speed. If the wind speed increases, the thermal comfort conditions can be more comfortable, but if the wind speed decreases, the daytime hours in summer will present a PET above 34 °C. Furthermore, decreased in wind speed improved thermal comfort conditions in dry season/summer time. The simulation results confirm that wind speed has an influence on the mitigation of unpleasant thermal conditions; however, shade conditions have more influence for this purpose.

7.3. The urban structure determines the behavior of urban microclimate

Based on simulation results, some aspects about thermal comfort of Jakarta should be exposed (Table 7.3. Annual percentage of threshold based on PET (climate station 2009-2014) and Figure 7.7. By comparing calculated results of the urban station at different configurations, it is observed that above the 23 °C thresholds, if the wind speed increases, PET frequency reduces, whereas if the wind speed decreases, the PET frequency increases. In all shade situations, the PET frequency is reduced above all thresholds. Therefore, shade and wind speed increase can improve thermal comfort situations in terms of PET above 30 °C. Also, heat stress conditions can be mitigated by shade and wind speed increase in conditions of PET above 35 and 45 °C, respectively. The combination that involves shade situations with the increase in wind speed is the most important strategy with significant reduction of heat stress. Therefore, during the summer period, increasing wind speed and providing shaded areas are recommended. On the other hand, for shade situation, it is observed that if the wind speed increases, the PET frequency increases, whereas if the wind speed decreases, the PET frequency reduces below the 22°C thresholds.

Thermal comfort can be improved by wind speed decreases in conditions of PET below 22 °C. Therefore, during dry season, heat stress can be mitigated shadowing and increasing the wind speed. The simulations performed show that thermal comfort can be affected by modifications of wind speed and solar radiation fluxes. Our findings confirm those reported by a similar research Abreu et al. 2014 and Cuba Rodríguez Algeciras et al. 2015. Similar to our results, it was perceived that shading is the main factor affecting quantitative heat stress, followed by wind speed modifications, so the shaded pedestrian is one of the most important strategies to mitigate heat stress (Ali-Toudert and Mayer 2007; Fröhlich andMatzarakis 2013;Ketterer and Matzarakis 2014).

The urban form determines the behavior of urban microclimate and consequently the presence of people in public spaces (Lin 2009; Lin et al. 2012); therefore, the description of local climatic conditions of a region in relation to the proper distribution and sizing of urban obstacles is needed to improve thermal comfort in outdoor spaces. A study of Mediterranean climate in the Island of Tinos, Greece (Andreou 2013) shows that north-south orientation streets with aspect ratios between 0.5 and 1.5 can reduce extreme thermal conditions. In addition to orientation and aspect ratio, the application of climatology urban design should consider other factors depending on the location such as ventilation, the density of the buildings and the trees (Givoni 1994; Lin et al. 2010), the materials used in facades, and the pavement type (Oke 1984) to improve pedestrian thermal comfort.

Table 7.3. Annual percentage of threshold based on PET (climate station 2009-2014)

Configuration	**Cold Condition**			**Heat Condition**		
	PET < 14°C	PET < 18°C	PET < 22°C	PET> 34°C	PET> 38°C	PET> 42°C
	%	%	%	%	%	%
PET (Original)	0.76	20.96	37.86	24.87	10.41	9.94
v + 1	0.23	16.27	35.74	29.32	10.04	9.69
v - 1	0.23	16.27	35.31	29.32	10.04	9.69
Tmrt = Ta	0.01	13.65	40.93	0.35	0.35	0.00
Tmrt = Ta (v + 1)	0.02	18.93	44.26	0.35	0.00	0.00
Tmrt = Ta (v - 1)	0.00	8.28	33.17	0.45	0.00	0.00

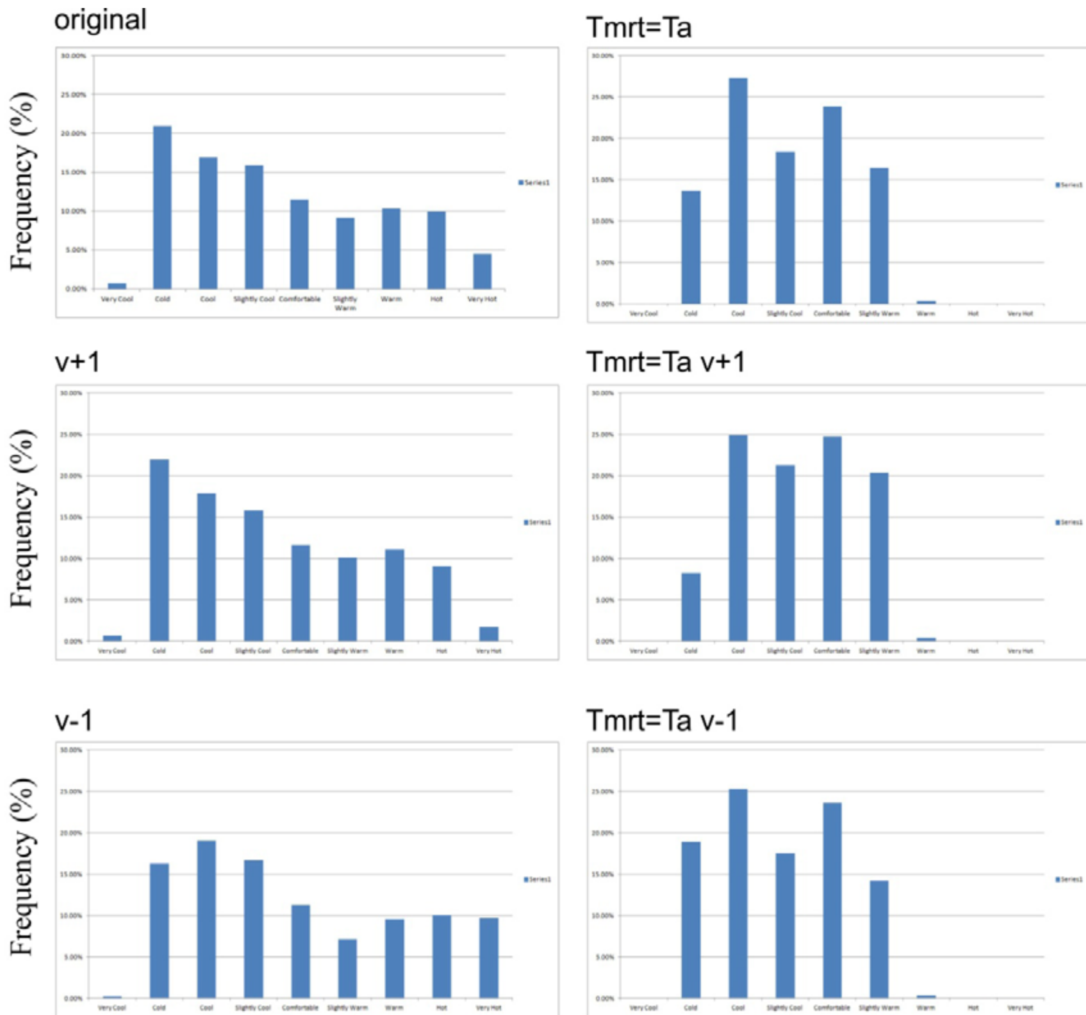


Figure 7.7. Detail of Annual Frequency of PET simulation based on data climate station 2009-2014

7.4. Correlation between urban structure parameters and climatic variables

7.4.1. Theme Park and climatic variables

Table 7.4 shows the characteristic of environment in theme park and climatic variables.

Table 7.4.Environmet Characterictic of Point measurements in Theme park and average Ta, Rh, v, Tmrt and PET on March

	Site Measurement	**SVF**	**GnPR**	**Paved area (Albedo)**	**Ta**	**Rh**	**Wind**	**Tmrt**	**PET**
					^oC	**%**	**m/s**	**^oC**	**^oC**
TIJA	A	0.2	3.65	30.7	27.97	71.42	4.92	42.53	28.90
	B	0.25	2.25	63.01	27.98	78.64	4.25	40.72	28.84
	C	0.44	3.12	50.04	28.47	85.18	3.08	44.56	31.77
	D	0.47	2.37	12.87	27.42	85.21	3.08	42.87	29.95
	E	0.82	0.5	72.27	29.12	83.88	1.34	49.89	37.23
	F	0.95	0.9	65.16	29.26	72.22	1.42	51.73	38.40
TMII	A	0.16	3.6	82.17	27.20	82.54	4.07	40.03	27.84
	B	0.1	1.87	42.46	28.61	66.17	2.69	41.44	31.94
	C	0.51	0.89	56.45	27.32	77.40	0.64	46.24	36.29
	D	0.42	2.15	53.17	28.02	66.70	1.61	44.20	33.24
	E	0.89	0.99	56.19	28.20	72.07	2.75	49.31	34.74
	F	0.92	1.28	70.06	28.06	69.74	1.60	50.04	35.28
KBR	A	0.08	4.18	67.58	29.93	78.36	1.66	44.42	35.42
	B	0.12	6.08	11.99	26.81	83.72	0.79	42.22	33.84
	C	0.47	4.17	19.32	27.30	84.10	0.78	43.89	33.99
	D	0.45	4.05	49.92	28.93	69.03	1.96	42.57	32.85
	E	0.98	2.88	21.24	28.51	75.39	1.79	50.76	36.15
	F	0.93	2.78	35.13	28.11	75.61	0.91	51.17	38.25

Table 7.5. Environmet Characterictic of Point measurements in Theme park and average Ta, Rh, v, Tmrt and PET on September

	Site Measurement	SVF	GnPR	Paved area (Albedo)	Ta	Rh	Wind	Tmrt	PET
					oC	%	m/s	oC	oC
TIJA	A	0.2	3.65	30.7	30.14	79.45	3.21	44.72	33.57
	B	0.25	2.25	63.01	27.42	90.83	2.71	40.53	29.66
	C	0.44	3.12	50.04	28.14	85.22	2.10	44.62	32.44
	D	0.47	2.37	12.87	27.94	78.64	4.24	42.98	29.51
	E	0.82	0.5	72.27	29.13	83.88	1.37	49.82	37.08
	F	0.95	0.9	65.16	28.12	85.20	2.09	49.72	34.46
TMII	A	0.16	3.6	82.17	29.21	75.37	2.72	41.92	31.78
	B	0.1	1.87	42.46	26.98	71.36	2.42	40.27	30.47
	C	0.51	0.89	56.45	28.81	73.07	0.50	47.90	39.29
	D	0.42	2.15	53.17	27.57	82.59	0.46	45.08	36.31
	E	0.89	0.99	56.19	29.73	67.55	0.66	52.58	41.61
	F	0.92	1.28	70.06	28.02	67.10	0.95	51.43	38.18
KBR	A	0.08	4.18	67.58	29.36	82.12	1.12	43.97	35.19
	B	0.12	6.08	11.99	28.77	83.31	2.01	43.12	33.16
	C	0.47	4.17	19.32	30.95	76.23	1.99	46.24	36.17
	D	0.45	4.05	49.92	28.21	88.01	1.03	42.38	34.16
	E	0.98	2.88	21.24	29.87	71.52	1.98	51.91	37.78
	F	0.93	2.78	35.13	26.92	88.44	1.16	49.26	35.43

In order to check how far environment characteristic affects the urban structure such as Sky View Factor, Green Plot Ratio, and paved area (Albedo) are compared with each variables of climatic using the statistical package, R. For correlation analysis the Pierson's r coefficient (for normally distributed data) is used.

The correlation can be seen as follows, Table 7.6 and Table 7.7.:

Table 7.6. Correlation of Environment Characteristic and Climatic Variables on March

	SVF	*GnPR*	*Paved area (Albedo)*
Ta	0.21	-0.27	0.42
Rh	-0.15	0.30	-0.18
Wind	-0.39	0.04	0.14
Tmrt	0.93	-0.54	0.12
PET	0.69	-0.34	0.06

A significant correlation value is should be more than 0.25. SVF has a significant correlation with Tmrt, wind speed, and PET with the value are 0.93, 0.416, and 0.69. But SVF has correlation with negative number with the wind speed. SVF will affect the Tmrt in the parks, when the value of SVF increase then the Tmrt will follow increase. The more open the site will get more radiation come in. Different with negative values of correlation between SVF and wind speed, it means when the value of SVF decreases the wind speed has more speed. Also Green Plot Ratio has the strongest correlation with Tmrt with a negative value (-0.532), it means Tmrt will increase when the GnPR decrease. The ratio of vegetation in the microclimate can affect the sun radiation penetrate into the environment. Paved area (Albedo) has a correlation with tie in the theme parks. Paved area (Albedo) can be material that reflects the radiation into the environment so there is a strong correlation between the albedo and the Ta.

Table 7.7. Correlation of Environment Characteristic and Climatic Variables on September

	SVF	*GnPR*	*Paved area (Albedo)*
Ta	0.00	0.26	-0.16
Rh	-0.19	0.28	0.01
Wind	-0.35	0.24	-0.39
Tmrt	0.90	-0.50	0.09
PET	0.62	-0.36	0.17

There is a different correlation between environment characteristic and climatic variable on March and September. We can see in Table 7.6 and Table 7.7 paved area has correlation with Ta (temperature) on March but there is no correlation on September. That can be explained the paved area (albedo) get significant direct sun radiation in March, while on September the sun radiation did not penetrate much in the parks. When we consider the position of the sun is different between March and September in Jakarta. Paved area (albedo) has the strongest correlation with wind speed in negative value on September. It means more bigger area of Paved area more the wind speed will be higher in the parks.

How much stronger the correlation between environmental characteristic and climatic variable, can be seen in graphic scatter as follows, see Figure 7.8 and Figure 7.9. R square in March shows bigger value than in September, it means SVF value in March tend has more correlation than in September. It proves that in March PET value change more quick according to the location.

The r squares of SVF and PET is below 0.5, it means the value of r square is small. It proves that the value of thermal comfort (PET) not only be correlated with environment parameters, but also correlated with other factors i.e. human activity and the clothing that people using.

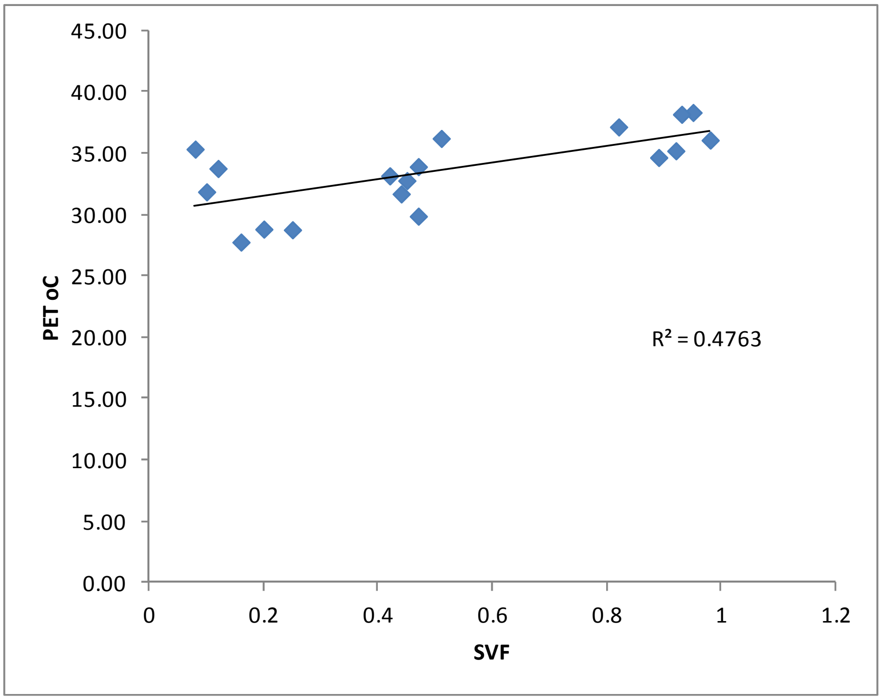


Figure 7.8. Scatter plot of SVF and PET value in March

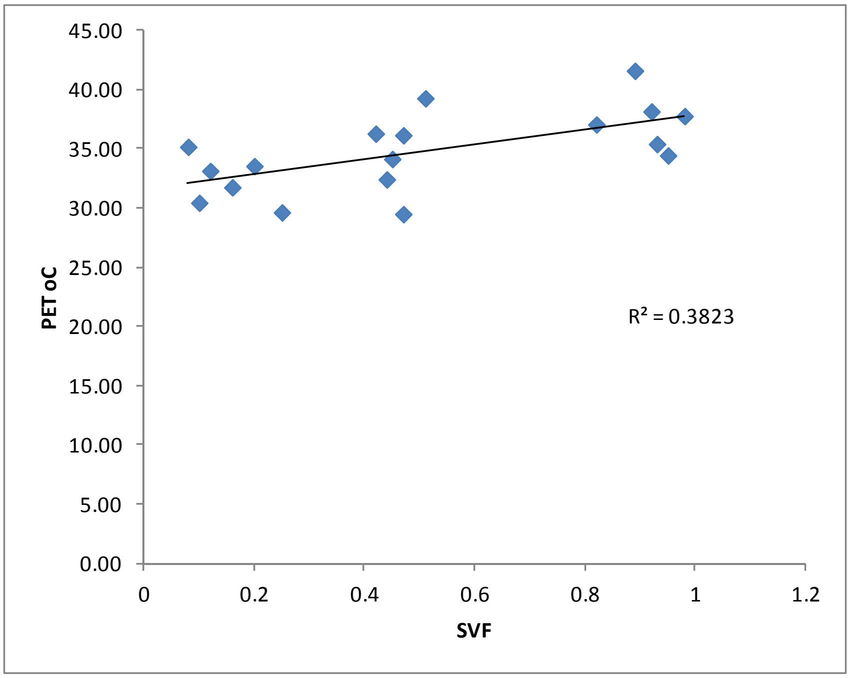


Figure 7.9. Scatter plot of SVF and PET value in September

The biggest correlation of SVF happens with Tmrt, see Figure 7.10 and Figure 7.11.

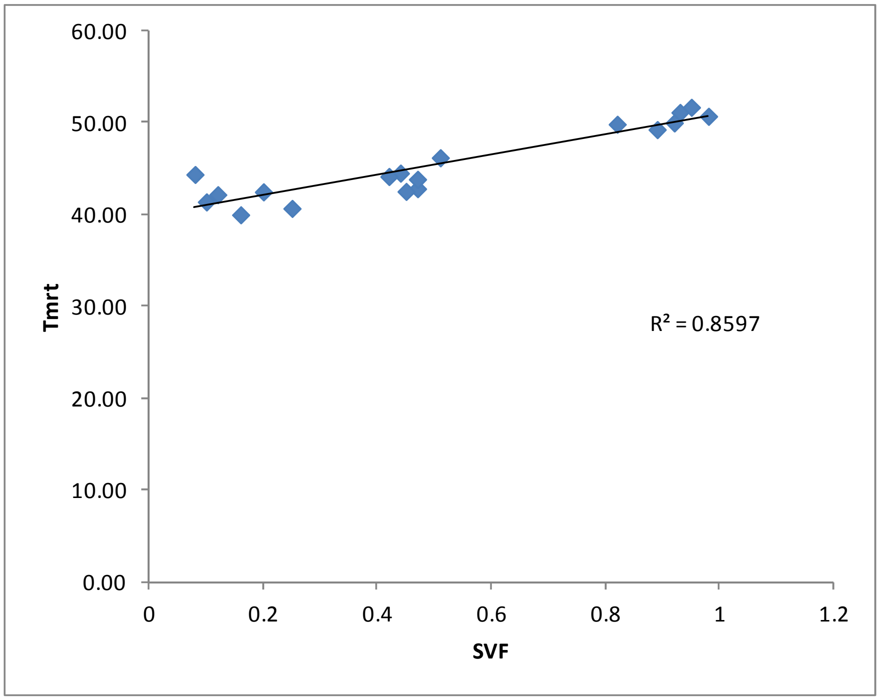


Figure 7.10. The Scatter plot of SVF and Tmrt in March

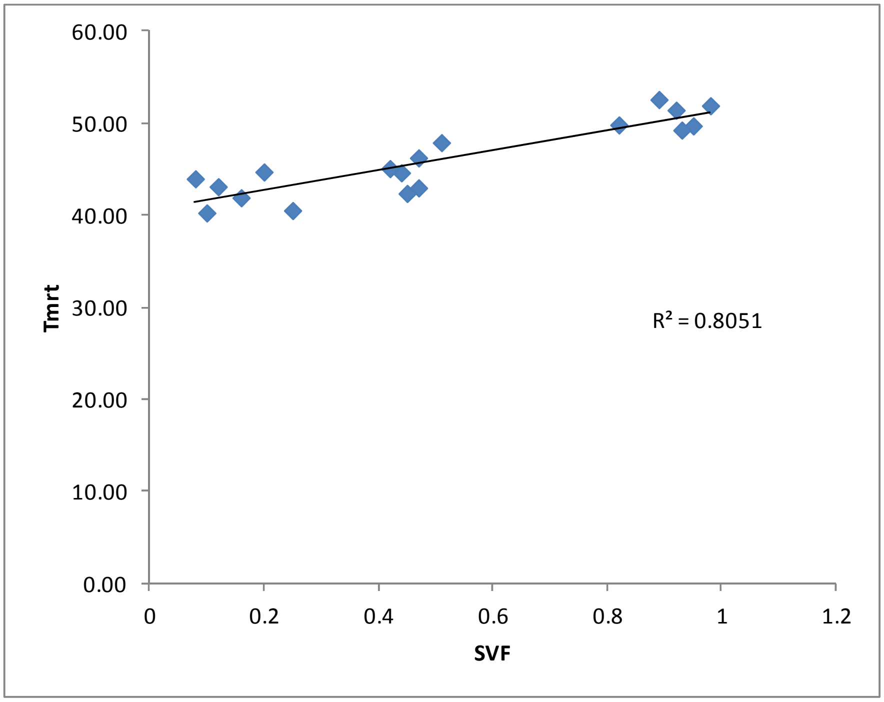


Figure 7.11. The Scatter Plot of SVF and Tmrt in September

Correlation SVF and Tmrt prove that the location tends opened is much more get the sun penetration and will be hotter than the location in the shaded area. Theme parks as tourist destination parks should be considered about shadowing.

7.4.2. Correlation between Urban Structure Parameters and Climatic Variables in Superblock

Due to the variability and complexity in the urban form the theory from Bourdic et al. Are proposed to be used to find the correlation between urban structure and climatic variable in this study case. There are two variables are suggested, i.e. Surface to Volume ratio of surrounding buildings (Volumetric Compactness = Building Surface (S)/Building Volume (V)=S/V) (Sharmin, 2015). Other variables that should be calculated is Surface (including plot-size of the area measured) to volume ratio = (S + Plot) /V and Green Plot Ratio by Ong, 2000 . The ratio of Height and width street was also calculated manually using the average building height and average street width (H/W) in the point measured area. All of the data of urban structure variables and climatic variable can be seen in Table 7.8.

All of the urban structure variables mentioned above will compare with SVF (Sky view factor) and others climatic variables such as Ta, Rh, wind speed, and Tmrt. The correlation analysis uses the Pierson's coefficient for normally distributed data.

Table 7.8. Measurement result of Urban structure parameters and climatic variables in October

Point Measured	H/W Ratio	SVF	Surf2Vol Ratio	SurfPlot2Vol Ratio	GnPR	Ta	Rh	Wind	Tmrt	PET
1	1.08	0.54	0.24	0.26	0.45	27.56	79.33	3.54	31.88	26.17
2	0.28	0.61	1.8	1.92	0.56	27.49	74.58	3.84	32.38	26.20
3	0.82	0.61	0.86	1.02	0.7	28.25	71.58	4.39	32.73	26.84
4	0.88	0.48	1.16	1.35	1.5	27.55	82.50	4.76	31.30	25.68
5	5.28	0.42	1.12	1.132	0.3	27.73	76.83	1.37	32.98	28.66
6	1.54	0.69	1.7	1.83	0.7	27.91	77.46	4.05	32.90	27.05
7	0.47	0.74	1.27	1.405	1.8	28.53	77.42	2.16	34.14	29.23
8	0.32	0.35	0.23	0.45	2.8	26.59	78.42	4.20	30.30	24.25

Table 7.9. Measurement result of Urban structure parameters and climatic variables in February

Point Measured	**H/W Ratio**	**SVF**	**Surf2Vol Ratio**	**SurfPlot2Vol Ratio**	**GnPR**	**Ta**	**Rh**	**Wind**	**Tmrt**	**PET**
1.00	1.08	0.54	0.24	0.26	0.45	28.25	71.58	4.39	26.84	32.73
2.00	0.28	0.61	1.80	1.92	0.56	27.49	74.58	3.84	26.20	32.38
3.00	0.82	0.61	0.86	1.02	0.70	27.73	76.83	1.37	28.66	32.98
4.00	0.88	0.48	1.16	1.35	1.50	27.55	82.50	4.76	25.68	31.30
5.00	5.28	0.42	1.12	1.13	0.30	27.56	79.33	3.54	26.17	31.88
6.00	1.54	0.69	1.70	1.83	0.70	27.91	77.46	4.05	27.05	32.90
7.00	0.47	0.74	1.27	1.41	1.80	28.53	77.42	2.16	29.23	34.14
8.00	0.32	0.35	0.23	0.45	2.80	26.59	78.42	4.20	24.25	30.30

Table 7.10. Correlation between urban structure parameters and climatic variables in October

	H/W Ratio	*SVF*	*Surf2Vol Ratio*	*SurfPlot2Vol Ratio*	*GnPR*
Ta	0.091	0.808	0.445	0.411	-0.425
Rh	-0.003	-0.335	-0.215	-0.206	0.349
Wind	-0.684	-0.051	-0.097	-0.013	0.237
Tmrt	0.258	0.778	0.561	0.505	-0.457
PET	0.496	0.547	0.434	0.365	-0.410

Table 7.11. Correlation between urban structure parameters and climatic variables in February

	H/W Ratio	*SVF*	*Surf2Vol Ratio*	*SurfPlot2Vol Ratio*	*GnPR*
Ta	0.007	0.777	0.248	0.185	-0.455
Rh	0.242	-0.312	0.197	0.256	0.397
Wind	0.047	-0.483	-0.091	-0.097	0.085
Tmrt	-0.096	0.832	0.272	0.246	-0.325
PET	-0.089	0.915	0.392	0.346	-0.425

Table 7.10 shows the correlation between urban structure parameters and climatic variables in October. In the urban context SVF has the strongest correlation with Tmrt (0.78). Increasing SVF value makes the Tmrt value increase. Open space area will penetrate the sun radiation into the area. Another important correlation that has to be mentioned is Surface to Volume ratio has strong correlation with Tmrt as well. It means the building surface affects the radiation surrounding. The H/W ratio in the urban affect the wind speed that can be seen in the table above the correlation between H/W ratio and wind has negative value (-0.6).

Table 7.11. shows the correlation in February because of the sun position is different there are different correlation between urban structure and climatic variables in February and

October. In October sun position is in the north of Jakarta so it changed the wind direction. In this month wind correlation with H/W ratio has a correlation in positive value.

GnPr show the other side of the correlation, although small correlation GnPR affects the Ta and Tmrt in the urban context. This correlation between GnPR in the urban is higher than in the theme parks. It means the thermal comfort in the urban context is more affected by the green area. Surface to volume ratio do not have correlation with the Tmrt or Ta but has a direct correlation with PET.

There is a different way correlation between H/W ratio and wind speed, it should be a different time of measurement. In October wind has strong correlation with H/W Ratio but in March do not has correlation. In October the correlation between H/W and wind speed is in negative value.

How strong the correlation between SVF and Tmrt and PET can be seen in the graphs below.

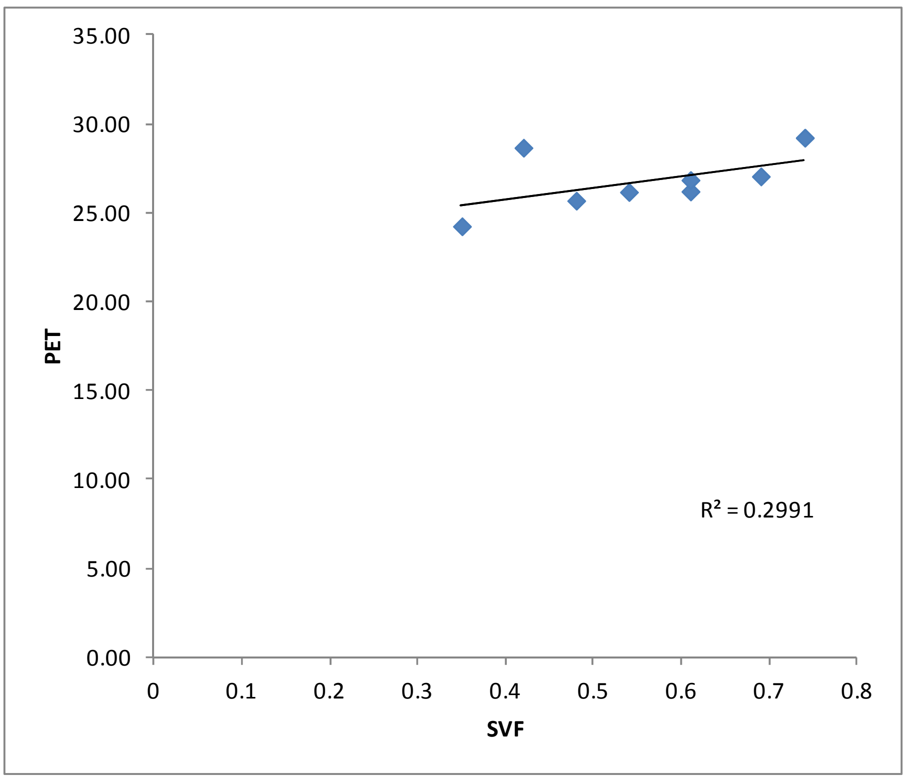


Figure 7.12. Correlation between SVF and PET in October

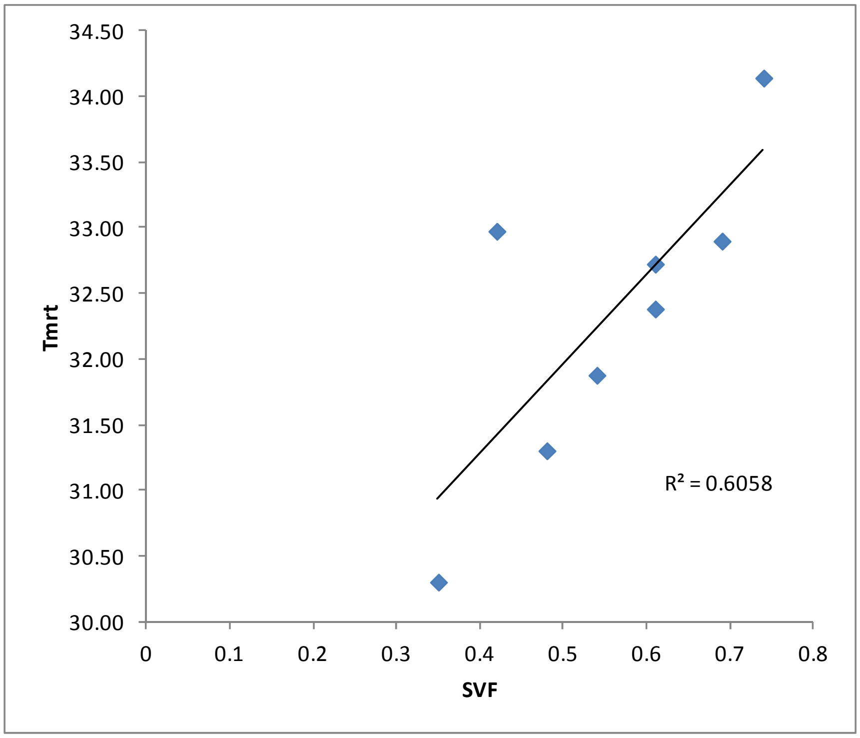


Figure 7.13. Correlation between SVF and Tmrt in October

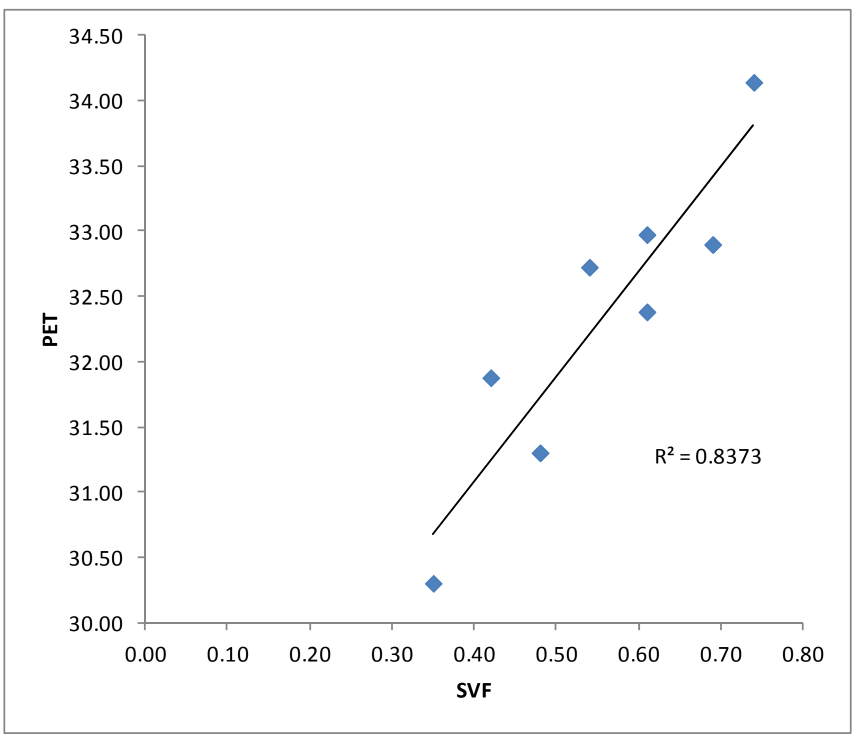


Figure 7.14. Correlation between SVF and PET in February

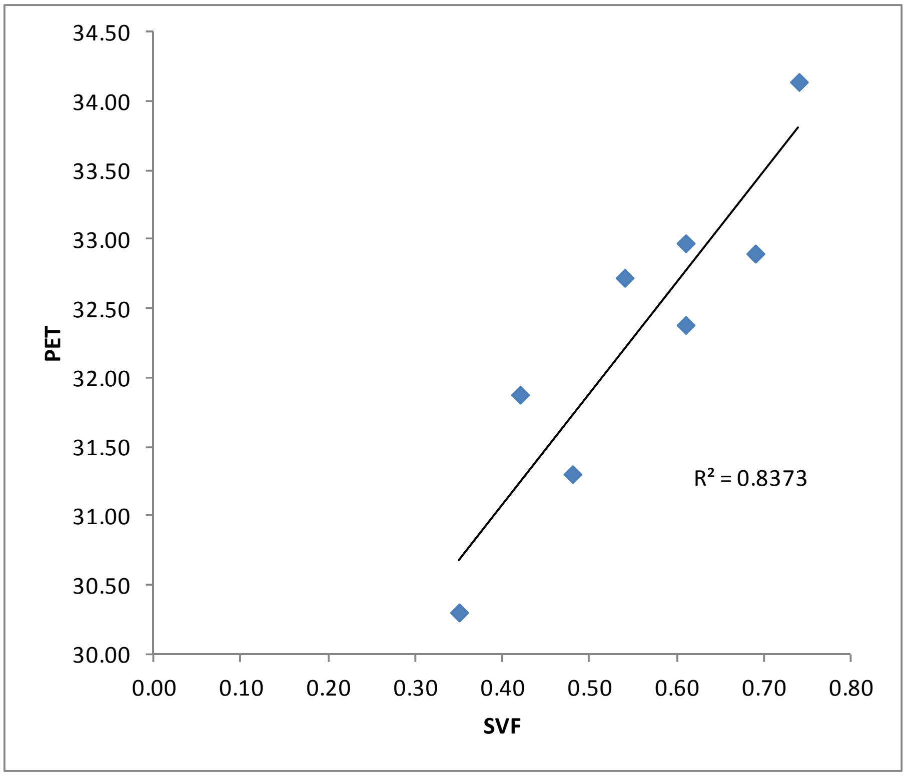


Figure 7.15. Correlation between SVF and Tmrt in February

Chapter 8

CONCLUSION AND RECOMMENDATION

Summary

Thermal comfort conditions of open space in Jakarta is very affected by the microclimate depend on each location. Jakarta's microclimate has shown uncomfortable conditions. Overall measurements of open spaces in the Jakarta have shown an uncomfortable, although in some places in the morning at 7am is still in a comfortable condition in 0.5 PMV or 22 ° C PET, but at the same time the conditions change became uncomfortable quickly or heat increase more than 1 PMV or above 34 ° C PET.

Heat peaks occurred between 12pm to 1pm vary depending on the location. The scale of comfortable began at 7am everyday between 22-24 °C PET and become uncomfortable at 34-38 °C PET in the daytime. Open space of Theme Parks in Jakarta could never reach the point of comfort.

High rise building affects thermal comfort, high rise building can make an uncomfortable condition surrounding and trap the heat in a whole day as well. In contrast, thermal comfort in residential area changes quickly from morning to afternoon. High-rise building on the other hand has a disadvantage in thermal comfort in outdoor, but in other hand, high rise building has the advantage shadowing the surroundings that make the temperature lower. So building placement is important to be considered, to create the shadowing outside building.

The open area with the shaded of the plantation is the location can be tolerated as the location most comfortable because the high wind speed is not hindered by the buildings, and had the longer thermal acceptable period. In the general thermal comfort difficult to be achieved in the superblock

Urban ventilation should be created by building arrangement through formation and planning. Urban planner and architects have to take into account the thermal comfort and wind velocity and distribution in pedestrian level through building arrangement and planning.

In the level pedestrian wind experience decreasing the velocity, thus the thermal comfort at that level difficult to be achieved. Park is the most area with best wind velocity. The wind velocity near the building (high rise) experiences decreasing the velocity.

The comfortable distance of walking in a hot-humid city like Jakarta is 350 m average based on walking comfort simulation. It can be reached more than 450 m distance if the city can reduce the Tmrt value and the humidity, therefor the shading area has to be considered by the urban planner and architect. Buildings can be designed as the shading area, therefor the designer should pay attention to the solar movement, and building orientation.

8.1. Contribution to knowledge

Science either architecture or landscape design has been developed very advanced the need for further development of science that combines architecture and landscape design that really thermal comfort as its foundation. Further development of the science of architectural design and landscaping is more concerned with the environmental balance to get a better thermal environment, sustainable energy or better.

Materials science in the field of architecture is still very rare, especially material science related to landscape design that can explain in more detail the value of a material such as albedo value, especially material related to tropical conditions such as in Indonesia. In the case of researchers be some very hard time determining the value of the albedo of a material, because most of the material already has a value of albedo is not necessarily the same as the value used in the country of Indonesia, so that needs to be further developed research material.

Computer simulations related to thermal comfort are mainly used in landscape design and the city has not been widely used. Whereas the results obtained are very useful in determining and deciding a good design. With the development of computer tools, both speed and the ability to save this simulation will be more easily used and developed as a tool in the decision making both in the design of a landscape area and in urban design.

This dissertation tried to open new insights into how to design an open area that considers to the simulation of thermal comfort in deciding the design.

Need to do research and development of software with the values of the tropics. In some cases a simulation of this study should be an adjustment to the tropics, especially the humid tropics, such as Indonesia, and takes a lot of time. If the existing software developed for the tropics will be easier to simulate.

8.2. Future work

Follow up and Review

UHI phenomenon is a matter which has clear locality and close relation with wide-range socioeconomic activities. So it is necessary to take numerous measures each part such as the central government, local governments, business and residents. The review of research will be carried out flexibly in accordance with necessity, taking account of the progress of research on mechanism of UHI and development of technologies and countermeasures.

The combination of built environment and the natural environment made the urban structure, which effect on how people everyday life and move in the city. The urban structure development should consider developing the overall performance of the whole society and living environment.Local actions towards a sustainable city has to be mapped as the key strategy in urban development.

Traffic emissions can be reduced by good Urban structure design. Environmental cost can be happened because of car oriented urban structure design which encourages the use of cars and thus creates in terms of increased pollution, noise, vibrations which also affect the natural environment.

In a sustainable city, coordination between land-use and transport planning can encourage spatial settlement patterns that help access to basic necessities (e.g. food, healthcare, education, leisure facilities) and reduces the need to travel.

Urban surface and structure planning, a part of master planning, terms the process by which the use of land in urban is controlled in the public interest. Master planning carries the issues on a more local level. The master plan is consequently an official document that sets out the suggested land-use rights for a specific area and contains the building rights as directed by the local planning authority. The master plan includes the basic design layout for detailed planning, building lines and planning conditions. The specific details of a development, such as urban layout, Floor Area Ratio, Building Coverage Ration, façade design of buildings, energy supply systems, levels of insulation, the fenestration, materials of buildings, and so on are key elements in detailed master planning process.

Master planning and design of an energy efficient in the urban area is a process of trade-offs between planning and design choices and planning and design parameters. There are priorities and conflicts that have to be considered in the process. Urban comfort and compactness of the urban structure at the same time can be addressed with a view to impacts on energy consumption and related emissions.

8.3. Conclusion and Recommendation

On a building level, the use of energy related to heating, cooling, ventilation, air-conditioning and natural lighting related to site conditions, orientation and microclimate, and use of electrical energy. The district level addresses the relations between different buildings and their impacts on each other. Each individual building needs to have both energy consumption and peak demand information.

The ultimate objective of responsibility this research and possible future similar follow-ups is to bring strategies of urban surface modifications and urban structure modification into possible regulatory consideration by urban temperature and energy control and districts management.

Technology is the key factor whether as just an information tool or design and planning tool as well. Application of technology is important in the process of urban sustainable development.

REFERENCES

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

Akbari, H., Menon, S., Rosenfeld, A., (2009). Global cooling: increasing world-wide urban albedos to offset CO2. *Climate. Change* 94: 275–286.

Akbari, H., Menon, S., Rosenfeld, A., (2010). Global cooling: increasing world-wide urban albedos to offset CO2. Climate. Change 94: 275–286.

Atkins, K., and Thompson, M., (2000). *Sportscience* A spreadsheet for Partitional Clorimetry, Accessed March 20, 2014. http://www.sportsci.org/jour/0003/ka.html

Ahmed, K.S., 2003, Comfort in urban spaces: Defining the boundaries of outdoor thermal comfort for the tropical urban environments. Energy & Building, 35, 103-110.

Alvarez S, Guerra J, Velazquez R., (1991), Climatic control applications in outdoor spaces at Expo’92, presented at Proceedings of the Ninth International Passive and Low Energy Architecture (PLEA), Architecture and Urban Space, Seville, Spain,

Ali-Toudert F, Mayer H., (2007), Effects of asymmetry, galleries, overhanging facadesand vegetation on thermal comfort in urban street canyons. Sol Energ; 81:742e54

Handy, S., (2005). Critical Assessment of the Literature on the Relationships Among Transportation, Land Use, and Physical Activity. *TRB Special Report 282*, 102. doi:Cited By (since 1996) 31\rExport Date 27 September 2011

Amirudin, Saleh 1969, *Iklim dan Arsitektur*, Dept. Pekerjaan Umum, Dirjen Cipta Karya, Lembaga Penyelidikan Masalah Bangunan, Bandung

ASHRAE, 2001: *Chapter 8 – Comfort, In: Handbook of Fundamentals,* American Society for heating Refrigerating and Air Conditioning, Atlanta: 8.1-8.29. USA

ASHRAE (2001): Chapter 13 – *Measurements and instruments*, *In: Handbook of Fundamentals*, American Society for heating Refrigerating and Air Conditioning, Atlanta: 13.26 –13.27. USA

Bosselmann, Peter (2005), *Thermal Comfort For Pedestrians, Sense Of Time And The Bridging Of Barriers, Paper for “Walking City” International Conferen*ce, June 2-3, Porto, Portugal

Bourbia, F., & Awbi, H. . (2004). Building cluster and shading in urban canyon for hot dry climate. *Renewable Energy*, *29*(2), 249–262. doi:10.1016/S0960-1481(03)00170-8

Bruse, M. (2007): Simulating human thermal comfort and resulting usage patterns of urban open spaces with a Multi-AgentSystem, in: Wittkopf, St. and Tan, B. K. (eds.): *Proceedings of the 24th International Conference on Passive and Low Energy Architecture PLEA*, **24**, 699-706.

Brown R.D., Gillespie T. (1986), *Estimating outdoor thermal comfort using a cylindrical radiation thermometer and an energy budget model*. Int. J. Biometeorol. 30: 43-52.

Brown R.D., Gillespie T. (1995), *Microclimate Landscape Design*, John Willey and Sons Inc., New York

Brown R.D., Gillespie T. (1986), *Estimating outdoor thermal comfort using a cylindrical radiation thermometer and an energy budget model*. Int. J. Biometeorol. 30: 43-52.

Brown, R., Gillespie, T., (1995), Microclimatic Landscape Design: Creating Thermal Comfort and Energy Efficiency. John Wiley and Sons, New York.

Besser, L. & Dannenberg, A., (2005), Walking to public transit: Steps to help meet physical activity requirements. American Journal of Preventative Medicine, 29, 273-281.

Buys, L. & Miller, E., (2010), Conseptualising convenience: Transportation practices and perceptions of inner-urban high density residents in Brisbane, Australia. Transport Policy, doi: 10.1016/j.tranpol.2010.08.012

Bekele, S., Jones, I., and Rajamani, G. (2008). Microcliamte study of a city in hot and humid climate. In: Council on Tall Buildings and Urban Habitat 8th World Congress, 2008.

Bradshaw, Vaughn (2006), *The Building Environment: Active and Passive Control Systems*, Wiley; 3 edition, ISBN: 0471689653

Cervero, Robert and Michael Duncan, (2003), Walking, Bicycling, and Urban Landscapes: Evidence From the San Francisco Bay Area. American Journal of Public Health, 93(9): 1478-1483.

Chen L, Ng E., (2012), Outdoor thermal comfort and outdoor activities: a review of research in the past decade. Cities; 29: 118e25.

Djongyang, N., Tchinda, R., and Njomo, D. , (2010). Thermal comfort: A review paper. *Renewable and Sustainable Energy Reviews*, 14, 9, 2626-2640.

de Dear R, "deDear’s calculator", Accessed March 20 2014 http://web.arch.usyd.edu.au/~rdedear/

Eliasson, I., (2000), The use of climate knowledge in urban planning. *Landscape and Urban Planning* 48: 31-44.

Ewing, R., Handy, S., Brownson, R., Clemente, O., & Winston, E., (2006), Indentifying and measuring urban design qualities related to walkability. Journal of Physical Activity and Health, 3, S223-S239.

Huttner, Sebastian; Bruse, Michael; (2009), *Numerical Modeling Of The Urban Climate –A Preview On Envi-Met 4.0,* The Seventh International Conference On Urban Climate, 29 June - 3 July 2009, Yokohama, Japan

Bruse, M., H. Fleer, (1998): *Simulating Surface-Plant-Air Interactions Inside Urban Environments With A Three Dimensional Numerical Model*, Environment Model Software.

DeVau, M. , 2011, Strategies to Address the Climatic Barriers to Walkable, Transit-Oriented Communities in Florida, *Goergia institute of Technology School of City and regional Planning, Master Thesis*.

Fanger PO (1970) Thermal Comfort. New York: McGraw-Hill

Fukazawa, T., Havenith, G., (2009), Differences in comfort perception in relation to local and whole body skin wettedness. Eur. J. App. Physiol. 106, 1, 15-24.

Gagge A.P., Fobelets A.P., and Berglund L.G., (1986), A standard predictive index of human response to the thermal environment. *ASHRAE Trans*. 92(2): 270-290.

Goncalves, J.C.S. & Duarte, D. (2008). Paper 604: Environmental urban design for central urban areas in Sao Paulo, Brazil. In: PLEA 2008 – 25th Conference on Passive and Low Energy Architecture, 2008, Dublin.

Gonzalez RR (1995) Biophysics of heat exchange and clothing: applications to sport physiology. Medicine Exercise Nutrition and Health 4, 290-305

Gulyas, A., Unger, J., Matzarakis, A., (2006), Assessment of the microclimate and human comfort conditions in a complex urban environment: Modelling and measurements. Build. Environ. 41, 1713–1722.

Greenwald, Michael J. and Marlon G. Boarnet, (2001), The Built Environment as a Determinant of Walking Behavior: Analyzing Non-Work Pedestrian Travel in Portland, Oregon. Institute of Transportation Studies, Irvine, University of California,

Hartog and Havenith, (2009), Analytical Study of the Heat Loss Attenuation by Clothing on Thermal Manikins Under Radiative Heat Loads. *International Journal of Occupational Safety and Ergonomics (JOSE)* 2010, Vol. 16, No. 2, 245–261

Havenith, Holmer, and Parson, (2002), Personal Factor in Thermal Assessment: Clothing Properties & Metabolic Heat Production, *Journal: Energy and Building Elsevier Science* 34: 581-591.

Hyodo, T, Fujiwara, A, Montalbo, C.T., Soehodho, S, (2005), Urban travel behavior characteristics of 13 cities based on household interview survey data, Journal of the Eastern Asia Society for Transportation Studies, Vol. 6, pp. 23 - 38,

Honjo T., (2009), Thermal comfort in outdoor environment. Global Environ Res; 13: 43e7.

Höppe P., (1993), Heat balance modelling. Experientia 49 (9), 741–746.

Höppe PR, (1999), The physiological equivalent temperature – a universal index for the biometeorological assessment of the thermal environment. *Int J Biometeorol*

Eliasson, I., (2000). The use of climate knowledge in urban planning. Landscape and Urban Planning 48: 31-44.

Givoni B. (1976): *Man, Climate and Architecture*. Van Nostrand Reinhold. New York.

Gosling, S. N., Bryce, E. K., Dixon, P. G., Gabriel, K. M. a, Gosling, E. Y., Hanes, J. M., … Wanka, E. R. (2014). *A glossary for biometeorology*. *International Journal of Biometeorology* (Vol. 58). doi:10.1007/s00484-013-0729-9

Gulyas, A., Unger, J., Matzarakis, A., (2006). Assessment of the microclimate andhuman comfort conditions in a complex urban environment: Modelling and measurements. Build. Environ. 41: 1713–1722.

Gómez, F., Gil, L., Jabaloyes, J., (2004). Experimental investigation on the thermal comfort in the city: relationship with the green areas, interaction with the urban microclimate. Build. Environ. 39: 1077–1086.

Givoni B. (1997): *Climate considerations in building and urban design*, Van Nostrand Reinhold. New York.

Höppe PR, (1999). The physiological equivalent temperature – a universal index for the biometeorological assessment of the thermal environment. International J Biometeorol, 24: 699-706

Holmer B., Postgård U., and Eriksson M. (2001). Sky view factors in forest canopies calculated with IDRISI. Theoretical and Applied Climatology 68, 33-40

Humphreys, M.A, Nicol, J.F. (2001). The Validity of ISO-PMV for Predicting Comfort Votes in Every-day Thermal Environments, Moving Thermal Comfort Standards into the 21st Century. Windsor, UK, Loughborough University, 406-430.

Hwang R.L, Lin T.P., Matzarakis A., (2011), Seasonal effects of urban street shading on long-term outdoor thermal comfort, Build. Environ. 46: 863-870.

Houghton F.C., Yaglou C.P. (1977), *Determination of the comfort Zone.* ASHVE Research report No. 673. ASHVE Transactions 29: 361.

Huttner, Sebastian; Bruse, Michael; (2009), *Numerical Modeling Of The Urban Climate –A Preview On Envi-Met 4.0,* The Seventh International Conference On Urban Climate, 29 June - 3 July 2009, Yokohama, Japan

Huang R.L, Lin T.P., Matzarakis A., (2011), Seasonal effects of urban street shading on long-term outdoor thermal comfort, Build. Environ. 46:863-870

Handy S., 2005, Critical Assessment of the Literature on the Relationships Among Transportation, Land Use, and Physical Activity, Resource paper for Does the Built Environment Influence Physical Activity? Examining the Evidence, Special Report 282, Transportation Research Board and Institute of Medicine Committee on Physical Activity, Health, Transportation, and Land Use.

Höppe P. R. (1999). *The physiological equivalent temperature – a universal index for the biometeorological assessment of the thermal environmen.*, Int. J. Biometeorol. 43.

Indonesia Real Estate Law. Construction of a Superblock Area in the Special Capital City Region of Jakarta, Accessed May 20, 2013. http://www.indonesiarealestatelaw.com/2013/11/06/construction-of-a-superblock-area-in-the-special-capital-city-region-of-jakarta/

ISO 7730. (1994). Moderate thermal environments – Determination of the PMV and PPD indices and specification of the conditions for thermal comfort. International Standard.

Jakarta Weather Data: http://weatherspark.com/#!graphs;a=Indonesia/Jakarta.

Jendritzky, R., De Dear, R., Havenhit, G., 2012, UTCI- Why another thermal index? Int. J. Biometeorol. 56 (3), 421–428.

Jacobs, J. (1961). The Death and Life of Great American Cities. New York: Random House.

Johansson E, Emmanuel R. The influence of urban design on outdoor thermal comfort in the hot, humid city of Colombo, Sri Lanka. Int J Biometeorol 2006; 51:119e33.

Jusuf, Steve Kardinal, Hien, Wong Nyuk (2007), *GIS-Based and Simulation Study of Urban Heat Island in Institutional Campus,* Prosiding SENVAR 08, Departemen Arsitektur UK Petra, Surabaya

Johnson G, Watson I., 1984. The Determination of View-Factors in Urban Canyons. Journal of Climate and Applied Meteorology 23: 329-335.

Jauregui, E. (1990/91). *Influence of a large urban park on temperature and convective precipitation in tropical city*. Energy and Buildings, 15-16, 457-463.

Koenigsberger, O.H., Ingersoll, T.G., Myhew, A., Szokolay, S.V. (1973), *Manual of Tropical Housing and Building; Part 1: Climatic Design*, Longman Group Limited, London.

Kukreja, CP. (1980), *Tropical Architecture*, McGraw-Hill, New Delhi.

Katarina, T. and Syaukat, S., 2015, Asian Cities Climate Resilience. Working paper series 13. The Asian Cities Climate Change Resilience Network (ACCCRN, www.acccrn.org) Rockefeller Foundation. ISBN 978-1-78431-122-3. http://pubs.iied.org/10721IIED.html

Kashef, M., 2010, Neighborhood design and walkability: A synthesis from planning, design, transportation and environmental health fields. Alhosn University Journal of Engineering & Applied Sciences, 3, 87-105.

Katzschner, L. and Mülder, J. (2006), *Regional climatic mapping as a tool for sustainable development*, Journal of Environmental Management.

Koerniawan, MD, (2010), Recreation Park And Thermal Comfort: Site Measurement And Predictive Simulations. Assessment Of Open Spaces In Taman Impian Jaya Ancol, Jakarta, Indonesia, YSRIM 2012.

Katzschner, L., Bosch, U. and Röttgen, M. (2004). *A methodology for bioclimatic microscale mapping of urban spaces*. University of Kassel, Kassel, Germany

Landsberg, H.E., 1981. The Urban Climate. Academic Press, New York. ASIN: B00ECIJM4Q, pp: 155

Lindberg F., Holmer . 2006, Sky View Factor Calculator User Manual - Version 1.1, University of Gothenburg, Göteborg Urban Climate Group.

Lin, T.P., A. Matzarakis, J.J. Huang, 2006, Thermal comfort and passive design of bus shelters. Proc. 23rd Conference on Passive and Low Energy Architecture (PLEA2006).

Lin TP, Matzarakis A., 2008. Tourism climate and thermal comfort in Sun Moon Lake, Taiwan. Int Journal of Biometeorology 52:28 1-90.

Lin TP, Matzarakis A, Hwang RL., 2010. Shading effect on long-term outdoor thermal comfort. Building and Environment; 45: 213e21.

Lin, T.P., De Dear, R., Hwang, R.L., 2011. Effect of thermal adaptation on seasonal outdoor thermal comfort. Int. J. Climatol. 31: 302–312.

Lechner, Norbert (2000), *Heating, Cooling, Lighting: Design Methode for Architecture,* Second Edition John Wiley & Sons, NV, USA.

Lippmeier, Georg, (1980), *Tropen bau : Building in The Tropics*, Verlag Georg, D.W. Callwey, Muenchen,. hal. 8

Landsberg, G.H., 1981, The Urban Climate. *Academic Press*, New York.

Lin, T.P., A. Matzarakis, J.J. Huang, 2006, Thermal comfort and passive design of bus shelters. Proc. 23rd Conference on Passive and Low Energy Architecture (PLEA2006),

Lin TP, Matzarakis A., 2008, "Tourism climate and thermal comfort in Sun Moon Lake, Taiwan". *Int Journal of Biometeorology* 52:28 1-90.

Lin, T.P., 2009, Thermal perception, adaptation and attendance in a public square in hot an humid regions. Build. Environ. 44, 2017–2026.

Lin TP, Matzarakis A, Hwang RL., 2010, Shading effect on long-term outdoor thermal comfort. Building and Environment; 45:213e21.

Lin, T.P., De Dear, R., Hwang, R.L., 2011, Effect of thermal adaptation on seasonal outdoor thermal comfort. Int. J. Climatol. 31, 302–312.

Lin, T.P., Tsai, K.T., Hwang, R.L., Matzarakis, A., 2012, Quantification of the effect of thermal indices and sky view factor on park attendance. Landsc. Urban Plan. 107, 137–146.

Lin, T.P., Tsai, K.T., Liao, C.C., Huang, Y.C., 2013, Effects of thermal comfort and adaptation on park attendance regarding different shading levels and activity types. Build. Environ. 59, 599–611.

Litman, T., 2007, The Economic Value of Walkability. Victoria, BC: Victoria Transport Policy Institute.

Lovasi, G.S., Grady S., and Rundle, A., 2012, Steps Forward: Review and Recommendations for Research on Walkability, Physical Activity and Cardiovascular Health, Public Health Rev.; 33(4): 484–506.

Luxmoore, D.A., Jayasinghe, M.T.R., & Mahendran, M., 2004, Mitigating temperature increases in high lot density sub-tropical residential developments. Energy and Buildings, 37, 1212-1224.

Landsberg, H.E. (1981), The Urban Climate, Academic Press, New York.

Lee, H.Y., (1993). An application of NOAA AVHRR thermal data to the study of urban heat islands, Atmospheric Environment, 27B(1), 1-13.

Makaremi, N., Salleh, E.,. Jaafar, M. Z., GhaffarianHoseini, AH., 2012, Thermal comfort conditions of shaded outdoor spaces in hot and humid climate of Malaysia, Build. Environ. 48 : 7-14.

Matzarakis A, Mayer H., 1996, Another kind of environmental stress: thermal stress. WHO collaborating centre for air quality management and air pollution control. *Newsletters* 18: 7-10.

Mayer H, Höppe PR, 1987, Thermal comfort of man in different urban environments. *Theory Application Climatology* 38:43–49

Matzarakis, A., Mayer, H., and Iziomon, M.G., 1999, Applications of a universal thermal index: physiological equivalent temperature, *Int. J. Biometeorol*. 43: 76-84.

Matzarakis, A., Rutz, F., Mayer, H., 2007, Modelling radiation fluxes in simple and complex environments - application of the RayMan model. *International Journal of Biometeorology* 51: 323-334.

McGinn, A., Evenson, K., Herring, A., & Huston, S., 2007, The relationship between leisure, walking and transportation activity with the natural environment. Health & Place, 13, 588-602.

Metje N, Sterling M, Baker C., 2008, Pedestrian comfort using clothing values and body temperatures. J Wind Eng Ind Aerodyn; 96(4): 412e35.

Mishra AK, Ramgopal M., 2013, Field studies on human thermal comfort. An overview. Build Environ; 64: 94e106.

Morgan, D. L., Baskett, R. I., 1974: Comfort of man in the city. Int. J. Biometeor. 18, 184–198.

Murakami S, Ooka R, Mochida A, Yoshida S, Kim S, 1999, CFD analysis of wind climate from human to urban scale. Journal of Wind Engineering and Industrial Aerodynamics. 81:57–81.

Mangunwijaya, YB. (1981), *Pasal-Pasal Pengantar Fisika Bangunan*, Gramedia, Jakarta.

Matzarakis, Andreas. (2003), *Required Meteorological And Climatological Information For And Tourism*, Meteorological Institute, University of Freiburg, D-79085 Freiburg, Germany

Matzarakis, Andreas (2005), *Modelling Of Radiation Fluxes In Urban Areas And Their Relevance To Thermal Conditions Of Human*, Third Symposium on the urban environment, American Meteorological Society. 163-164.

Matzarakis, A. – de Freitas, C. – Scott, D. (eds.) (2004). Advances in tourism climatology. Ber.Meteorol. Inst. Univ. Freiburg Nr. 12.

Matzarakis, A., Mayer, H., and Iziomon, M.G. 1999. Applications of a universal thermal index: physiological equivalent temperature, International Journal Biometeorol. 43: 76-84.

Matzarakis, A., Rutz, F., Mayer, H., 2007. Modelling radiation fluxes in simple and complex environments - application of the RayMan model. International Journal of Biometeorology 51: 323-334.

Mayer H, Höppe PR 1987. Thermal comfort of man in different urban environments. Theory Application Climatology, 38:43–49

Matzarakis, Andreas, Rutz, Frank and Mayer, Helmut (2006), *Modelling the thermal bioclimate in urban areas with the RayMan Model*, PLEA2006 - The 23rd Conference on Passive and Low Energy Architecture, Geneva, Switzerland.

Matzarakis, A.and H. Mayer (20.-23 November 2000), *Atmospheric Conditions And Human Thermal Comfort In Urban Areas*, 11th Seminar on Environmental Protection Environment and Health".Thessaloniki, Greece,

*Mayer, H. – Matzarakis, A. (*1997). The urban heat island seen from the angle of humanbiometeorology. Proceed. Int. Symposium on Monitoring and Management of Urban Heat Island, Fujisawa, Japan.

Marlina, Endi. (2008). Panduan Perancangan Bangunan Komersial. Yogyakarta: Andi, Indonesia.

Michael Bruse, d., ENVI-met.com, 2003.

Nikolopoulou, Marialena (2004), *Designing Open Spaces in the Urban Environment: a Bioclimatic Approach*, RUROS (Rediscovering The Urban Realm and Open Spaces), Center for Renewable Energy Sources, Department of Buildings, Greece, Atenas: CRES

Nikolopoulou M, Baker N, Steemers K., 2001, Thermal comfort in outdoor urban spaces: Understanding the human parameter. Solar Energy, 70, 227–35.

Nicolopoulou, M., Steemers, K., 2003, Thermal comfort and psychological adaptation as a guide for designing urban spaces. Energy Build. 35 (1), 95–101.

Nikolopoulou, M., Lykoudis, S., Kikira, M., 2004, Thermal comfort models for open urban spaces. Designing Open Spaces in the Urban Environment: a Bioclimatic Approach, Rediscovering the Urban Realm and Open Spaces, Key Action 4 City of tomorrow and Cultural Heritage from the programme Energy, Environment and Sustainable Development. European Union, Bruxelles.

Nikolopoulou M, Lykoudis S., 2006, Thermal comfort in outdoor urban spaces: analysis across different European countries. Build Environ; 41: 1455e70.

Nikolopoulou M, Lykoudis S., 2007, Use of outdoor spaces and microclimate in a Mediterranean urban area. Build Environ; 42: 3691e707.

Oke, T.R. (2006), *Initial Guidance To Obtain Representative Meteorological Observations At Urban Sites*, World Meteorological Organization (WMO), Instruments And Observing Methods, Report No. 81.

Oke, T.R., 1984. Towards a prescription for the greater use of climatic principles insettlement planning. Energy Build. 7 (1), 1–10.

Oke, T.R., 2006. Initial Guidance To Obtain Representative Meteorological Observations At Urban Sites, World Meteorological Organization (WMO), Instruments And Observing Methods, Report No. 81.

O'Hare, D., 2006. Urban walkability in the subtropical city: Some intemperate considerations from SEQ. Subtropical Cities 2006 Conference Proceedings: Achieving Ecologically Sustainable Urbanism in a Subtropical Built Environment, Brisbane, Queensland, Australia.

Ong, B. L. (2002), Green plot ratio: an ecological measure for architecture and urban planning. Landscape and Urban Planning, 965 (2002), pp. 1-15.

Ochoa, J. M., Serra, R., & Roset, J., 1998 Vegetation influences on the human thermal comfort in outdoor spaces. In Proceedings of EPIC '98 2nd European Conference on Energy Performance and Indoor Climate in Buildings and 3rd International Conference on Indoor Air Quality Ventilation.

O'Hare, D., 2006, Urban walkability in the subtropical city: Some intemperate considerations from SEQ. *Subtropical Cities 2006 Conference Proceedings: Achieving Ecologically Sustainable Urbanism in a Subtropical Built Environment*, Brisbane, Queensland, Australia.

Oke, T.R., 1984, Towards a prescription for the greater use of climatic principles in settlement planning Energy Build.,7 , pp. 1–10

Okba, E.M., (2005), Building envelope design as a passive cooling technique, International Conference “Passive and Low Energy Cooling for the Built Environment”, Santorini, Greece

Ong, B. (2003). Green plot ratio: an ecological measure for architecture and urban planning. Landscape and Urban Planning, 63 (4). Retrieved June 19, 2009, from Science Direct database

Paramita, B, Koerniawan, MD, (2012), Solar Envelope Assessment In Tropical Region Building Case Study: Vertical Settlement in Bandung, Indonesia, Procedia Environmental Science. The 3rd International Conference on Sustainable Future for Human Security, Kyoto.

Pengelola Mega Kuningan, Master Plan. Accessed May 20, 2013. http://megakuningan.indo.asia/concept.html

Pinho, Ana (2003), *The influence of the built environment in microclimatic variations*, PLEA 2003 - The 20th Conference on Passive and Low Energy Architecture, Santiago – CHILE.

Rinehart, Hott; and Winston, (1999), *Introduction in Research in Education*. Sydney, h. 382.

Rinehart, Hott; and Winston, (1999), *Introduction in Research in Education*. Sydney, h. 382

Scudo, Gianni (2002), *Thermal comfort, Built Environment Sciences & Technology (BEST)*, Politecnico di Milano, Via Durando 10, 20158 Milano Text of paper to the COST C 11 "Green structures and urban planning" - Milan

Soegijanto, R.M. (1980), Pengendalian Kondisi Lingkungan Thermis dan Penerangan alami Siang Hari di Dalam Rumah Sederhana Type Perumnas di Jakarta dan Bandung, Desertasi Doktor, Teknik Fisika, ITB, Bandung

Spagnolo, J. – de Dear, R. 2003. A field study of thermal comfort in outdoor and semi-outdoor environments in subtropical Sydney Australia. Journal Building and Environment 38.

SPORTSCIENCE, A Spreadsheet for Partitional Calorimetry, Accessed March 20, 2014 http://www.sportsci.org/jour/0003/ka.html

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

Shudo, H., Sugiyama, J., Yokoo, N., and Oka T. (1997), A study on temperature distribution influenced by various land uses, Energy and Buildings, 26, 199-205.

Suryabrata, Jatmika Adi. (2011). Principles and Applications: Green Design (Presentasi). Jakarta: Dept. of Architecture & Planning Gadjah Mada University.

Straube, J.F., Burnett, E.F.P. (2005) Building Science for Building Enclosures. Building Science Press, Westford.

Straube, J.F. and Burnett, E.F.P., (1999) "Rain Control and Design Strategies". J. Of Thermal Insulation and Building Envelopes, July, pp. 41-56.

Trancik, Rogers (1986), *Finding Lost Space: Theories of Urban Design*, John Wiley and Sons.

Toudert, Toudert Ali (1997), *Street Design And Thermal Comfort In Hot And Dry Climate,* Meteorological Institute, University of Freiburg, Germany

Toudert, Toudert Ali, (2005), Dependence of Outdoor Thermal Comfort on Street Design in Hot and Dry Climate, Freiburg, Germany.

Thorsson S, Lindqvist M, Lindqvist S., 2004, Thermal bioclimatic conditions and patterns of behaviour in an urban park in Göteborg, Sweden. Int J Biometeorol; 48: 149e56.

Yeang, Ken. (1996). The Skycraper Bioclimatically Considered. Great Britain: Academy Editions.

Unger, J. 1999. Comparisons of urban and rural bioclimatological conditions in the case of a Central-European city. Int. J. Biometeorol. 43. pp. 139-144.

Unger, J. – Gulyás, Á. – Matzarakis, A. (2005), Effects of the different inner city micro-environments on the human bioclimatological comfort sensation, Int. J. Biometeorol.45

U.S. Department of Energy (U.S.D.O.E), 2004. Energy Efficiency and Renewable Energy: Building Envelope, www.eere.energy.gov.

Valsson, Ar. Valsson and Bharat, Dr. Alka (January 2008), *Natural and Man-made Parameter induced Spatial Variation in Microclimate,* ENVIRONMENT-ARCHITECTURE Time Space & People. Dept. of Architecture, LAD College, Nagpur, and Dept. of Architecture & Planning, MANIT Bhopal, India.

VDI (1998). Methods for the human-biometeorological assessment of climate and air hygiene for urban and regional planning, Part I: Climate. VDI guidline 3787. Beuth, Berlin.

Wonohardjo, Surjamanto, Koerniawan, M Donny, (2007), *Outdoor Thermal Environment Surrounding Water Elements in Hot Humid Area*, Proceeding of SENVAR 7, Department of Architecture Universitas Hasanuddin, Makasar.

Watson, D. and K. Labs, 1983. Climatic Building Design 'Energy Efficient Building Principles and Practice', New York, Mc Graw-Hill Book, Inc

Wilcox, David C. (2006). Turbulence Modeling for CFD (3 ed.). DCW Industries, Inc. ISBN 978-1-928729-08-2.

Yuen, B, & Wong, N. (2005). Resident perceptions and expectations of rooftop gardens in Singapore. Landscape and Urban Planning, 73 (4). Retrieved June 2012, from Science Direct database.

Zacharias J, 2004, Stathopoulos T, Wu H. Spatial behavior in San Francisco's plazas: the effects of microclimate, other people, and environmental design. Environ Behav; 36: 638e58.