SIMULATION OF WIND FLOW AT MHOR CHIT II BUS TERMINAL

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I am greatly indebted to my family, who consistently looked after other family burdens and provided whatever they could and had during the process of conducting my research.

The benefits derived from this work would be help departments to be responsible for managerial measures to reduce the temperature in these areas, making use of Natural wind to give maximum benefits.

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ABSTRACT

This research reflects the simulation of wind flow by using the CFD (Computational Fluid Dynamics) technique 3D thermal comfort zone at Mhor Chit II Bus Terminal. This simulation used average wind at 2.0 m/s which based on monthly data from the decade (2000-2011) recorded by Bangkok metrological. The influence of radiation from the sun can be felt throughout the entire day. In addition to the sun, the permanent flow of in – and out bus-traffic adds to the heat created by the bus engines. The bus station is located in the center of the city; it has a huge effect on the ventilation of buildings. The accumulated heat affects the health of the bus line operators and the passengers.

The findings indicate ambient conditions, measured with an Anemometer average about 40°C with average wind speeds of 2.5 m/s, while the average relative humidity lies around 38% - 55.9% by the hot weather,. These results in 63% of the population feeling exhausted, where as 33% are moody and at least 4% of the people feel anxiety over such extreme weather conditions.

Therefore, the result of this study helps departments of Mhor chit II bus terminal to be responsible for managerial measures to reduce the temperature in these areas, making use of Natural wind to give maximum benefits.

KEY WORDS: COMPUTATIONAL FLUID DYNAMICS/ MHOR CHIT II BUS TERMINAL/ THERMAL COMFORT/ PREDICTED MEANS VOTE (PMV)/ QUESTIONAIRE.

86 pages

การจำลองการไหลของลมของสถานีขนส่งหมอชิต 2
SIMULATION OF WIND FLOW AT MHOR CHIT II BUS TERMINAL

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บทคัดย่อ

การจำลองการไหลของลมร่วมกับเขตความสบายของสถานีขนส่งหมอชิต 2 ซึ่งเป็นพื้นที่ที่มีการก่อสร้างด้วยคอนกรีตที่มีคุณสมบัติการสะท้อนรังสีจากดวงอาทิตย์ ที่สาดส่องตลอดทั้งวัน รวมถึงความร้อนจากเครื่องยนต์รถบัสที่ให้บริการในพื้นที่มีการเข้า - ออกตลอดวัน ส่งผลถึงสภาพอุณหภูมิในพื้นที่ และการที่ลักษณะอาคารมีการก่อสร้างที่ขวางทิศทางลม ส่งผลถึงการระบายความร้อนในพื้นที่เช่นเดียวกัน ซึ่งจากอุณหภูมิที่สูงขึ้นอาจจะมีผลต่อการทำงานของผู้ปฏิบัติงานในสถานีขนส่งหมอชิต 2

จากการศึกษา พบว่าเมื่อทำการจำลองพื้นที่การไหลเวียนอากาศในพื้นที่โดยใช้หลักการพลศาสตร์การไหล (Computational Fluid Dynamics) พบว่าการจำลองการไหลของลม ความเร็วลมเฉลี่ยในพื้นที่ 2 เมตรต่อวินาที อุณหภูมิเฉลี่ยสูงสุดในพื้นที่ 40 องศาเซลเซียส เมื่อทำแบบสัมภาษณ์สำหรับผู้ปฏิบัติงานในพื้นที่และใช้เครื่องมือตรวจวัด ความเร็วลม ความชื้น และอุณหภูมิ ในพื้นที่พบว่า อุณหภูมิในพื้นที่สูงสุดประมาณ 40 องศาเซลเซียส ความเร็วลมเฉลี่ย 2.5 เมตรต่อวินาที และความชื้นสัมพัทธ์ 38% - 55.9% จากการใช้แบบสอบถามพบว่ากลุ่มตัวอย่างตอบมากที่สุด 63% รู้สึกอ่อนเพลีย รองลงมาเป็น 33% รู้สึกหงุดหงิด และที่น้อยที่สุดคือ รู้สึกกังวล 4% ซึ่งคนในพื้นที่ส่วนใหญ่ให้คะแนนความสบายอยู่ที่ระดับ 3 หมายถึง ร้อนมาก และเมื่อเปรียบเทียบกับค่าเขตความสบายของคนไทย ควรอยู่ที่อุณหภูมิ 36 องศาเซลเซียส ความเร็วลมมากกว่า 3 เมตรต่อวินาที และความชื้นที่ 40-70%

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CHAPTER I
INTRODUCTION

1.1 Statements of Problem

Travelling by bus is rising in popularity since transportation has become more convenient with lower costs to the public safety and tourism industry. This also applies as well to migrants seeking work in the cities.

Major locations for Bangkok bus terminals of bus lines north and northeast are: Mhor Chit II Bus Terminal, Coastal Eastern Bus Terminal (Ekamai) and the Southern Bus Terminal. Mhor Chit II Bus Terminal, which have a number of services for travelers and destinations, that the main bus to go to the North, North-East, central and the East of Thailand.

The buildings around the area of the Mhor Chit II Bus Terminal are mostly of concrete design so that the influence of radiation from the sun can be felt throughout the entire day. In addition to the sun, the permanent in – out bus traffic adds to the heat from the bus engines. Since the bus station is located in the center of the city, it has a huge effect on ventilation of buildings. The bus stations and the accumulation of heat affect the health of passengers and or the bus line operators.

The normal range of human body temperature varies due to an individual's metabolism rate; the higher (faster) it is the higher the normal body temperature or the slower the metabolic rate the lower the normal body temperature. Other factors that might affect the body temperature of an individual may be the time of the day or the part of the body in which the temperature is measured. The body temperature is lower in the morning, due to the rest the body received and higher at night after a day of muscular activity and after food intake. The skin temperature would be expected to rise to 37°C at which point perspiration is initiated and increases until the evaporation cooling is sufficient to hold the skin at 37°C. The body will delete the heat by thermal radiation to the surrounding cooler area of the body. But if temperatures around the body are not cool enough, the heat in the body will increase instead. The overheated bodies affected by the sun can cause such as Heat Exhaustion, Heat Stroke, Heat Cramp, Heat Rash, Dehydration, and Heat Neurosis.

In 2008, there were18 patients of heat stroke, in 2009 there were 80 deaths, there were 2010, 4 patients that they had been treated and then 32 patients been hospitalized with the main national health insurance.

"Thermal Comfort" is a term used by the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) and is defined by the following: "Thermal comfort is a condition of mind which expresses satisfaction with the thermal environment. Because there are large variations, both physiologically and psychologically, from person to person, it is difficult to satisfy everyone in a space."(ASHRAE, 2004).Thermal comfort is affected by metabolic rate, clothing insulation, air temperatures, radiant temperature, air speed and humidity.

The most effective way to analyze the direction and wind speed on structures, such as simulated wind tunnel and computational fluid dynamics(CFD) application, has been widely used in wind tunnels to analyzing the impact of wind on the structure and Computational Fluid Dynamics(CFD) has not become widely used in Thailand.

This study focuses on the test model with the technique of Computational Fluid Dynamics (CFD), an analysis of the flow dynamics for a ventilation area, located within the Mhor Chit II Bus Terminal.

1.2 The Purpose of the Research.

The main objective of this research is to simulate wind flow such as wind speeds and wind direction in the Mhor Chit II Bus Terminal, which dedication for the installation of buildings, followed by the following sub-objectives.

1) Study the performance of the Computational Fluid Dynamics (CFD) to analyze the speeds and direction of wind on the buildings.

2) To analyze the Thermal Comfort, taking into account wind speeds and wind directions at building locations, within the Mhor Chit II Bus Terminal.

1.3 The Scope of the Research.

1) This study will explore the structure in terms of the shape of an object, but not for the elastic behavior of the air (Aero Elasticity).

2) Only average local wind speeds and directions are being considered, but will not cover monsoon or strong seasonal winds.

1.4 Positive Expectations.

1) To analyze the Thermal Comfort, Application of the Computational Fluid Dynamics (CFD), the software "Solid Works" was used.

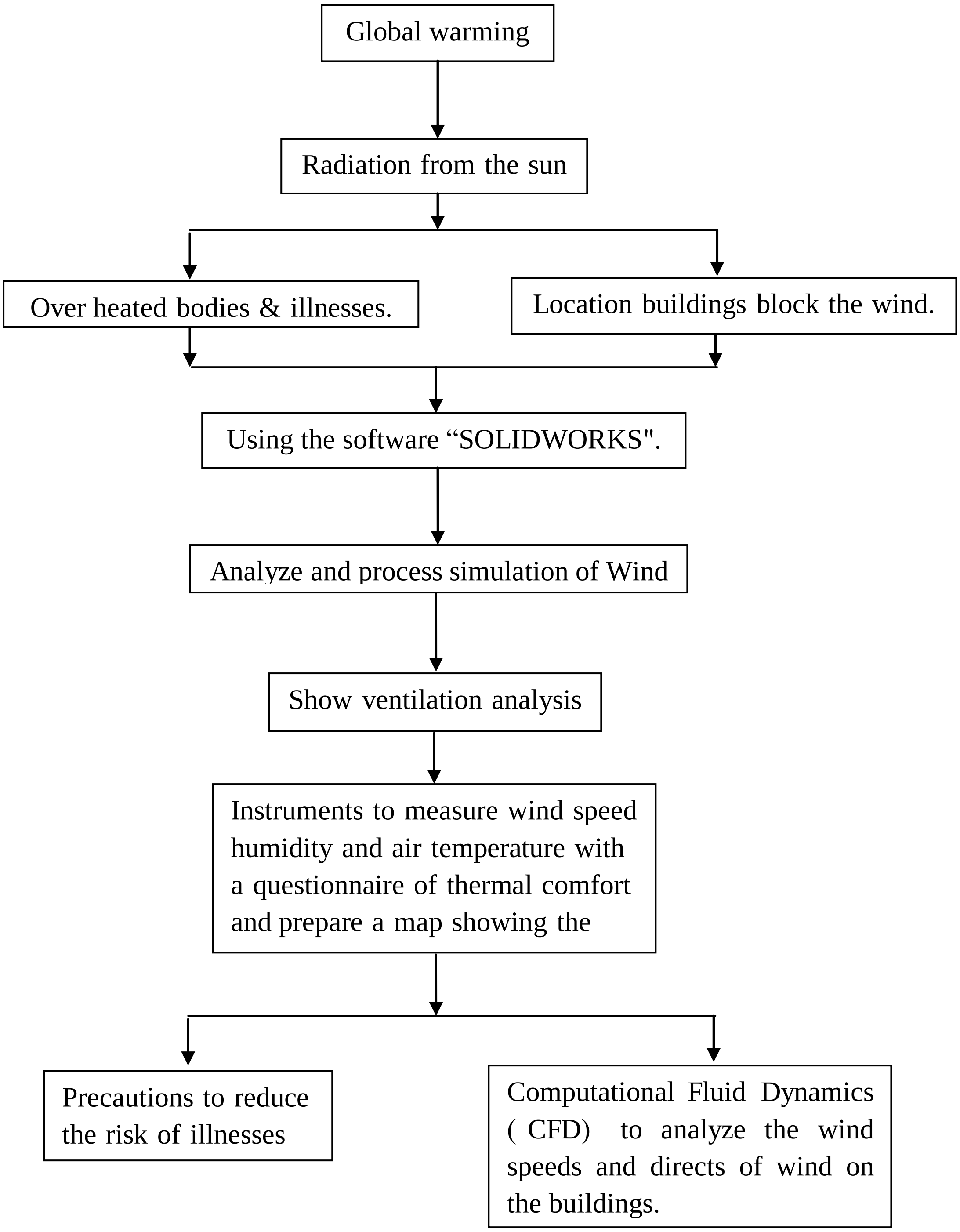
2) Guidelines for land use and management in Mhor Chit II Bus Terminal

3) A data risk area of Thermal Comfort.

4) Guidelines for the protection of public life in the Mhor Chit II Bus Terminal

5) Precautions to reduce the risk of heat exhaustion, heat stroke and heat cramp.

1.5 Conceptual Framework



CHAPTER II
THEORIES AND RELATED LITERATURES

The researcher had reviewed the concept, the theory and the literature of Computational Fluid Dynamics (CFD) as well as the Thermal Comfort relating to this study.

2.1 The General Condition of the Study Area

The new Mhor Chit II bus terminal is located on the Kamphaengphet Road, near Chatuchak week-end market (Figures 2.1 and Figures 2.2). This modern bus terminal serves the transportation to various provinces in the north, north-east and central areas of the country.

Figure 2.1 Mhor Chit II bus terminal

Source: Google Earth, (2011)

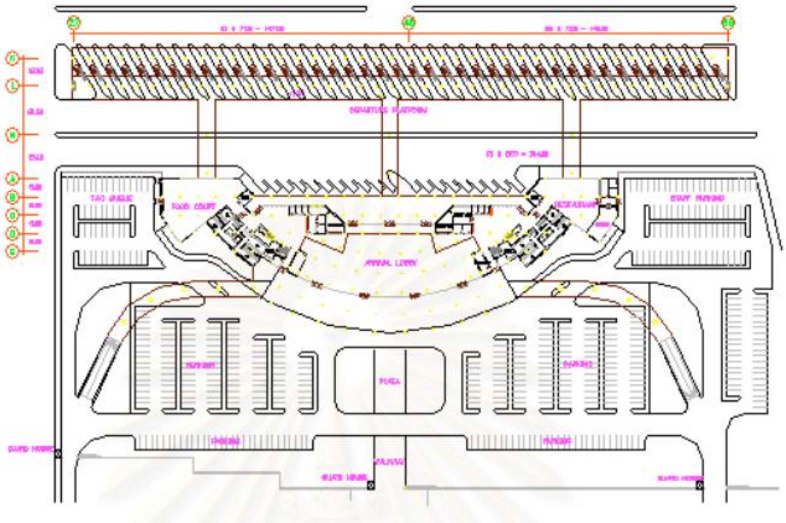


Figure 2.2 Chart showing the plan of the Mhor Chit II bus terminal building
Source: Athinan, (2000)

Mho Chit Station II is divided into three parts. Part one is the terminal building containing four floors. Part two is the bus parking area and the corridor connecting the third floor of terminal building where the passengers wait for bus to northeastern. Part three is the bus services (cleaning, fuel, maintenance and etc.).

2.2. Theories

2.2.1 Computational Fluid Dynamics (CFD)

Computational Fluid Dynamics (CFD) has been used in the aid of computers by covering the fluid flow of physical laws. In applications CFD were studies for general treatment (Versteeg and Malalasekera, 1995) and shallow water equations (Abbott and Basco, 1989). In theory, it can predict all eddy structures, from the large to the smallest. This approach knew as Direct Numerical Simulation (Wright and Baker, 2004). CFD are based on Physical laws of Conservation of Mass and Newton's 2nd law by CFD uses Navier –Stokes as equations for incompressible flow.

$$\sigma_{\mu i}/\ \sigma_{xi} = 0 \qquad (2.1)$$

$$[\sigma\ (\rho\mu_i)/\ \sigma_t] + [\sigma\ (\rho\mu_i u_j)/\ \sigma_{xj}] = \sigma_\rho/\ \sigma_{xi}$$

$$+\ \sigma/\ \sigma_{xj}(\mu(\sigma_{ui}/\ \sigma_{xj})) + S_i \qquad (2.2)$$

Where x_i is the three coordinate directions, u_i is the velocities in these directions, p is pressure, ρ is the density and μ is viscosity. Equation (2.1) is Conservation of mass, Equation (2.2) is a momentum equation, so the first term is the time variation and the second is the convection term.

2.2.2 The Finite Volume Method

The Finite Volume Method is the basic of the control volume formulation of analytical fluid dynamics. At first step is to part of the number of control volumes of concern located of the control volume. The next step is adaptability to integrate the form of the governing equations over control volume. Insert profiles then assumed to describe the variation of the concerned variable. The result was called the discretization equation. By the way, that is explicit the conservation principle for the control volume.

The most captivating is the effecting explication satisfies the preservation of amount such as mass, momentum, energy, and species. This is precisely satisfied for any control volume as well as for the whole computational domain and for any number of control volumes. The Finite Volume Method have ideal for compressible flows in computing discontinuous solutions arising. Any discontinuity must satisfy the Rankine - Hugoniot jump condition which is an effect of conservation. Since finite volume methods are conservative they automatically satisfy the jump conditions, therefore give physically correct weak resolutions.

The basic equation of flow in the form of the equation is the general form of φ, which variables have the following.

$$\frac{\partial(\rho u\phi)}{\partial x} + \frac{\partial(\rho v\phi)}{\partial y} = \frac{\partial}{\partial x}\left(\Gamma_\phi \frac{\partial\phi}{\partial x}\right) + \frac{\partial}{\partial y}\left(\Gamma_\phi \frac{\partial\phi}{\partial y}\right) + S_\phi \qquad (2.3)$$

2.3 Basic Flows of the Wind.

Wind is caused by deviation in air pressure. When a difference in pressure exists, the air was speed up from higher to lower pressure. The air flows are defined as follows:

1) Laminar
2) Turbulent
3) Separated
4) Eddy

2.3.1 Laminar

Laminar flow expresses fluid flow which befalls in "sheets" parallel to mutually. If there is a surface nearby, the flow lines essentially run parallel to it. Two shred places in the flow as markers would flow parallel to mutually but perhaps at different speeds. In nonscientific terms laminar flow is "smooth". When this nice and tidy pattern gives out, the flow becomes turbulent. It no longer flows in parallel sheets, and two marker particles placed in the flow at the same time would trace out the path that would be autonomous and largely random.

2.3.2 Turbulent

Laminar flow or streamline flow occurs when a fluid flows in parallel layers, with no agitation between the layers (Belcher, 2000). In fluid dynamics, laminar flow is a flow regime, characterized by high momentum diffusion and low momentum convection.

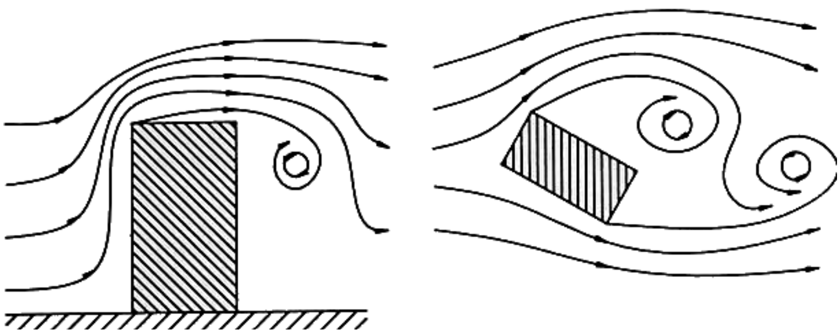
2.3.3 Separated

The boundary layer travels far enough against a opposed pressure gradient, so boundary layer have speed, relative to the object, falls almost to zero. Flow separation can often result in expanded drag, particularly pressure drag which is caused by the pressure differential between the fronts and back of the object as it travels through the fluid. For this reason much attempt and research has gone into the design of aerodynamic and hydrodynamic surfaces which defer flow separation and keep the local flow attached for as long as possible.

2.3.4 Eddy

An eddy is the swirling of a fluid and the inverted current created when the fluid flows pass a barrier. The moving fluid creates a space void of downstream-flowing fluid on the downstream side of the object. Fluid behind of the obstacle flows into the void creating a swirl of fluid on each edge of the obstacle, followed by a short inverted flow of fluid behind the obstacle flowing upstream, toward the back of the obstacle. This phenomenon is most visible behind large emanant rocks in swift-flowing rivers.

An effect of turbulence is that the dynamic loading on a structure counts on the size of the eddy, dimensions are akin with the structure, give rise to well correlated pressures as they enclose the structure (Mendis et al. 2007). On the other side, small eddy result in pressures on various parts of a structure that come to be almost uncorrelated with length of separation (Figure 2.3).



(a) Elevation (b) Plan

Figure 2.3 Generation of eddies
Source: Mendis et al. (2007)

2.4 Near Ground Wind Speeds

The wind speed is used as a measure of air exchange. It expresses the speed of the wind stream, at the same time the atmosphere influence or pushes away air masses. Within built-up areas, as resist to the open countryside, an average of 20 - 30% decrease in the wind speed at near ground can be expected (Figure 2.4). The wind is defined in terms of a vector of direction and speed. The continuous wind measurements are taken, as per international agreement (World Meteorological Organization, 1983). At fixed least disturbed stations at a height of 10 meters above the ground.

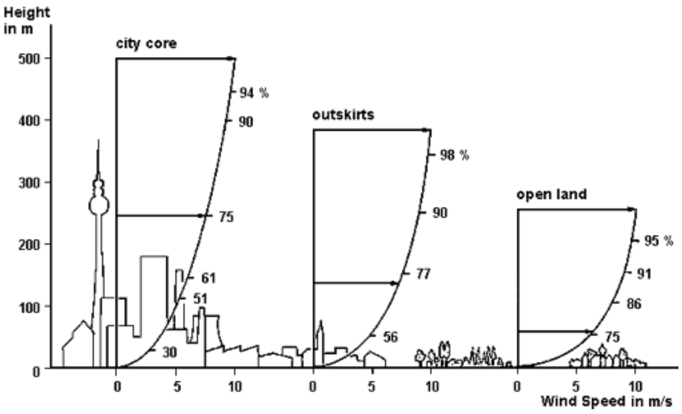


Figure 2.4 Decreases in wind speed influenced by varieties of terrain roughness
Source: Baumbach, (1991)

The Beaufort scale of wind speeds for using at the sea and later spread to the land by stating the effects of wind on people, trees, etc., serves as a convenient starting point (Table 2.1). In the British Building Research Station staff members have been steady winds in a wind tunnel. It was found that with winds gusting to 20 m/sec (45 mph) people had problem to balance, especially if they are comes from the side. For example, if the wind speed 12 to 23 m/sec in 2 to 3 sec, some people were forced to their hands and knees.

Table 2.1 Beaufort scale and wind effects on land

Beaufort Number	**Average Speed (mph)**	**Effects**
1	1-3	No noticeable wind. Smoke rises nearly vertically.
2	4-7	Wind felt on face, leaves rustle.
3	8-12	Hair is disturbed, clothing flaps.
4	13-18	Dust and loose paper raised, hair disarranged.
5	19-24	Force of wind felt on body. Limit of agreeable wind on land.
6	25-31	Some inconvenience in walking.
7	32-38	Difficulty when walking against wind.
8	39-46	Difficulty with balance in walking.
9	47-54	Danger in being blown over.

Source: Schriever, (1976)

2.5 Thermal Comfort

"Thermal Comfort" is a term used by the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) and is defined by the following: "Thermal comfort is a condition of mind which expresses satisfaction with the thermal environment. Because there are large variations, both physiologically and psychologically, from person to person, it is difficult to satisfy everyone in a space" (ASHRAE, 2004). The environmental conditions required for comfort are not the same for everyone (Yamtraipat et al. 2005). However, wide laboratory and field data have been collected that give the necessary statistical data to identify conditions that a particularized percentage of occupants will find thermally comfortable.

Metabolic rate, Clothing insulation, Air temperature, Radiant temperature, Air speed, Humidity are six primary factors must be add when defining conditions for thermal comfort.

2.5.1 Metabolic rate

Metabolic rate is necessary for a thermal comfort assessment. It expresses the heat that produces inside our bodies as human fulfill physical activity. The more physical work the more heat human produce, the more heat must to be lost so it does not overheat. Metabolic Equivalent Task (MET) is a concept used to indicate the amount of oxygen or energy the body uses during do the activity (Table 2.2).

Table 2.2 Some values of metabolic rates

Activity	Metabolic rates	
Reclining	46 W/m^2	0.8 Met
Seated relaxed	58 W/m^2	1.0 Met
Clock and watch repairer	65 W/m^2	1.1 Met
Standing relaxed	70 W/m^2	1.2 Met
Car driving	80 W/m^2	1.4 Met
Standing, light activity(Shopping)	93 W/m^2	1.6 Met
Walking on the level,2 km/h	110	1.9 Met
Standing, medium activity(domestic work)	116	2.0 Met
Washing dishes standing	145	2.5 Met
Walking on level, 5 km/h	200	3.4 Met
Building industry	275	4.7 Met
Sport-running at 15 km/h	550	9.5 Met

Source: Costoiu, (2007)

2.5.2 Clothing insulation

Wearing too much clothing may be a first cause of heat stress even if the environment is not determined warm or hot.

2.5.3 Air temperature

This is the temperature of the air enclosing the body. It is usually given in degrees Celsius (°C) or degrees Fahrenheit (°F).

2.5.4 Radiant temperature

Radiant temperature is the heat that radiates from a warm material. Radiant heat may be present if there are heat sources in an environment.

2.5.5 Air speed

Speed of air flow across the worker may help cool off the worker. Air velocity is an important factor in thermal comfort because people are fast to feel it. Unmoving air in indoor environments that are artificially heated may cause people to feel airless. Moving air in warm or humid conditions can extend heat loss through convection without any change in air temperature.

2.5.6 Humidity

Relative humidity is the comparison between the actual amount of water vapor in the air and the maximum amount of water vapor that the air can hold at that air temperature. Relative humidity between 40% and 70% is normal the thermal comfort. In workplaces, which are not air-conditioned, the relative humidity may be higher than 70%, in warm or hot humid days. Humidity in indoor environments can vary greatly.

2.6 Comparison of Thermal Comfort Model

To determine climatic design process in accordance with comfort zone (Saberi et al., 2006). It could be divided to four main parts:

A. Study of the design subject (climate-activities-clothing)

B. Defining the comfort zone (monthly-daily)

C. Gathering the climatic design advices (shading-thermal mass-evaporative cooling-thermal insulation-suitable orientation)

D. Designing the project (a climatic building)

2.6.1 Fanger Thermal Equation

These factors are air temperature, humidity, air speed, mean radiant temperature (MRT), metabolic rate and clothing levels. The "Fanger" comfort equation is based on experiments with American college students, exposed to a uniform environment under steady state conditions. The comfort equation founds the relationship among the environment variables, clothing type and activity levels. It shows the heat balance of the human body in terms of the net heat exchange arising from the effects of the six factors identified by Macpherson(Saberi, et al., 2006). Finally with these variables "Fanger" could establish the general comfort equation (2.4).

$$(M/A_{Du})\,(1-\eta)-0.35\,[43-0.06(M/A_{Du})\,(1-\eta)-P_a] \qquad (2.4)$$

$$-0.42[(M/A_{Du})\,(1-\eta) - 50]-0.0023(M/A_{Du})\,(44/P_a) - 0.0014(M/A_{Du})\,(34-T_a)$$

$$=3.4\times10^{-8} f_{cl}[(t_{cl}+273)^4]+ f_{cl}\, h_c(t_{cl} - t_a)$$

It is clear from eqn. (2.4) that the human thermal comfort is a function of:

1) The type of clothing t_{cl}, f_{cl}

2) The type of activity and $M/_aD_u$

3) Environmental variables V, t_a, t_{mrt} and Pa

The thermal comfort equation is just applicable to a person in thermal with the environment. However, the equation only gives data on how to get optimal thermal comfort by joining the factor involved. Therefore, it is not instantly suitable to ascertain the thermal sensation of a person in an arbitrary climate where these variables may not content the equation (Fanger, 1982) used the heat balance equation to predict a value for the degree of sensation using his own experimental data and Fanger's Predicted Mean Vote (PMV) model was occurred in the 1970's from research lab and climate chamber studies. Participants were dressed in standardized clothing and entire standardized activities, while exposed to different thermal environments. The thermal conditions and participants recorded how hot or cold they felt, using the seven-point ASHRAE thermal sensation scale (Table 2.3).

Table 2.3 Thermal sensation scales

Expression	**Cool**	**Slightly cool**	**Neutral**	**Slightly warm**	**Warm**	**Hot**	**Very hot**
ASHRAE	1	2	3	4	5	6	7
Fanger	-3	-2	-1	0	1	2	3

Source: ASHRAE, Fundamentals, (2001)

The PMV is a complex mathematical expression involving activity, clothing and the four environmental parameters. It is expressed by equation (2.5).

$$PMV = (0.303\times e^{-0.036\times M} + 0.028)\times L \qquad (2.5)$$

In which M is metabolic rate (W/m^2) and L is thermal load on the body that calculated as equation (2.6).

$$L = (M-W)-3.05\times 10^{-3}\times [5733-6.99\times (M-W)-P_a]$$

$$-0.42\times [(M-W)-58.15]-1.7\times 10^{-5}\times M\times (5897-P_a)-1.4\times 10^{-3}\times M\times (34-t_a, \qquad (2.6)$$

$$-3.96\times 10^{-8}\times f_{cl}\times [(t_{cl}+273)^4]-f_{cl}\times h_c\times (t_{cl}-t_a)$$

$$t_{cl} = 35.7-0.028(M-W) - I_{cl}\,[3.96\times 10^{-8} f_{cl}](t_{cl}+273)^4 - (t_r+273)^4 + f_c\, h_{cl}\,(t_{cl}-t_a)$$

$$hc = 2.38(t_{cl}-t_a)^{0.25} \text{ for } 2.38(t_{cl}-t_a)^{0.25}>12.1$$

$$=12.1\sqrt{v_{ar}} \text{ for } 2.38(t_{cl}-t_a)^{0.25}<12.1\sqrt{v_{ar}}$$

$$f_{cl} = 1.00+1.290\, I_d \text{ for } I_{cl}<0.078 \text{ m}^2(\text{KW})^{-1}$$

$$= 1.05+0.545 I_{cl} \text{ for } I_{cl}>0.078 \text{ m}^2(\text{KW})^{-1}$$

PMV is the predicted mean vote, M is the metabolic rate in (Wm^{-2}) of body surface area, W is the effective mechanical power (Wm^{-2}), I_{cl} is clothing insulation (1CLO = 0.155 m^2($KW)^{-1}$ (thermal resistance of clothing), f_{cl} is clothing area factor (is the ratio of a person's surface area while clothed, T_a is the indoor air temperature (ºC), T_r is the mean radiant temperature (ºC), V_{ar} is relative air velocity (ms^{-1}) (relative to the human body), p_a is the water vapor particle pressure (pa), h_c is convective heat transfer coefficient ($wm^{-2}K^{-1}$) and t_{cl} is clothing surface temperature (ºC).

The PMV model associated two personal variables (clothing insulation and activity level) and four physical variables (air temperature, air velocity, mean radiant temperature, and relative humidity) can be used to predict the neutral temperature with a margin of error of 1.4ºC compared to the neutral temperature, defined by the equation of thermal sensation. This thermal feel unambiguous in index to the PMV.

Fanger model operated 6 entry data and gives comfort zone concerning to them. For used this model must be contain human factors and environmental factors.

2.6.2 Adaptive model

Humphreys and Nicol, (1998) researched the thermal impartiality of the human body, which the person feels thermally impartial "comfortable". Their studies were basic on lab and field works in which people were different conditions. The results of their experiments were statistically analyzed by using regression analysis. Figure 2.5 shows the thermal impartiality of the general climatic circumstance. It showed that 95% of the impartial temperature is connected with the different of outdoor mean temperature (Sayigh and Marafia, 1998). The regression equation is approximated by T_n is neutral temp (^oC), T_m is Mean outdoor temp(^oC).

$$T_n = 11.9 + 0.534 T_m \qquad (2.7)$$

A different empirical correlation function was carried out by Auliciemes is:

$$T_n = 17.6 + 0.314 T_m \qquad (2.8)$$

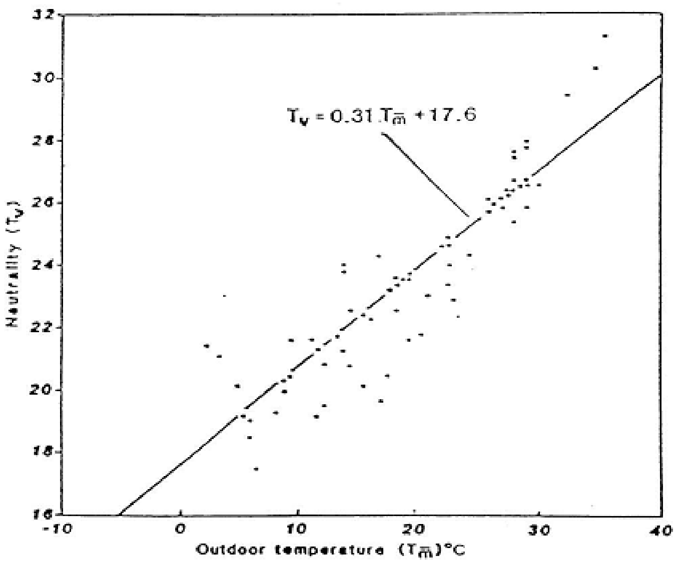


Figure 2.5 Relationship between outdoor temperatures with neutral temp

Source: Humphreys and Nicol, (1998)

2.6.3 Olgyay Bioclimatic Chart

Olgyays bioclimatic chart, in Figure 2.6 was one of the first endeavors at an environmentally aware building design. It was occurred in the 1950s to unite the outdoor climate into building design. The chart predict the zones of human comfort in relation with ambient temperature and humidity, mean radiant temperature (MRT), wind speed, solar radiation and evaporative cooling. On the dry bulb temperature was the ordinate with relative humidity. The center is the comfort zone, indicated separately with winter and summer ranges. Under zone is also the limit above which shading was essential. Temperatures above the comfort limit the wind speed need to build up, shown in relation to humidity, where the ambient conditions are hot, dry and the Evaporative Cooling (EC) essential for comfort.

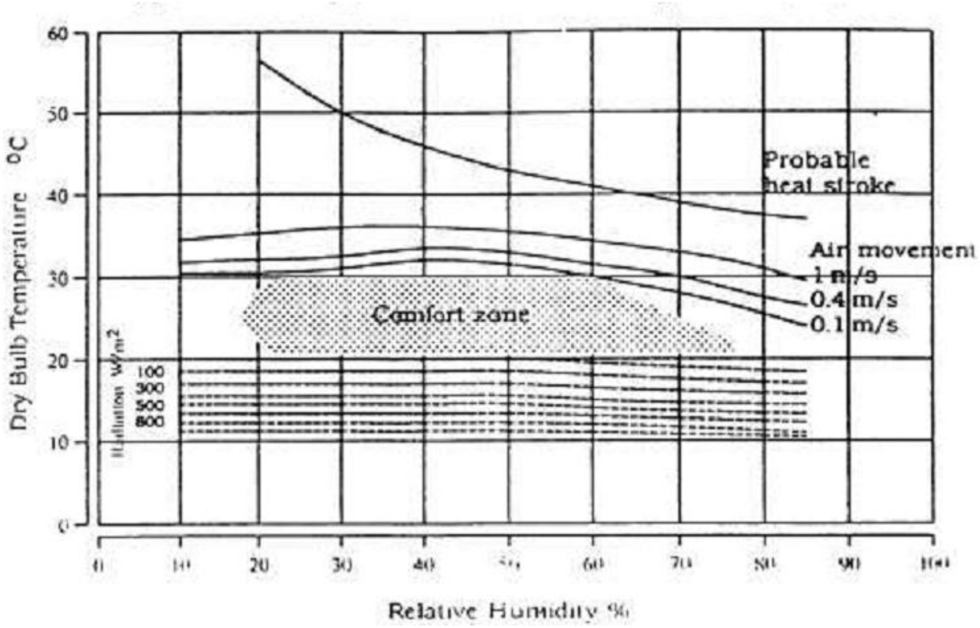


Figure 2.6 Olgyay bioclimatic charts

Source: Olgyay, (1963)

2.6.4 Givoni Bioclimatic Chart

Givoni's bioclimatic chart (Figure 2.7) purposed at predicting the indoor conditions according to the outdoor generated conditions. In this chart the linear relationship between the vapor pressure and temperature amplitude. The chart union different temperature amplitude and vapor pressure of the ambient air on the psychometric chart and correlated with specific boundaries of the passive cooling techniques overlaid on the chart. Evaporative cooling, natural ventilation, thermal mass, cooling and passive heating were including in techniques.

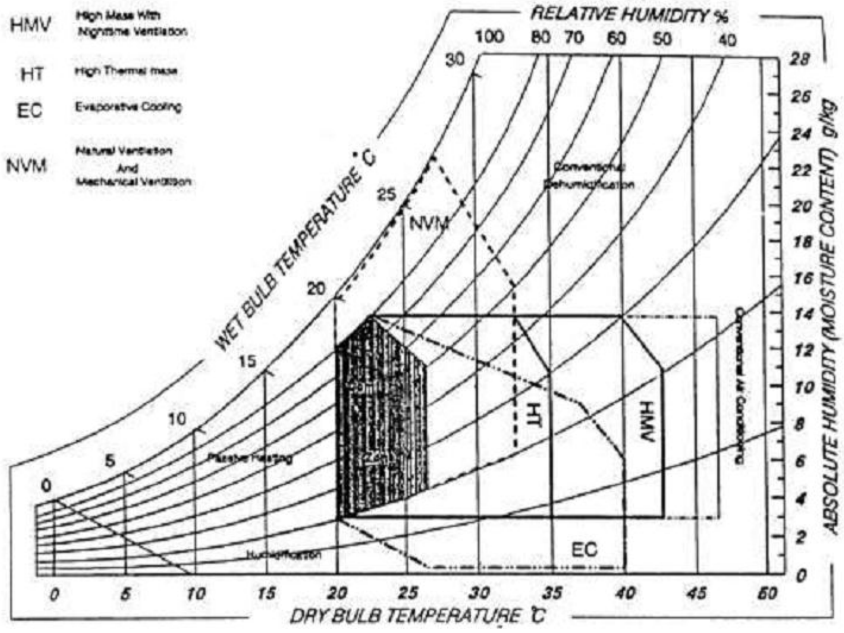


Figure 2.7 Givoni bioclimatic charts

Source: Givoni, (1967)

2.6.5 Measurement of Error

The PMV model is based on climate experiments, which the four physical variables (mean radiant temperature, air temperature, air velocity and relative humidity) closely controlled and monitored it can be. The cloth insulation and activity level can be correctly quantified. In field study settings, that more difficult to control these six variables. Contribute to the discrepancies found between PMV and actual thermal sensations are difficulties to Measurement error (Benton, Bauman and Fountain, 1990) “to make a fair comparison, it is essential that all four environmental factors are properly measured and that a careful estimation is made of the activity and clothing. Poor input data will provide a poor prediction” (Fanger, 1994).

2.7 Thermal Comfort in Thailand

The comfort zone is defined as the range of climatic conditions in which the number of people cannot feel thermal discomfort. Human thermal comfort was based on six thermal ‘‘quantitative” factors: air relative humidity, air temperature, and mean radiant temperature, velocity, activity and clothing insulation (Fanger, 1972). However, thermal comfort not only count on those six variables but also on ‘‘non quantitative” factors such as mental states and habits. Human comfort preferences vary in different locations and long term experience in any climate show in many studies (Dear and Nicol, 1997). From higher temperatures of people who live in hot and humid climate where can sufferance high with compare the people who live in colder regions. Therefore, Thailand is located in a hot and humid region, so Thai people look like to have a sufferance to high air temperature.

Table 2.4 wind speed and relative humidity at temperature comfortable level

Humidity	Wind speed (m/s)	Thermal to comfort
50-60	0.2	28.01
	0.5	28.81
	1.0	30.56
	1.5	32.48
60-70	0.2	27.17
	0.5	28.30
	1.0	30.15
	1.5	31.46
70-80	0.2	27.20
	0.5	28.29
	1	30.27
	1.5	31.24
50-80	2	33.47
	3	35.53

Source: Atthajariyakul, (2008)

2.8 Physiological basis

The human body continuously produces heat. This metabolic heat production can be of two kinds:

- Basal metabolism, due to biological processes which are continuous and non-conscious.
- Muscular metabolism, whilst carrying out work, which is consciously controllable (except in shivering).

This can be expressed as power density per unit body surface area (W/m^2) in a unit devised for thermal comfort studies, called the met. 1 met = 58.2 W/m^2. For an average sized man this corresponds to approximately 100 W. Du Bois (1916) proposed an estimate of the body surface area, on the basis of body mass (M, in kg) and height (h, in m), which is referred to as the "DuBoisArea"(m^2).

$$A_D = 0.202M^{0.425}h^{0.725} \qquad (2.9)$$

Table 2.5 Metabolic rate at different activities

Activity	Met	W/m²	W(av)
Sleeping	0.7	40	70
Reclining, lying in bed	0.8	46	80
Seated, at rest	1	58	100
Standing, sedentary work	1.2	70	120
Very light work (shopping, cooking, light industry)	1.6	93	160
Medium light work (house, machine tool)	2	116	200
Steady medium work (jackhammer, social dancing)	3	175	300
Heavy work (sawing, planning by hand, tennis) up to	6	350	600
Very heavy work (squash, furnace work) up to	7	410	700

Source: Auliciems and Szokolay, (1997) The deep body temperature is about 37°C, while the skin temperature can vary between 31°C and 34°C under comfort conditions. Differences occur in time between parts of the body, based on clothing and blood flow. There was a continuous transport from heat to deep tissues of the skin.

In too hot conditions the body reacts by vasodilatation: subcutaneous blood vessels expand and increase the skin blood supply, which in turn expand heat dissipation. If this cannot repair thermal equilibrium, the sweat glandule are activated, and the cooling mechanism will operate is a call evaporative. Sweat can be happened for short periods at a rate of 4 L/h, but the mechanism is fatigable.

When these mechanisms cannot repair equilibrium conditions, certain body heating, hyperthermia will happen. When the deep body temperature gets about 40°C, heat stroke may occurred. This is a circulatory failure (venous return to the heart is reduced) bring to fainting. First symptoms are: fatigue, headache, dizziness, nausea, loss of appetite, vomiting, flushing of face and neck, glazed eyes, shortness of breath, rapid pulse rate (up to 150/min), as well as mental disturbances, poor judgment, apathy or irritability.

2.9 Danger from Heat.

Heat illness or heat-related illness includes minor conditions such as Heat Exhaustion, Heat Stroke, Heat Cramp, Heat Rash, Dehydration and Heat Neurosis.

2.9.1 Heat Exhaustion

Being in a hot air for a long time can bring to fainting because the bodies get a high temperature needs more blood to feed the skin to sweat. If the heart cannot pump more blood to the blood supply, the muscles and brain need to feed the blood, if they cannot pump the blood to the muscles and brain it makes a breeze because the brain lacks oxygen.

2.9.2 Heat Stroke

Patients can die from Sun Stroke or Heat Stroke, so that is an emergency If there is no sudden help. Normal body temperature is about 37°C sweat can permit to body temperature cool down. In the case of the mechanism to control body heat does not work. The rectal temperature is reaching above 41°C, the body can no longer cool, the central nervous system can damages from resulting of the high amount of heat. The blood vessels do not control the growth of nerve system, but encourage the sweat glandule. Sweat is often causing for acute renal failure, liver damage, respiratory failure, blood clotting mechanism due to coagulation factor deficiencies. Most affected persons will die eventually.

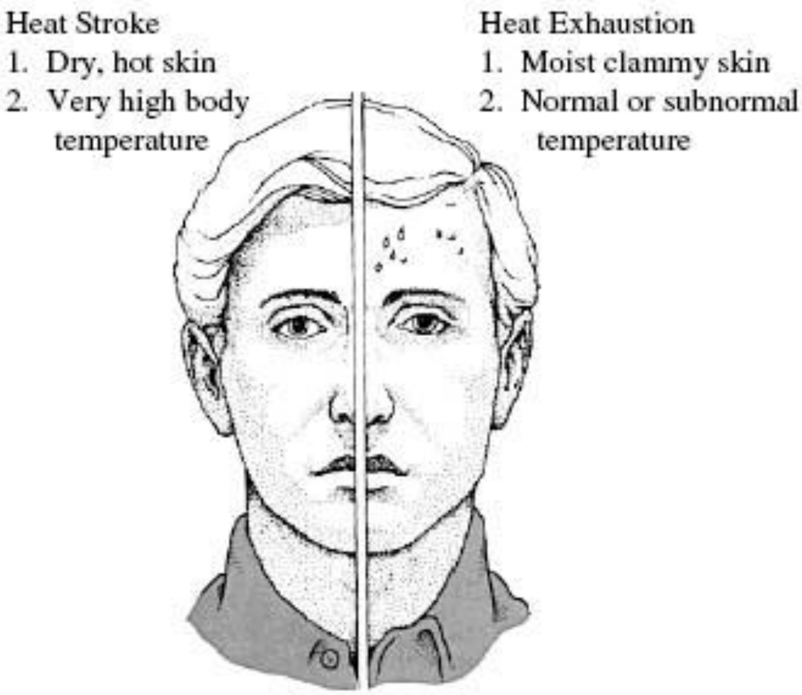


Figure 2.8 Signs and Symptoms of Heat Stroke and Heat Exhaustion

Source: The National Agricultural Safety Database, (2004)

2.9.3 Heat Cramp

The sweat lets the body loose a large amount of minerals, so physical contact for a long time in hot weather is caused of cramp, causing muscle and pain convulsion. From drinking cold water too fast may also result of cramps. The skin always be kept at a temperature less than the inside body, the temperature environment should be below the skin temperature, but not immoderate heat dissipation.

2.9.4 Heat Rash

Heat rash can happen when sweat ducts become clogged and the sweat cannot get out to the surface of the skin. Instead, it becomes trapped below the skin's surface, causing a mild soreness or rash. Heat rash can see often in hot, humid weather. Prickly heat or Miliaria is called heat rash.

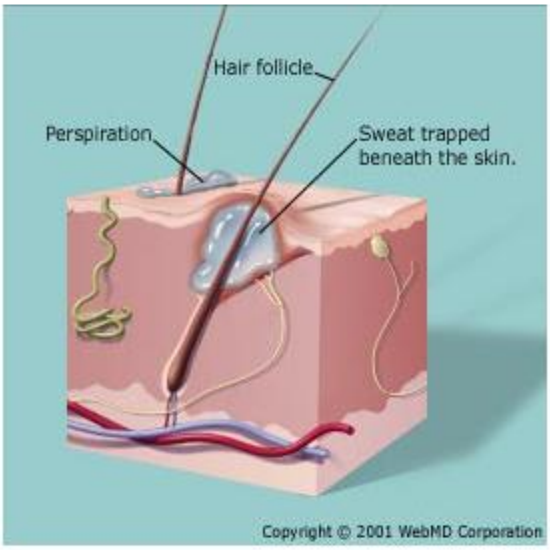


Figure 2.9 Causes of heat rash

Source: Norman Levine, (2010)

2.9.5 Dehydration

Water is a significant element of the body, Up to 75% of water of the body's weight. Cells of the body (intracellular space) found most of the water in there.

The water leaving the body is greater than the amount being taken in dehydration will be happen. The body is always changing and very dynamic. This is particularly true with water in the body.

To lose water routinely when:

- Breath and humidified air leaves the body (this can be seen on a cold day
- Sweat to cool the body
- Having a bowel movement or eliminate waste by urinating.

Table 2.6 Thirst, decreased urine volume, abnormally dark urine, tiredness, irritability, lack of tears when crying, headache, dry mouth, dizziness when standing due to orthostatic hypotension, and in some cases insomnia are symptoms of mild dehydration.

Table 2.6 Symptoms associated with Dehydration

Symptom	**Minimal or no dehydration** (**<3% loss of body weight)**	**Mild to moderate dehydration** (**3%–9% loss of body weight)**	**Severe dehydration** (**>9% loss of body weight)**
Mental status	Well; alert	Normal, fatigued or restless, irritable	Apathetic, lethargic, unconscious
Thirst	Drinks normally; might refuse liquids	Thirsty; eager to drink	Drinks poorly; unable to drink
Heart rate	Normal	Normal to increased	Tachycardia, with bradycardia in most severe cases
Quality of pulses	Normal	Normal to decreased	Weak, thread, or impalpable
Breathing	Normal	Normal; fast	Deep
Eyes	Normal	Slightly sunken	Deeply sunken

Table 2.6 Symptoms associated with Dehydration (cont.)

Symptom	**Minimal or no dehydration (<3% loss of body weight)**	**Mild to moderate dehydration (3%–9% loss of body weight)**	**Severe dehydration (>9% loss of body weight)**
Tears	Present	Decreased	Absent
Mouth and tongue	Moist	Dry	Parched
Skin fold	Instant recoil	Recoil in <2 seconds	Recoil in >2 seconds
Capillary refill	Normal	Prolonged	Prolonged; minimal
Extremities	Warm	Cool	Cold; mottled; cyanotic
Urine output	Normal to decreased	Decreased	Minimal

Source: Duggan , Santosham and Glass, (1992)

2.9.6 Heat Neurosis

Heat Neurosis caused by exposure to high heat and high heat for a long time to affect the mind, causing anxiety, lack of ability to concentrate, Performance loss, and irritability.

2.10 The number of illness from the heat

The National Health Security Office (NHSO) and Bureau of Occupational and Environmental Diseases, Department of Disease Control, Ministry of Public Health, Thailand, shows the number of illness from the heat in Thailand from 2008 to 2009 (Table 2.7) .In 2009, 4 out of 81 people having the heat illness died.

Table 2.7 The number of illness from the heat in Thailand since 2008-2009

Name of diseases.	number of illness	
	2009	2008
T670 Heatstroke and sunstroke	32	9
T671 Heat syncope	22	6
T672 Heat cramp	4	-
T673 Heat exhaustion, anhidrotic	3	1
T674 Heat exhaustion due to salt depletion	2	-
T675 Heat exhaustion, unspecified	16	2
T676 Heat fatigue, transient	-	-
T677 Heat edema	1	-
T679 Effect of heat and light, unspecified	1	-
Total	81	18

Source: National Health Security Office (NHSO) and Bureau of Occupational and Environmental Diseases, Department of Disease Control, Ministry of Public Health, Thailand, (2010)

2.11 Annual Mean Maximum Temperature in Thailand (°C)

The mean radiant temperature is low and the air temperature is high, elevated air speed is less effective at increasing heat loss. Conversely, elevated air speed is more effective at increasing heat loss when the mean radiant temperature is high and the air temperature is low.

Thus, the curve in Figure 2.10, which corresponds to the relative, difference between air temperature and mean radiant temperature must be used. It is acceptable to interpolate between curves for intermediate differences.

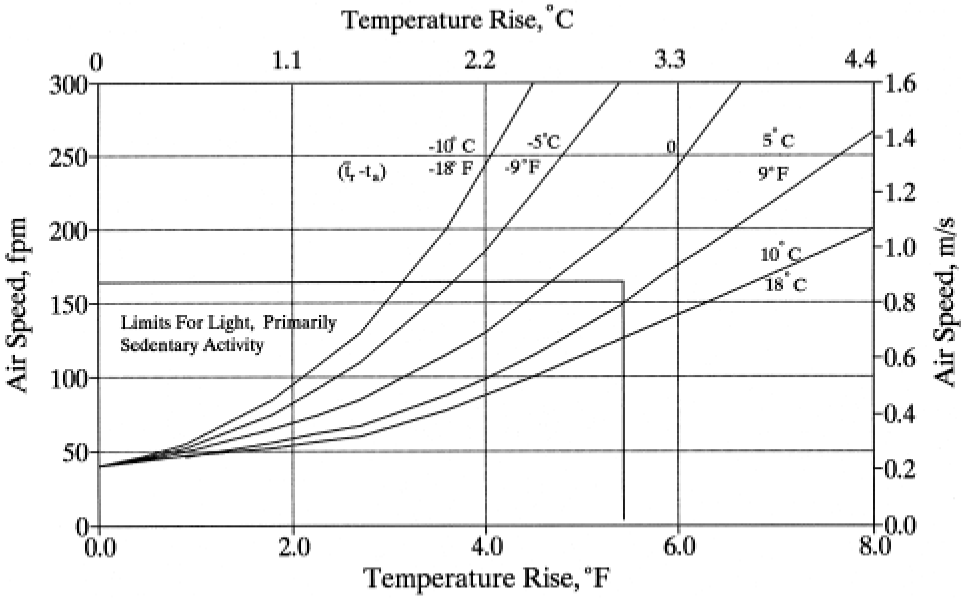


Figure: 2.10 Air speeds required offsetting increased temperature

Source: ANSI/ASHRAE STANDARD, (2004)

The statistical data show the highest temperature during the summers from 1951 to 2010, with data taken from the Meteorological Department. They show that, in the 60 years of weather recording, which have been recorded from the 4 weather stations in Bangkok, (namely the Bangkok Metropolis, Bangkok Port at Klong Toei, Bang Na Agro-meteorological Stations and Don Muang Airport), during the months of February, March, April and May the summer temperatures can reach 40°C. In Figure 2.11 data, taken from the Meteorological Department, show that the annual mean maximum temperature in Thailand is likely to rise since the years from 1951-2009.

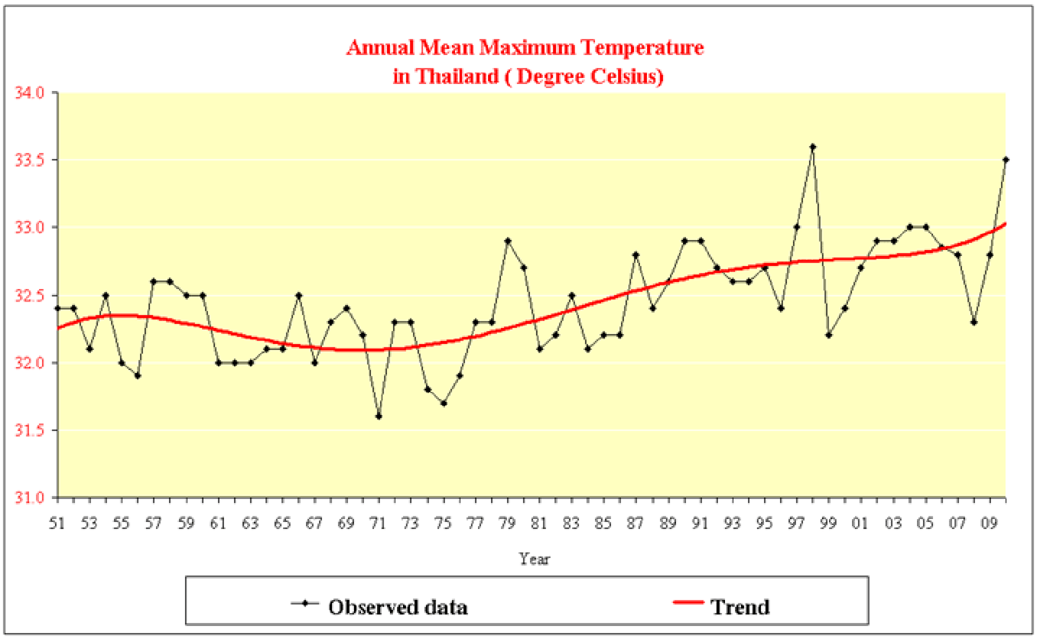


Figure 2.11 Annual Mean Maximum Temperatures in Thailand

Source: Thai Meteorological Department, (2006)

2.12 Related Researches

These studies relate to the study of simulation of wind flow and thermal comfort at the Mhor Chit II Bus Terminal.

2.12.1 Relevant Studies of Thermal Comfort

Atthajariyakuln and Lertsatittanakorn (2008) do research of small fan assisted air conditioners for human thermal comfort and energy saving in Thailand. In the study 15 students were tested in a 12,000 Btu/h split type air conditioner and 2.5, 3.5, 2.5 m 3 test room equipped. During the tests, the room air temperature was changing the temperature every 1 h from 25, 26, 27 and 28ºC. In front of each subject have a small fan with 15 cm diameter was placed. In every hour, the small fans are changing velocity from 0.2, 0.5, 1, 1.5 and 2 m/s. researcher were asked to vote for the thermal sensation. The results showed that when a small fan was used to supply local air velocity from 0.5 to 2 m/s in accordance with personal preference. This would abate the electricity on presupposition of the air conditioning unit. According to the proposal method, this can save power for buildings in the economic sector as high as 1959.51 GWh/year.

Charles (2003) used thermal comfort models. The first, Fanger's Predicted Mean Vote (PMV) Model, union four physical variables (relative humidity air velocity, air temperature, and mean radiant temperature), and two personal variables (clothing insulation and activity level) can be used to a large group of people for predict the average thermal sensation. The second, Fanger's Draught Model, predicts the percentage of resident unhappy with local draught, from three physical variables (air temperature, mean air velocity, and turbulence intensity).

Daghigh et al. (2009) find out the thermal comfort was attraction by air exchange rate in an air-conditioned at the University Putra Malaysia (UPM). Results questions in office and indoor air quality are presented of 60 survey responses to thermal comfort. Found that the relationship between ACH and thermal comfort and three linear regression equations of PMV versus ACH, which can be derived for this office.

2.12.2 Relevant Studies of Computational Fluid Dynamic and Winds

Huber (2003) studied the collapse of New York World Trade Center towers on September 11, 2001. To demonstrated some of the shortcomings in conducting rapid exposure and risk analysis in urban areas where the understanding of airflow around large buildings is poor.

Supachart, et al. (2007) Studied the way of cool air distribution inside the van, by Computational Fluid Dynamics method by using the model of air flow and the air temperature distribution in 2 dimensions, which is 4.2 meter long and 1.3 meter high. The condition of outlet air is 2, 3 and 4 m/s and the direction of front outlet air is 0° to 60° with the angle of 30° to 90° with the roof plane. As per the results, 4 m/s and 0° front outlet air, 90° roof outlet air, this is the lowest average human skin temperature.

Shimsang, et al. (2008) investigated the airflow pattern and carbon monoxide (CO) spread in an underground car parking in for design a suitable circulation air system, using computational fluid dynamics (CFD) technique. The underground car park is reconsidered with the sources of CO from 27 cars. Analysis of air flow and carbon monoxide (CO) circulation air is dominated by continuity, momentum and species transport equations. The results of simulation show that case 1 gives a good result for ventilating and CO dispersion. The average concentration of CO is about 14.8 ppm.

Thongbai (2008) Studied a simulation of wind flow by the use of integration of computational fluid dynamics (CFD) and geographic information system (GIS) techniques for 2-D and 3-D thermal comfort zone mapping, aim to more development of research in integration between GIS and land architecture which will enlargement the perceptive of architecture problems.

CHAPTER III

METHODOLOGY

In order to achieve the objectives of the research, to study computational fluid dynamic of the wind speeds and wind direction in Mhor Chit II Bus Terminal and to simulate in using areas, software "SolidWorks" is imported in conjunction with computational fluid dynamic (CFD). Data for simulation areas were collected from existing documents, observation, Public Works Department, Google Earth, and Flash Earth. The data of stimulations areas could be explained.

3.1 Data for the Research

The data for stimulated areas need to be known including specific information of buildings in Mhor Chit II Bus Terminal such as the height of the building, the position of the building, number of floors of the building and the structures neighboring in the study area (Table 3.1).

1) Data from Public Works Department and the Transport co., ltd include number of floors of the building and the position of the building.

2) Data from Meteorological Department include wind speeds and wind directions since 2000-2011from Thai Meteorological Department Monitoring at Don Muang Airport (Table 3.2).

3) Data from Meteorological Department include radiative forcing since 2000-20011 from Thai Meteorological Department Monitoring at Bangkok Station (Table 3.4).

4) Questionnaires used pattern from American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE).

Table 3.1 Types, sources of data for this study

Type of Data	Sources	Objectives
Data of the building: dimensions and location of building	Public works Department, the Transport co., ltd	Basic data to simulated building
Mhor Chit II Bus Terminal geographical information	Google Earth, Flash Earth	Basic data to simulated areas
Wind speeds, Wind direction	Meteorological Department	Average of wind speeds and wind direction
Radiative forcing	Meteorological Department	Primary data collected from questionnaires

Table 3.2 The average annual wind speed and directions in Bangkok 2000-2011 at Don Muang Airport (Code of station: 455601)

No.	Year	wind direction	wind speed (Knot)
1	2000	S	6
2	2001	S	7
3	2002	S	5.7
4	2003	S	5.8
5	2004	S	6.3
6	2005	S	5.6
7	2006	S	4
8	2007	S	5.3
9	2008	S	5.3
10	2009	W	5.7
11	2010	S	6.6
12	2011	S	3.9
		Average	5.6

Source: Meteorological Department, (2011). Note 1 knot = 0.514 m/s.

Table 3.3 The average annual radiative forcing (W/m^2) in Bangkok 2000-2009 at Don Muang Airport (Code of station: 455601)

Station	year	5:00 AM	6:00 AM	7:00 AM	8:00 AM	9:00 AM	10:00 AM	11:00 AM	12:00 PM	1:00 PM	2:00 PM	3:00 PM	4:00 PM	5:00 PM	6:00 PM	7:00 PM	Maximum per years (W/m^2)	Average per years (W/m^2)
Bangkok Station	2000	0	0	11	59	109	151	180	205	244	239	199	151	100	44	6	244	113
	2001	0	0	19	74	135	195	236	276	289	283	246	188	125	60	11	289	142
	2005	0	0	15	67	130	182	233	276	296	286	232	182	98	37	3	296	136
	2006	0	0	15	71	128	182	227	277	307	291	240	168	101	44	3	307	137
	2007	0	0	15	68	127	192	243	266	269	249	230	179	101	37	2	269	131
	2008	0	0	14	67	142	197	238	278	304	278	236	178	109	38	3	304	139
	2009	0	0	16	74	147	212	247	270	261	248	207	162	100	40	3	270	133
Maximum per time (W/m^2)		0	0	19	74	147	212	247	278	307	291	246	188	125	60	11	307	142
Average per time (W/m^2)		0	0	15	69	133	190	232	266	285	271	229	175	107	45	5	-	-

Source: Meteorological Department, (2011)

3.2 Software SolidWork

SolidWork is a 3D mechanical CAD (Computer Aided Design) program that runs on Microsoft Windows and is being developed by Dassault Systems SolidWorks (Miltiadis, 2010). It can create surface models in 3D Solid Models into separate parts and Assembly to create a 2D Standard Engineering (CADD = Computer Aided Design and Drafting), (Figures 3.1).

The efficiency of the Software SolidWorks is built to create a simulation of the complete Mechanical Engineering Design. Engineering calculations and the detection error it can be used in 3D Solid Models to reduce products costs and shorten the time.

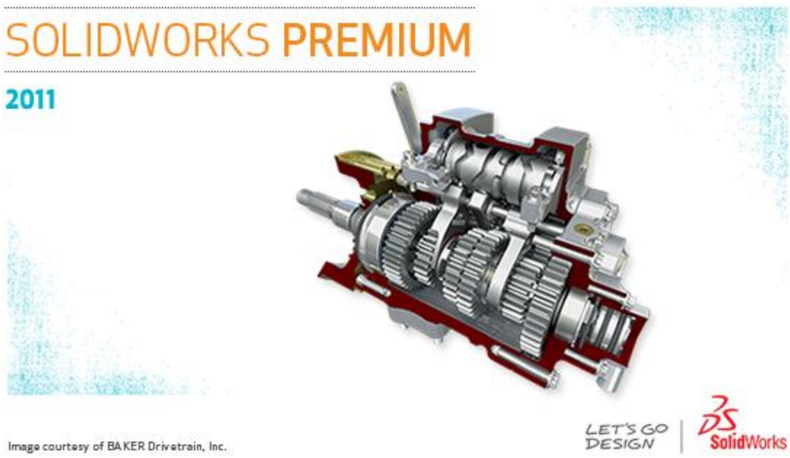


Figure 3.1 Software SolidWorks

3.3.1 The behavior of the Software SolidWorks

The major performance of SolidWorks is divided into 3 mode Part, Assembly, and Drawing modes as can be explained as follows:

Part Mode is a separation of the work, to start work in the assembly and drawing modes. 2D and 3D sketch to lead to the creation in this step

Feature-Based Modeling is designed to know the properties of the Solid Model created. The user can change and edit the Model.

The density, material, mass, weight, etc. are a computer model in Solid Model and the 3D Model can be seen at any point of view.

3.3 The study procedures

In this study, the wind effect on human comfort in computational fluid dynamic in the area of Mhor Chit II bus terminal has been divided into 3 stages.

3.3.1 First stages

The first stage is to simulate the studies area, by using the equations for referable wind continuity equation, momentum equation, and energy equation. For turbulence flow simulation can describe by standard $\varepsilon - k$ model in chapter II. In determining the value of the velocity distribution at outside the building using the finite volume method, that development from finite difference the application of this research will consider only two dimensions in the first step is to divide the area of the building as a small called grid generation process.

3.4.2 Second stages

The second stage is to integrate the continuity equations and momentum equations of the model. Throughout the study area, this is called discretization. The final step in the simulation is to solve equations that can be integrated by implicit method for Semi-Implicit Method for Pressure Linked Equation (SIMPLE) used to solve for the velocity at different locations in the area. The simulation area includes the height of the building, direction of the building. The simulation area is set to simulate the flow of air in the area, the technique CFD use to simulate the flow in study area, by using the software "SolidWorks", for simulation area using flow turbulence and simulation wind flow cross the building. Results are shown the flow and direction of the wind like Figures 3.2. The flow and speed of the wind contain the maximum, minimum and average wind speeds.

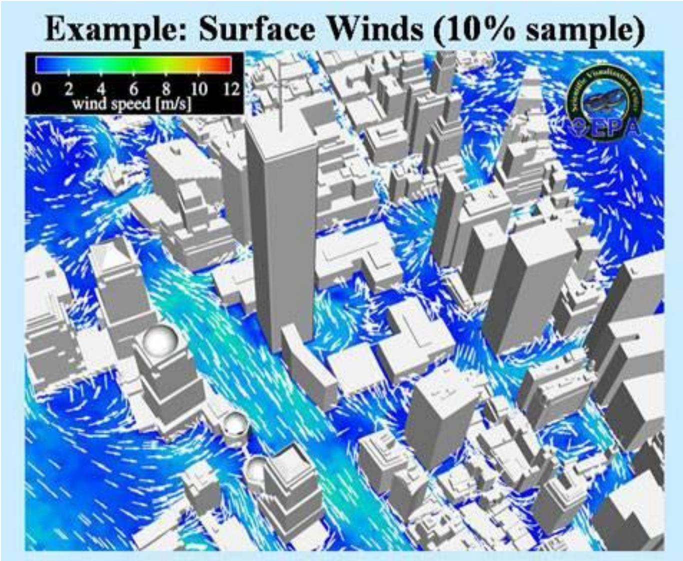


Figure 3.2 Predicted wind speed (m/sec). Flow field details for a horizontal slice at the surface

Source: U.S. Environmental Protection Agency, (2004)

3.4.3 Third stage

To accuracy of the information generated can be analyzed by using the equipment such as anemometer LM-8000 (4 in 1 professional measuring instrument: anemometer, hygrometer, thermometer, light meter) for measure wind speed, temperatures and humid in April to May 2012 at the study area and using questionnaire of thermal comfort to peoples working around the Mhor Chit II us terminal at 1 PM to 2 PM, that radiative forcing is high.

Figure 3.3 Anemometers. LM-8000

Source: LEGA Engineering Co., Ltd.

The correspondences were chosen by the purposive sampling method. The samples were categorized in two groups, people working at Mhor Chit II bus terminal and people working at the poor wind. The number of samples using the finite population by Yamane (1973):

$$n = N/(1+N\,(e)^2)$$

e = precision, n = simple size, N = population size

The number of stores at the rim of the terminal at the Mho Chit II Bus Terminal has approximately 172 including of 25mobile device stores, 52 food stores, 61 clothing and shoes stores, 16 groceries stores and 18 store of record store. The employees receive passengers of the bus 39 points; employees receive passengers of the van 16 points. Workers were about 343 workers. Therefore, the total numbers of questionnaire 185 copies are required.

The questionnaire about the predicted mean vote (PMV) which is based on the quantifying people's thermal sensation of people voting +1, +2, +3, 0, -1, –2 or –3 (hot-cold) and processing the data of predicted mean vote as a percentage and compare the results with Predicted Mean Vote were processed equations and neutral temperature in Thailand (Khedari et al., 2000).

Table 3.4 Predicted Mean Vote equations and neutral temperature

Relative humidity	Air velocity (m/s)	PMV equation	Neutral temperature (ºC)
50%1 RH 160%	0.2	PMV = 0.4576 Ti - 12.817	28.01
	0.5	PMV = 0.4121 Ti - 11.873	28.81
	1	PMV = 0.4016 Ti - 12.412	30.56
	1.5	PMV = 0.4114 Ti - 13.363	32.48
6O%<RHI70	0.2	PMV = 0.4954 Ti - 13.462	27.17
	0.5	PMV = 0.4466 Ti - 12.640	28.30
	1	PMV = 0.5222 Ti - 15.744	30.15
	1.5	PMV = 0.3991 Ti - 12.555	31.46
7O%<FSII80%	0.2	PMV = 0.5753 Ti - 15.65	27.20
	0.5	PMV = 0.4793 Ti - 13.560	28.29
	1	PMV = 0.3596 Ti - 10.885	30.27
	1.5	PMV = 0.3587 Ti - 11.207	31.24
50%1 RI-3 180%	2	PMV = 0.5308 Ti - 17.767	33.47
	3	PMV = 0.203 1 Ti - 7.2158	35.53

Source: Khedari et al., 2000)

CHAPTER IV
RESULTS

After collecting data for the simulation study area, the research was conducted by means of models for simulation of the wind flows at Mho Chit II Bus Terminal, which was the preferred study area.

The implementation process had started in April of 2012 for the Mho Chit II Bus Terminal, verifying the direction of the winds. The properties of the fluids, to be used in research, which simulates the arrangement of buildings in the Mho Chit II Bus Terminal, which calculates the velocity of the air and the heat transferred through the Mho Chit II Bus Terminal, were applied to examine the accuracy of the simulation area. Following the simulation, a survey for the comfort of the climatic surroundings, and the relationship between wind speeds, temperature and humidity at The Mho Chit II Bus Terminal were added to the research.

4.1 Simulation of the Mo Chit II Bus Terminal.

Figure 4.1 show the simulation areas at Mho Chit II Bus Terminal by means of the “SolidWork” software. Building sizes were used to calculate flow information, received from the Company's Mho Chit II Bus Terminal. For simulation, the structure in the shape of an object (Appendix A) was explored, but did not include the elastic behavior of the air (Aero-Elasticity). All of which have been studied by the use of CFD, which was used to analyze the flow of the air stream.

The condition of the winds was: speed of 2 m/s, pressure of 1 bar at the buildings, temperature: 40ºC. The prevailing direction of the winds in the area around the Mho Chit 2 Bus Terminal was the south.

Computational fluid dynamics (CFD) techniques based on the speed of 2 m/s as the average wind speed, as in Figure 4.3 show in-line directions and colors of the average wind speeds. All buildings are arranged in parallel to the wind directions and transverse direction the wind. This represents the average wind speed at parallel buildings. The winds will speed over the buildings and get forced to pass through the gaps between the buildings, however the wind will not flow through the buildings and in the case of buildings transverse to the winds, the average wind speed was lower than the parallel standing buildings, but the winds can approach the building in a better way.

Figure 4.3 show the wind speed and wind direction changes and its effects on the buildings. Figure 4.4 show in color, the separations of wind speeds at Mho Chit II Bus Terminal, for better understanding.

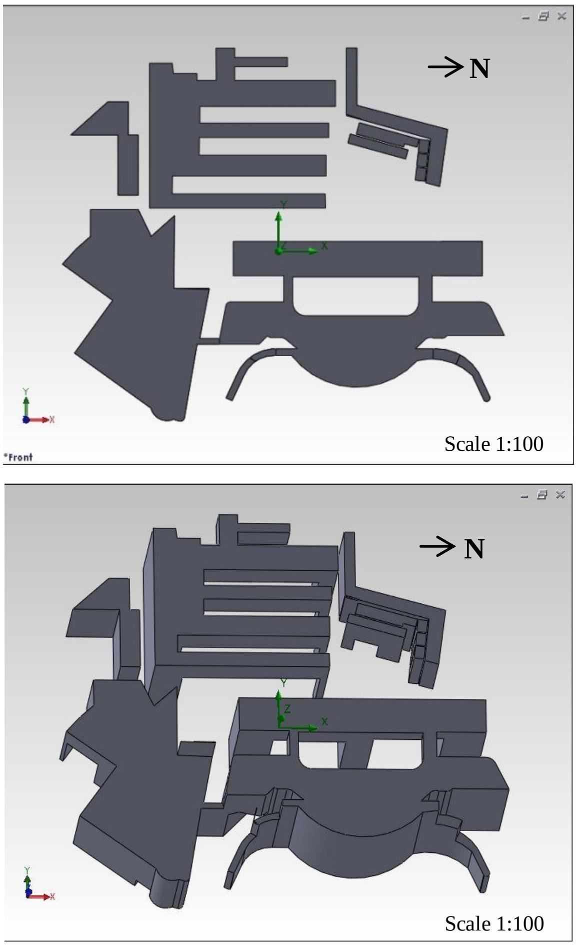


Figure 4.1 Simulation Area, illustrated by “SolidWorks” Software at Mho Chit II Bus Terminal

Figure 4.2 Displays the Lines of Wind Speeds at Mho Chit II Bus Terminal

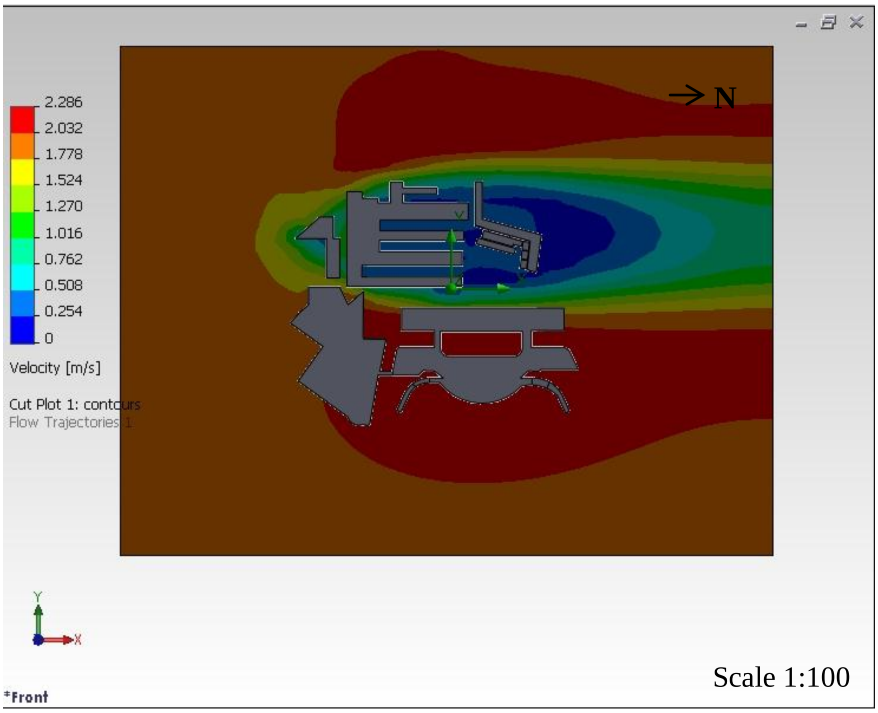


Figure 4.3 Displays the Separations of Wind Speeds at Mho Chit II Bus Terminal

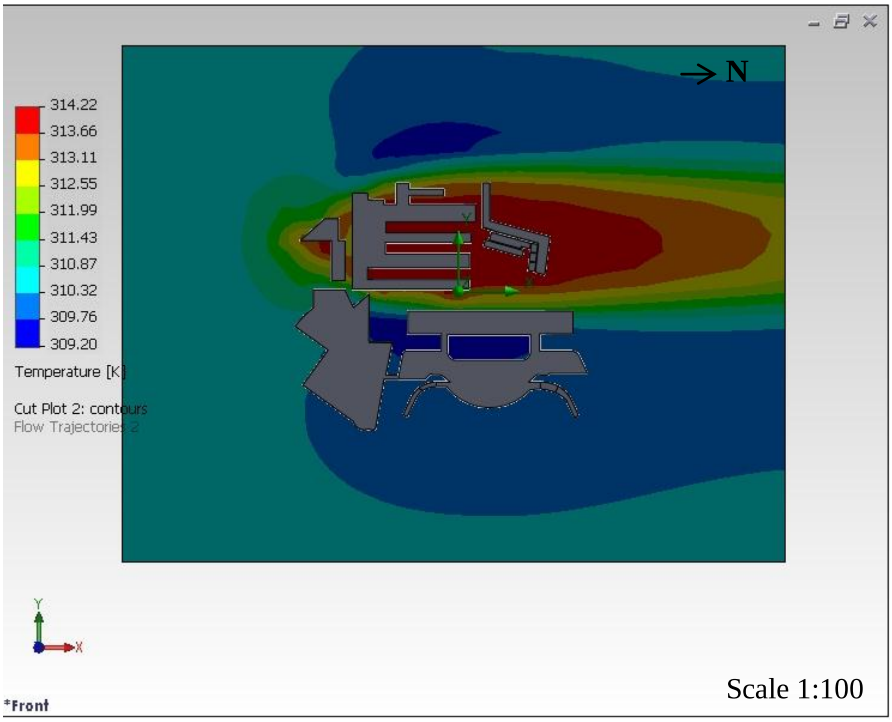


Figure 4.4 Displays the Separations of Temperature at Mho Chit II Bus Terminal

4.2 The Heat Distribution within Mo Chit II Bus Terminal

From Figures 4.4, it can be seen, that the temperatures throughout the buildings, during the month of April, can reach as high as 314.22 K, and low temperature fewer than 309.20 K and Figures 4.8 it can be seen, that the temperatures throughout the buildings from use of measuring equipment within the Mho Chit II Bus Terminal, can reach as high as 313.73 K, and low temperature fewer than 309.42 K, while the wind speeds at simulation range around 2 m/s and wind speed at the buildings from use of measuring equipment within the Mho Chit II Bus Terminal range around 2.5 m/s. The result of the calculations showed, that the areas behind the buildings, parallel to the winds, were high in temperatures. Since the gaps between buildings are narrow, the flow of air causes convective heat, even at low temperatures. Considering the thermal effect, it can be seen that temperatures are proportional to the air distribution. It was further observed, that in the presence of air through the gaps between buildings, the area temperature is lower than the wind spots.

4.3 Comparison of the Simulation to determine the wind speed, humidity and temperature

After a simulation flow, using the "Computational Fluid Dynamics" (CFD) Technique and the "SolidWorks" software for the simulation area and the simulation of wind flows, the simulation results have been verified for accuracy of the information generated. It was analyzed by using equipment, such as the Anemometer LM-8000 (4 in 1 professional measuring instrument: Anemometer, Hygrometer, Thermometer, Light Meter) to measure wind velocities, temperatures and humidity from April to May in 2012, at these given study area.

4.4 The Results of Applied Scientific Measuring Instruments

4.4.1 The Results of the Temperature by Usage of Scientific Measuring Instruments

Following the use of a measuring equipment, such as Anemometer LM-8000 (4 in 1 professional measuring instrument: Anemometer, Hygrometer, Thermometer, Light meter) to measure wind velocities, temperatures and humidity during the months of April to May 2012 at the given research area, specific results were found.

Figure 4.9 and 4.11 it can be seen, that the temperature 36ºC (309 K), which is the temperature range at which the Thai people can feel comfortable. Measured with installed thermometers in the study area, the maximum temperature reached 40ºC (313 K); the lowest temperature was 37ºC (309 K). Zone "a" temperatures were around 40ºC (313 K), 39ºC (312 K) and 38.5ºC (311.5 K), zone "b" measured temperatures reached 39.1ºC (312 K), 39ºC (312 K) and 38ºC (311 K). Due to the fact, that one "a" and "b" were exposed to open space, sunlight could be reflected through the building, which prevented air from flowing freely. At zone "c" temperatures reached 37ºC (309 K), 38ºC (311 K) and 37ºC (309 K), because this area is surrounded by trees, planted around the area. As a consequence, less sunlight is being reflected.

Figure 4.5 Location of Equipment Installation at Mho Chit II Bus Terminal

4.4.2 The Results of the Humidity, when Using Scientific Measuring Instruments

After the use of an equipment, such as Anemometer LM-8000 (4 in 1 professional measuring instrument: Anemometer, Hygrometer, Thermometer, Light meter) to measure wind velocities, temperatures and humidity during the months of April to May 2012 at the given research area, the following results were found in Table 4.2 humidity in the study area are between 38 - 55.9 %. The range of humidity, in which the Thai people feel comfortable, lies around 40-70%.

4.4.3 The Results of the Wind Velocities, when Using Scientific Measuring Instruments

After the use an equipment, such as Anemometer LM-8000 (4 in 1 professional measuring instrument: Anemometer, Hygrometer, Thermometer, Light meter) for measure wind velocities, temperatures and humidity during the months of

April to May 2012 at the given research area, the following results were found: Table 4.4, Figures 4.6 and Figures 4.7, shows that the measured wind velocities, measured in the study area, resulted in a maximum wind speed of 3.1 m/s, and a low wind speed of 1.8 m/s. Wind speeds greater than 3.0 m/s let the Thai people feel comfortable. Zone “a” wind speed was 2.9, 2.1 and 2 m/s, Zone “b” wind speed measurements were 2.8, 1.8 and 2.3 m/s. Despite the fact, that Zone “a” and “b” were open space areas, the buildings blocked wind flows and changed wind direction, so the air could not freely. At Zone “c”, the wind speeds were 2.8, 2.1 and 3.1 m/s, but Zone “c” has trees planted around the area, which changed wind direction and wind speeds.

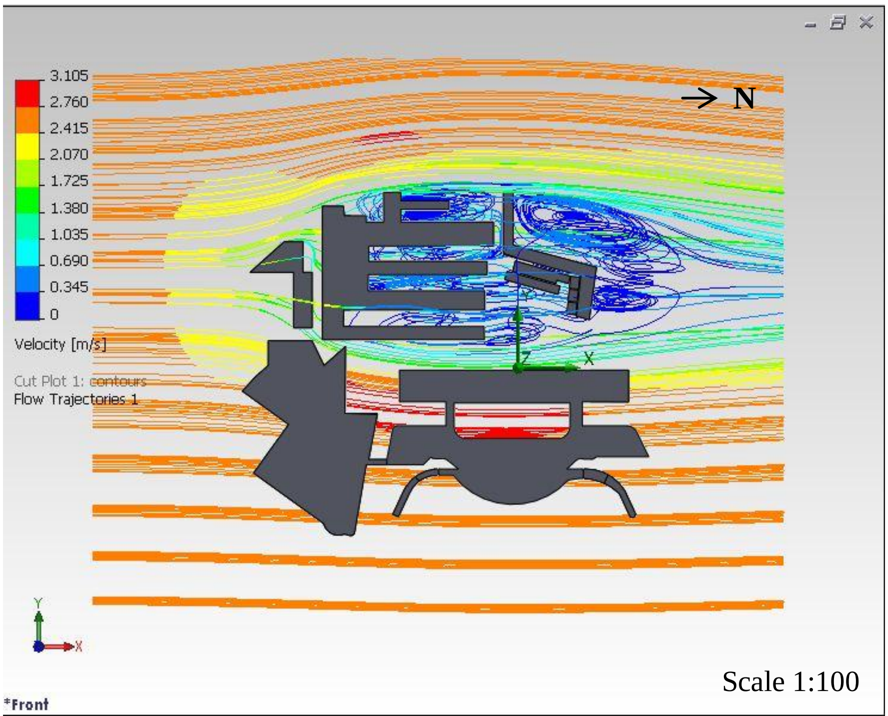


Figure 4.6 Displays the Line of Wind Speeds use of measuring equipment at Mho Chit II Bus Terminal

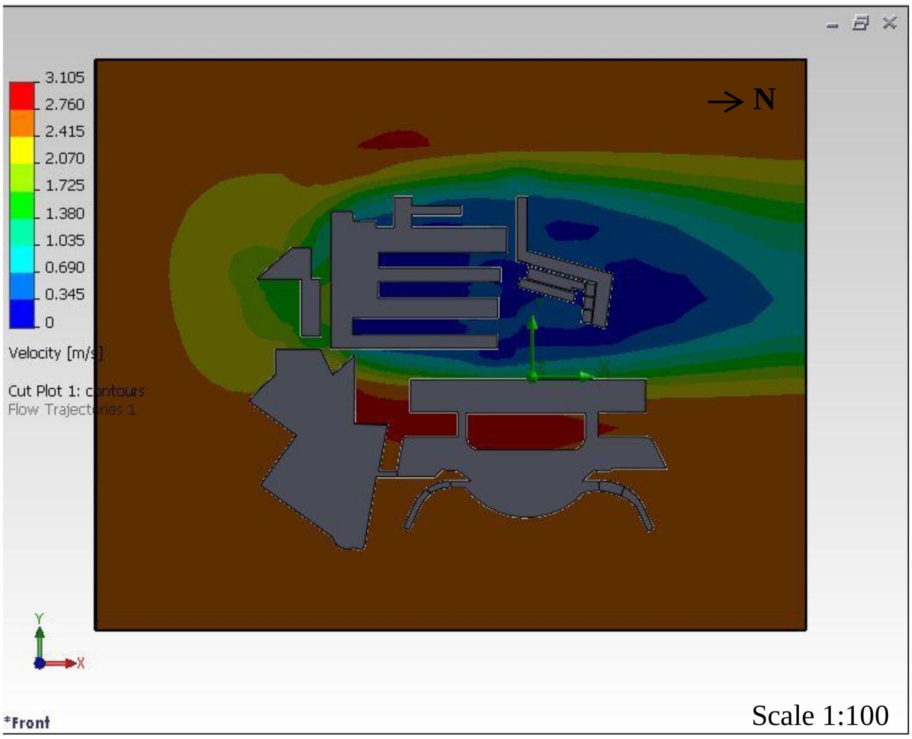


Figure 4.7 Displays the Separations of Wind Speeds use of measuring equipment at Mho Chit II Bus Terminal.

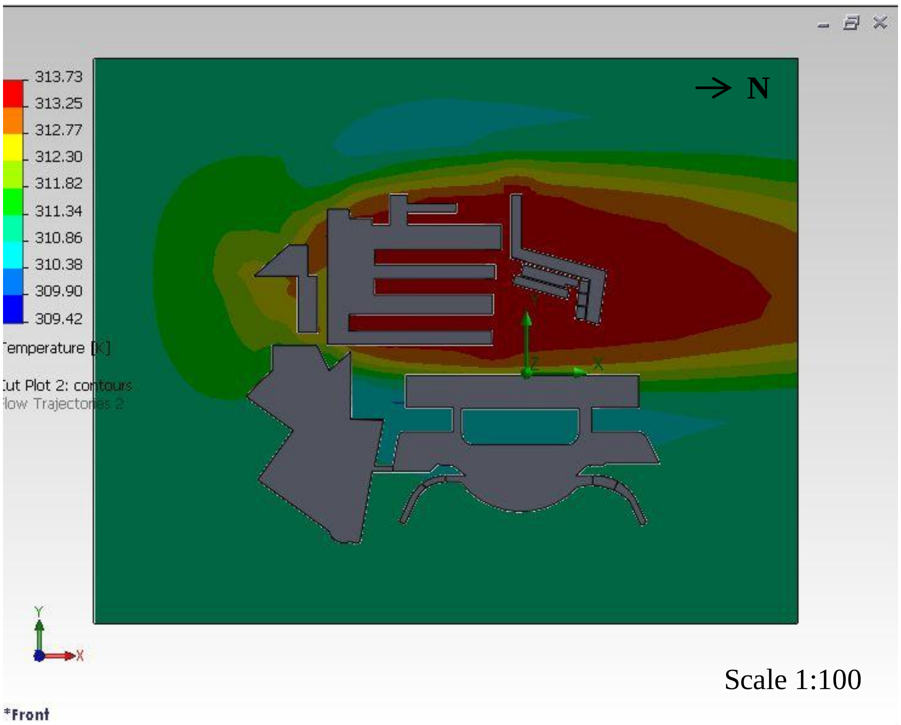


Figure 4.8 Separations of Heat Concentration use of measuring equipment within the Mho Chit II Bus Terminal.

Figure 4.9 The Results of the Temperature by use of Scientific Measuring Instruments

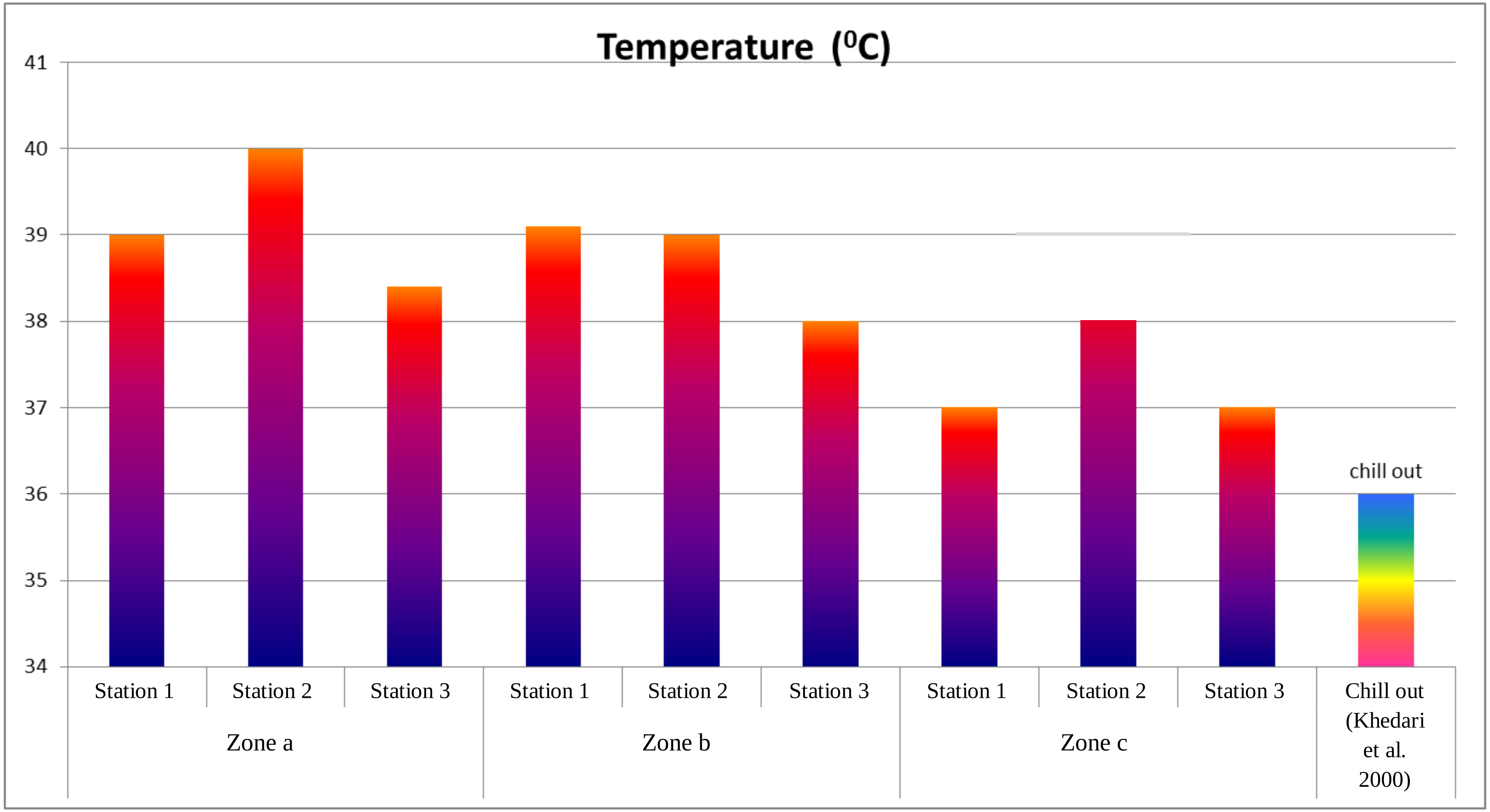


Figure 4.10 The results of the Humidity by Use of Scientific Measuring Instruments

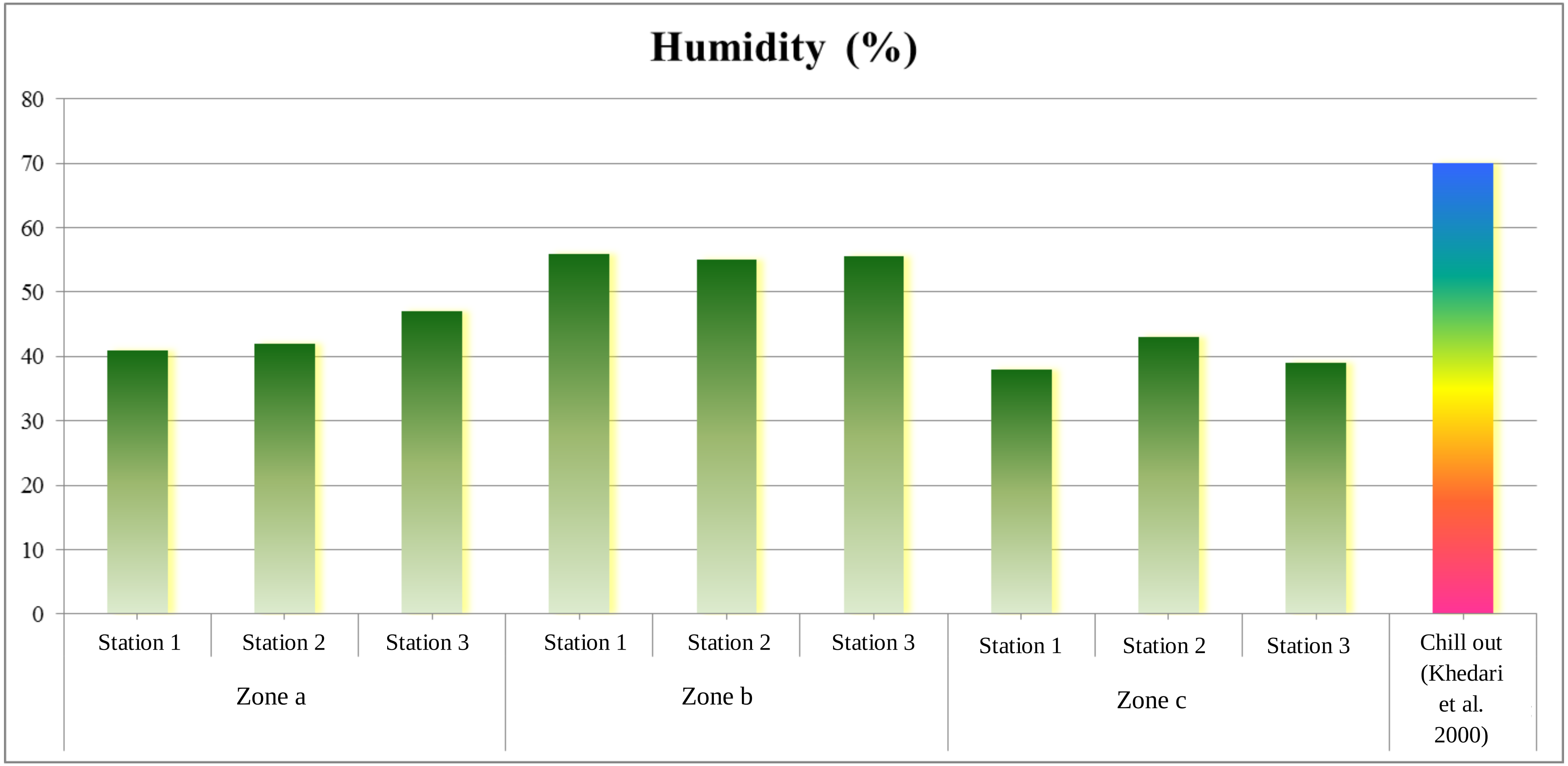
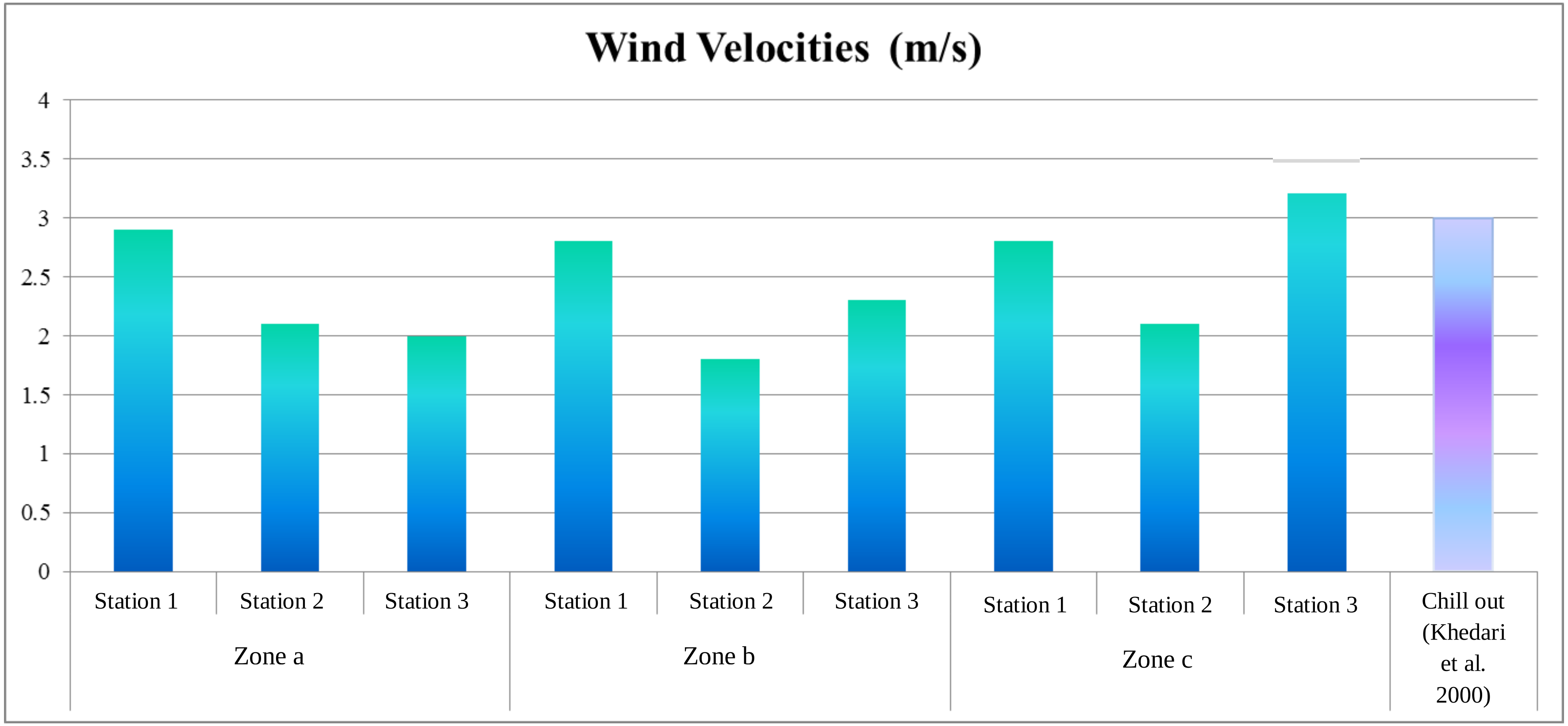


Figure 4.11 The Results of the Wind Velocities by use of Scientific Measuring Instruments



The numbers of stores, outside the terminal at the Mhor Chit II Bus Terminal, cover approximately 162 locations, out of which 25 are mobile stores, 52 food stores, 61 clothing and shoe stores, 16 groceries stores and 18 record stores. There are 39 stations where terminal employees receive the bus passengers. There are then further 16 stations where employees receive incoming passengers. The total numbers of workers employed within the terminal is 343 people. Therefore, the total number of questionnaires required for this survey was 185 copies at around the Mhor Chit II Bus Terminal at 1 PM to 2 PM.

The surveyed area was divided into three parts based on the wind velocity, temperature and population of the area. Zone (a) (Figure 4.10) building, for storing busses, has wind speeds ranging from 0 m/s to 2.9 m/s and temperatures from 40.73ºC (313.73 K) - 38ºC (311 K) . The sample groups were found to contain gas station attendants, drivers, cleaners and small bus drivers. Zone (b) (Figure 4.11) treatment plants, stores and Public Transport had wind speeds from 0 m/s to 2.8 m/s and temperatures between 39ºC (312 K) - 38ºC (311 K). The sample group was found to contain vendors for clothing and shoes, vendors for records, vendors for groceries and food stuff. Zone (c) (Figure 4.12), The Bus Ticket Sales Building and Passenger Terminal, had wind speed from 0 m/s to 3.1 m/s, temperatures from 37ºC (309 K) 38ºC (311 K). The sample group was found to contain employees to receive the bus passengers and usher them to the appropriate buses, and employees, which receive incoming passengers.

Figure 4.12 Characteristics of the area by taking advantage of the area

Figure 4.13 Utilization of Zone “a”

Figure 4.14 Usages the areas of Zone “b”

Figure 4.15 Utilization of Zone “c”

4.5 Personal Characteristics

Data obtained by the questionnaires regarding the sex, age, occupation, duration of staying in a workplace, weight of respondents and the rating scale of the people (Table 4.1).

4.5.1 Sex

From the 185 questionnaires, it was found that the 43.24 % of the contacted persons were male, and 56.76 % of them were female.

4.5.2 Age

From the 185 questionnaires, the average of the contestants was found to be 47.19 years old. The oldest person was 65 years old, and the youngest was 15 years old. It was found that most of them were between the ages of 41-50 years old (31.8%), the second largest group were within the age range of 20-30 years old (29.73%).

4.5.3 Occupation

Most of sample people, 67.57% were the vendors of the own business and 32.43% were the employees in the Mho Chit II Bus Terminals.

4.5.4 Duration of Stay in Work Place

Categorized by length of stay in a given work place, the questioned persons at the Mho Chit 2 Bus Terminal, 52.43% indicated, that they had been at work at Mho Chit 2 Bus Terminal for over 8 hours 13.51 % and 34.05 % of the people had been working less than 8 hour.

4.5.5 Body weight of our respondents.

From the 185 questionnaires, categorized by sex and considering the weight of male contestants, the average weight was to be found at 76.20 kg. The highest weight was 84 kg, and the low weight was 57 kg. Average Weight of female contestants was found to be 64.67 kg. The highest weight was 85 kg, and the low weight was 46 kg.

4.5.6 The Rating Scale of the Workers

From the 185 questionnaires, it was found that 94.05 % of the samples were chosen: +3, meaning “very hot” and 5.95 % of the sample were chosen: +2 meaning “hot”.

4.5.7 Reaction of People

From the questionnaire 185 copies, it was found that the 63.24 % of the questioned people felt exhausted, where as 32.97 % were moody and at least 3.78 % of the persons felt of anxiety over such extreme weather conditions.

Table 4.1 Number and Percentage of Interviewed People, Categorized by Personal Characteristics

Personal Characteristics	Number	Percentage
1. Sex		
Male	80	43.24
Female	105	56.76
Total	185	100.00
2. Age		
Under 20 years old	6	3.24
20-30 years old	55	29.73
31-40 years old	37	20.00
41-50 years old	57	30.81
51-60 years old	20	10.81
Over 61 year old	10	5.41
Total	185	100.00
3. Occupation		
Sellers/ Business Owners	125	67.57
Employees at Mho Chit 2 Bus Terminal	60	32.43
Total	185	100.00
4. Duration of Stay in workplace		
Over 8 hours	97	52.43
8 hours	25	13.51
Less than 8 hours.	63	34.05
Total	185	100.00
5.Body weight of correspondents		
Male		
Less than 44 kg.	-	-
45-50 kg.	-	-
51-60 kg.	10	5.41
61-70 kg.	39	21.08

Table 4.1 Number and Percentage of Interviewed People, Categorized by Personal Characteristics (Cont.)

Personal Characteristics	Number	Percentage
71-80 kg.	22	11.89
Over 81 kg.	9	4.86
Female		
Less than 44 kg.	-	-
45-50 kg.	13	7.03
51-60 kg.	32	17.30
61-70 kg.	36	19.46
71-80 kg.	18	9.73
Over 81 kg.	6	3.24
6. The rating scale of the worker		
+3 very hot	174	94.05
+2 hot	11	5.95
+1 Warm	-	-
0 Slightly warm	-	-
Total	185	100.00
7. Population feeling		
Exhausted	117	63.24
Moody	61	32.97
Anxiety	7	3.78
Total	185	100.00

4.6 Results from Questionnaire at Zone (a): Building for Storing Busses (Table 4.2)

4.6.1 Sex

From the 61 questionnaires, it was found that the 60.66 % of the sample were male, and 39.34 % of them were female.

4.6.2 Age

From the 185 questionnaires, considering the ages of interviewed people, the average age were found to be 43.12 years old. The oldest person was 65 years old, and the youngest was 20 years old. It was found that most of them were between the ages of 41 to 50 years old (27.87 %), the second group was between the ages of 51 to 60 years (26.23 %).

4.6.3 Occupation

Categorized by occupations, most of the interviewed people, 47.54 % were sellers or small business owners, 52.46 % were employees in Mho Chit II Bus Terminals.

4.6.4 Duration of Stay in Workplace

Categorized by length of stay in workplace the interviewed people had stayed in Mho Chit II Bus Terminal, it was found that 14.75 % had been at work at Mho Chit 2 Bus Terminal for over 8 hours; 26.23 % had been at work for 8 hours, while 59.02 % had been worked for less than 8 hours.

4.6.5 Body weight of Respondents.

From the 185 questionnaires, categorized by sex, and considering the weights, the male people had an average weight of 66.73 kg. The highest weight was 80kg, and the lowest weight was 56 kg. The weight of female contestant was 62.23 kg as an average. The highest weight was 73 kg, and the lowest weight was 49 kg.

4.6.6 The Rating Scale of the Workers

From the 185 questionnaires, it was found that 93.44 % percent of the workers had selected +3 on a scale, which means “very hot” and 6.56 % of the workers had selected +2 on the scale, which stands for “hot”.

4.6.7 Population Feeling

From the 185 questionnaires, it was found that the 67.21 % of the workers felt exhausted, 29.51 % were moody and at least 3.28 % felt anxiety over such extreme weather conditions.

Table 4.2 Number and Percentage of Sample People, Categorized by Personal Characteristics at Zone (a)

Personal Characteristics	Number	Percentage
1. Sex		
Male	37	60.66
Female	24	39.34
Total	61	100.00
2. Age		
under 20 years old	2	3.28
20-30 years old	8	13.11
31-40 years old	12	19.67
41-50 years old	17	27.87
51-60 years old	16	26.23
over 61 years old	6	9.84
Total	61	100.00
3. Occupations		
Sellers/ Business Owners	29	47.54
Employees in Mho Chit II Bus terminal	32	52.46
Total	61	100.00
4. Duration of Stay in Work Place		
over 8 hours	9	14.75
8 hours	16	26.23
Less than 8 hours.	36	59.02
Total	61	100.00
5. Body weight of correspondents		
Male		

Table 4.2 Number and Percentage of Sample People, Categorized by Personal Characteristics at Zone (a) (Cont.)

Personal Characteristics	**Number**	**Percentage**
Less than 44 kg.	-	-
45-50 kg.	-	-
51-60 kg.	9	14.75
61-70 kg.	22	36.07
71-80 kg.	6	9.84
Over 81 kg.	-	-
Female		
Less than 44 kg.	-	-
45-50 kg.	2	3.28
51-60 kg.	8	13.11
61-70 kg.	8	13.11
71-80 kg.	6	9.84
Over 81 kg.	-	-
6. The Rating Scale of the Worker		
+3 very hot	57	93.44
+2 hot	4	6.56
+1 Warm	-	-
0 Slightly warm	-	-
Total	61	
7. Population Feeling		
Exhausted	41	67.21
Moody	18	29.51
Anxiety	2	3.28
Total	61	100.00

4.7 Results from the Questionnaire at Zone (b) Treatment Plants, Stores and Public Transport (Table 4.3)

4.7.1 Sex

From the 61 questionnaires, it was found that the 32.79 % of the interviewed persons were of male, and 67.21 % of them were of female gender.

4.7.2 Age

From the 185 questionnaires, when considering ages of the interviewed persons, the average age was found to be 23.57 years old. The oldest person was 56 years old, and the youngest was 15 years old. It was further found that most of them were between the ages of 21 to 30 years and represented 37.70% of all interviewed people, whereas the second group ranged between the ages 41 to 50 years, representing 26.23 % of all people of the survey.

4.7.3 Occupation

The people, when asked for their profession in zone (b), were sellers or small business owners, by 100 %.

4.7.4 Duration of Stay in Workplace

Categorized by length of stay in the workplace the interviewed people had stayed in Mho Chit II Bus Terminal for over 8 hour. This was 100 % of the people asked.

4.7.5 Body weight of correspondents.

From the 185 questionnaires, categorized by sex and considering the weights, the average male weighted 71.87 kg. The highest weight was 84 kg, and the lowest weight was 60 kg. Weight of female was average of their weight were found to be 58.88 kg. The highest weight was 76 kg, and the lowest weight was 46 kg.

4.7.6 The Rating Scale of the Workers

From the 185 questionnaires, it was found that the 93.44 % of the interviewed persons had chosen +3 a scale representing “very hot” and 6.56 %t of the selected people choose +2 on the scale, representing as “hot”.

4.7.7 Population Reactions

From the 185 questionnaires, it was found that about 55.74 % of the people interviewed of the sample felt, that they were exhausted, 37.70 % felt moody and at least 6.56 % of the interviewed felt anxiety over such extreme weather conditions.

Table 4.3 Number and Percentage of Interviewed People, Categorized by Personal Characteristics at Zone (b)

Personal Characteristics	Number	Percentage
1. Sex		
Male	20	32.79
Female	41	67.21
Total	61	100.00
2. Age		
under 20 years old	4	6.56
21-30 years old	23	37.70
31-40 years old	14	22.95
41-50 years old	16	26.23
51-60 years old	4	6.56
over 61 years old		
Total	61	100.00
3. Occupations		
Sellers / Small Business Owners	61	100.00
Employees in Mho Chit 2 Bus Terminal	-	-
Total	61	100.00

Table 4.3 Number and Percentage of Interviewed People, Categorized by Personal Characteristics at Zone (b) (Cont.)

Personal Characteristics	Number	Percentage
4. Duration of Stay in Work Pla		
Over 8 hours	61	100.00
8 hours	-	-
Less than 8 hours.	-	-
Total	61	100.00
5.Body weight of correspondents		
Male		
Less than 44 kg.	-	-
45-50 kg.	-	-
51-60 kg.	1	1.64
61-70 kg.	10	16.39
71-80 kg.	8	13.11
Over 81 kg.	1	1.64
Female		
Less than 44 kg.		
45-50 kg.	7	11.48
51-60 kg.	17	27.87
61-70 kg.	14	22.95
71-80 kg.	3	4.92
Over 81 kg.	-	-
6. The Rating Scale of the Workers		0.00
+3 very hot	57	93.44
+2 hot	4	6.56
+1 Warm	-	-
0 Slightly warm	-	-
Total	61	100.00

Table 4.3 Number and Percentage of Interviewed People, Categorized by Personal Characteristics at Zone (b) (Cont.)

Personal Characteristics	Number	Percentage
7. Population Reaction		
Exhausted	34	55.74
Moody	23	37.70
Anxiety	4	6.56
Total	61	100.00

4.8 Result from Questionnaire at Zone (c) the Bus Ticket Sales Building and Passenger Terminal (Table 4.4)

4.8.1 Sex

From the 63 questionnaires, it was found that 36.51 % of the interviewed people were of male, and 63.49 % of them were of female gender.

4.8.2 Age

From the 63 questionnaires, considering ages of interviewed persons, the average age to be found was 39.17 years old. The oldest person was 64 years old, and the youngest was 27 years old. It was also found that most of them were between the ages of 41 to 50 years (39.68 %), the second group was between the age of 21 to 30 years of age (36.51 %).

4.8.3 Occupation

Categorized by occupations, most of the interviewed people were sellers or small business owners (55.56 %). 44.44 % of them were employees in the Mho chit 2 Bus Terminal.

4.8.4 Duration of Stay in Workplace

Categorized by length of stay at the workplace, the interviewed persons, working at the Mho Chit II Bus Terminal, have been working at Mho Chit II Bus

Terminal for over 8 hours (42.86%). 14.29 % of the people had been working 8 hour and 42.86 % had been worked less than 8 hours.

4.8.5 Body weight of correspondents

From the 63 questionnaires, categorized by sex, and considering the weight of males, the average weight to be found was 73.5 kg. The highest weight was 85 kg, and the lowest weight was 68 kg. The average weight of the females was 64.77 kg. The highest weight was 85 kg, and the lowest weight was 47 kg.

4.8.6 The Rating Scale of the Workers

From the 185 questionnaires, it was found that 95.24 % of the interviewed persons were choose +3 scale, which stands for "very hot". Only 4.76 % of the surveyed people choose +2 on the scale, which is rated as "hot".

4.8.7 Population Reactions

From the 185 questionnaires, it was found about 68.85 % of the surveyed people felt exhausted, while 32.79 % were moody and at least 1.64 % felt anxiety over such extreme weather conditions.

Table 4.4 Number and Percentage of the Surveyed Persons, Categorized by Personal Characteristics at Zone (c)

Personal Characteristics	Number	Percentage
1. Sex		
Male	23	36.51
Female	40	63.49
Total	63	100.00
2. Age		
Under 20 years old	-	-
21-30 years old	23	36.51
31-40 years old	11	17.46
41-50 years old	25	39.68
51-60 years old	-	-

Table 4.4 Number and Percentage of Surveyed Persons, Categorized by Personal Characteristics at Zone (c) (Cont.)

Personal Characteristics	Number	Percentage
0ver 61 years old	4	6.35
Total	63	100.00
3. Occupations		
Sellers / Small Business Owners	35	55.56
Employees in Mho Chit II Bus Terminal	28	44.44
Total	63	100.00
4. Duration of Stay in Workplace		
Over 8 hours	27	42.86
8 hours	9	14.29
Less than 8 hours.	27	42.86
Total	63	100.00
5. Body weight of correspondents		
Male		
Less than 44 kg.	-	-
45-50 kg.	-	-
51-60 kg.	-	-
61-70 kg.	7	11.11
71-80 kg.	8	12.70
Over 81 kg.	8	12.70
Female		-
Less than 44 kg.		
45-50 kg.	4	6.35
51-60 kg.	7	11.11
61-70 kg.	14	22.22
71-80 kg.	9	14.29
Over 81 kg.	6	9.52
6. The Rating Scale of the Workers		

Table 4.4 Number and Percentage of Surveyed Persons, Categorized by Personal Characteristics at Zone (c) (Cont.)

Personal Characteristics	Number	Percentage
+3 very hot	60	95.24
+2 hot	3	4.76
+1 Warm	-	-
0 Slightly warm	-	-
Total	63	100.00
7. Population Feeling		
Exhausted	42	68.85
Moody	20	32.79
Anxiety	1	1.64
Total	63	100.00

4.9 Statistical Analysis Error of the data

4.9.1 Root Mean Square Error (RMSE)

The Root Mean Square Error (RMSE) is a frequently used method, to measure the difference between values, predicted by a model and the values actually observed from the environment, which is being modeled.

The RMSE is defined as the Square Root of the Mean Squared Error:

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n}(X_{obs,i} - X_{model,i})^2}{n}}$$

Where X_{obs} are observed values and X_{model} are modeled values at time/place i.

Table 4.5 Statistical Analysis Data of Wind Speeds (m/s)

Data	Zone		
	A	**B**	**C**
Simulation of Laminar Flow (m/s)	3	3.4	2.5
Simulation of Turbulence Flow (m/s)	1.50	1.77	2.28
Measurements (m/s)	2.33	2.30	2.60

Note: Significant of Laminar Flow = 0.115, Significant of Turbulence Flow = 0.089, RMSE of Turbulence Flow = 0.745, RMSE of Laminar Flow = 0.596

The wind speeds data (Table 4.5), arising from simulations, using the Computational Fluid Dynamics Method (CFDM), are compared with measurements of the Scientific Equipment, to be checked for errors by use of the statistical T-Test function. It shows that the wind speeds at Sig = 0.089 and $\alpha = 0.05$, stemming from the computer simulation, as per the Computational Fluid Dynamics Method and the wind speeds, using scientific equipment in the studies areas, were statistically not significantly different.

The Root Mean Square Error (RMSE) of Turbulence Flow equals 0.596, however the Root Mean Square Error (RMSE) of Laminar Flow results to 0.745. This indicates that the simulation of the Turbulence Flow is the better method, rather than the Simulation of the Laminar Flow.

Table 4.6 Statistical Analysis Data of Temperature (ºC)

Data	Zone		
	A	**B**	**C**
Turbulence Flow Method of Temperature (ºC)	41.22	36.76	36.76
Laminar Flow Method of Temperature (ºC)	37	37	40
Measurements (ºC)	39.1	38.7	37.33

Note: Significant of Laminar Flow = 0.92, Significant of Turbulence Flow = 0.828, RMSE of Turbulence Flow = 1.691, RMSE of Laminar Flow = 2.193, Percent Error of Turbulence Flow = 4.407, Percent Error of Laminar Flow = 5.714

The temperature data from the simulations (Table 4.6), using the Computational Fluid Dynamics Method, are compared with the measurements of the Scientific Equipment, to check for errors, by use of the statistical T-Test function. It shows that the wind speed, at Sig = 0.92 and $\alpha = 0.05$, resulting from the computer simulation with the Computational Fluid Dynamics method and wind speed by use of scientific equipment in the studies areas, were statistically not significantly different. The Root Mean Square Error (RMSE) indicates a Turbulence factor of 1.691, with a percent Error of 4.407, however the Root Mean Square Error (RMSE) of the Laminar Flow results to 2.193, with a percent Error of 5.714

4.10 Grid Dependence of Numerical simulation for wind speeds

In a numerical analysis of turbulent flow with a boundary fit coordinate system, dependence of computation accuracy on grid system can calculate in software “SolidWorks” (Table 4.7).

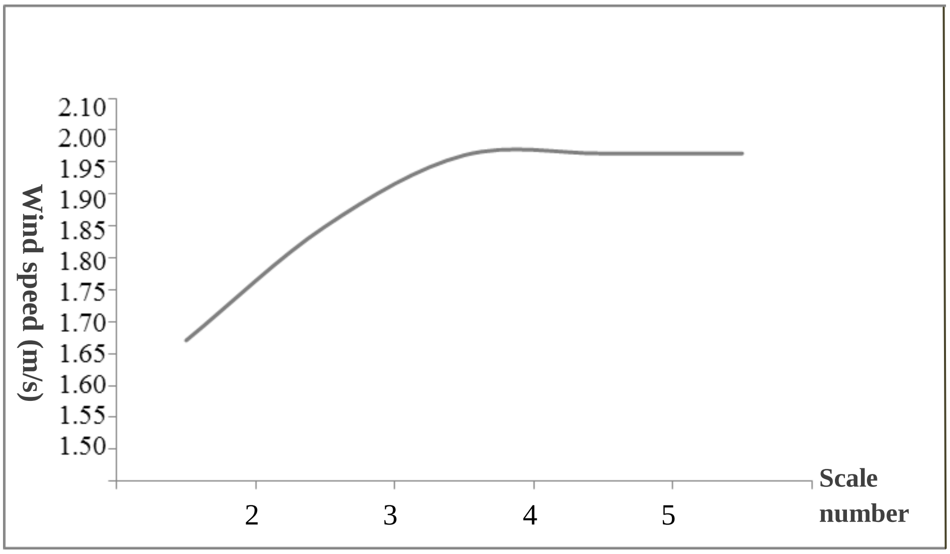
Table 4.7 Show the result of wind speeds by used Grid Dependence method

Scale	2	3	4	5
Wind speeds	1.720683	1.89919	2.010889	2.013646

Note: Scale numbers of application simulated runs in “SolidWork” have 1-7 scale (Slovenly - exhaustively).

Result of the scale was calculated differently, so selection the scale similar to the areas that is the best method, which measurement values at zone “b” station 1 was similar in the 2 m/s, when making simulation at different resolution scales number 2, 1.989 m/s was the simulation of wind speeds at resolution scale number 3, 2.010 m/s was the simulation of wind speeds at resolution scale number 4 and 2.013 m/s was the simulation of wind speeds at resolution scale number 5. Table 4.11 the resolution scale number 4 is calculated begin a constant value therefore, in the simulation area of research was selected simulation the wind speed at resolution scale number 4 (Figure 4.16).

Figure 4.16 Show trends of the wind speeds by used Grid Dependence method



CHAPTER V

CONCLUSION AND RECOMMENDATIONS

All engagement on site, which meant spending about 8 hours a day working in the area and environment is not conducive enough, to analyze the measures, which will improve the comfort of the operators , which will affect the performance of their work. And to conserve natural resources, it should be most recommendable to provide cooling by means of natural air convective heat blowers, which is an alternative to energy conservation.

5.1 Conclusions

Research in this study was divided into two steps: in the first step, the ventilation of heat transfer within the Mho Chit II Bus Terminal was investigated at the start of the procedure. To explore the building layout plan, the incident radiation and temperatures in Bangkok was part of the studies. Other criteria were the properties of the fluids, to be used in the research model, like the wind speed at 2 m/s, the value of the temperatures at the building in the South and in the month of April to study the rate of heat transfer, in comparison to parallel and transverse standing buildings to the winds. The second step was to check the accuracy of the maps, provided by the survey of the work area and to measure wind speeds, humidity and temperature measurements, by use of scientific metering equipment.

This research was conducted to study the airflow and heat transfer through the Mho Chit II Bus Terminal. For the study of the flow of the wind, the calculation results in the case of turbulent flows, caused by the use of equations Standard k-ε model, it can be summarized as Blockage Ratio (h/H) and the Ratio of the Length to the Height of the Barrier (l/h) and the characteristics of the flow (Flow characteristics).

5.1.1 Effect of Wind Velocities

The measured wind velocities, measured in the study area, resulted in a maximum wind speed of 3.1 m/s, and a low wind speed of 1.8 m/s. Wind speeds greater than 3.0 m/s let the Thai people feel comfortable. Zone “a” wind speed was 2.9, 2.1 and 2 m/s, Zone “b” wind speed measurements were 2.8, 1.8 and 2.3 m/s. Despite the fact, that Zone “a” and “b” were open space areas, the buildings blocked wind flows and changed wind direction, so the air could not freely. At Zone “c”, the wind speeds were 2.8, 2.1 and 3.1 m/s, but Zone “c” has trees planted around the area, which changed wind direction and wind speeds. Wind velocities in the area will increase on the grounds, in case that there is a barrier or a gap between the buildings. The wind passing the gap between the buildings will have higher velocities (Venturi Effect). The wind speed at the building will be lower, due to the arrangement of the transverse direction with the wind. It allows an undisturbed flow of the air in the space between the buildings.

5.1.2 Effect of heat transfer and thermal comfort

Zone (a) building, for storing busses, has wind speeds ranging from 0 m/s to 2.9 m/s and temperatures from 40.73ºC (313.73 K) - 38ºC (311 K) . The sample groups were found to contain gas station attendants, drivers, cleaners and small bus drivers, 93.44 % of the workers had selected +3 on a scale, which means “very hot” and 6.56 % of the workers had selected +2 on the scale, which stands for “hot”, 67.21 % of the workers felt exhausted, 29.51 % were moody and at least 3.28 % felt anxiety over such extreme weather conditions.

Zone (b) treatment plants, stores and public transport had wind speeds from 0 m/s to 2.8 m/s and temperatures between 39ºC (312 K) - 38ºC (311 K). The sample group was found to contain vendors for clothing and shoes, vendors for records, vendors for groceries and food stuff, 93.44 % of the interviewed persons had chosen +3 a scale representing “very hot” and 6.56 %t of the selected people choose +2 on the scale, representing as “hot”, 55.74 % of the people interviewed of the sample felt, that they were exhausted, 37.70 % felt moody and at least 6.56 % of the interviewed felt anxiety over such extreme weather conditions.

Zone (c), The Bus Ticket Sales Building and Passenger Terminal, had wind speed from 0 m/s to 3.1 m/s, temperatures from 37ºC (309 K) 38ºC (311 K). The sample group was found to contain employees to receive the bus passengers and usher them to the appropriate buses, and employees, which receive incoming passengers, 95.24 % of the interviewed persons were choose +3 scale, which stands for “very hot”, 68.85 % of the surveyed people felt exhausted, while 32.79 % were moody and at least 1.64 % felt anxiety over such extreme weather conditions.

On the rate of heat transfer through the wall, temperature is increased by ventilation. If there has good ventilation, the temperature in the research areas was reduced. From these studies, it was found that the temperature distribution was inversely proportional to the air circulation**.**

5.1.3 Suggestion

This study can be considered as a research, which can help the executive management in the decision to meet the needs of workers of the area who have to work under these extreme weather conditions. On the other hand, there is a good way to preserve energy. The buildings could function with their natural ventilation system. They should be designed and built with a very large surface area and uniform shape.

The buildings should be built high and have gaps between the buildings, therefore allowing more air distribution. The design of the layout should arrange the position of a particular building, facing the North to South direction, thereby blocking the sun and reducing the disparity of natural wind blocking. This study was meant to be an example how to simulate the flow of air in the summer, to support a building design guide.

5.1.4 Recommendation for Further Research

1. Further studies would be recommendable to analyses the comfort zone chart in Thailand, outside of the conditioned areas in the current year.

2. To provide experiments with the more accurate data of the simulation on virtual gaps, to gain more data for characteristics of roofs and objects, nearby building simulations.

3. To provide a more comprehensive model, to further study wind velocities, wind direction and temperature management areas, appropriate for every season.

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APPENDIX

เอกสารชี้แจงอาสาสมัครผู้เข้าร่วมโครงการวิจัยโดยการตอบแบบสอบถาม

และการพิทักษ์สิทธิผ้เข้าร่วมการวิจัย

เรียน ผู้ตอบแบบสอบถามทุกท่าน

ด้วยดิฉัน นางสาว ปาริสุทธิ์ สีทองดี นักศึกษาปริญญาโทสาขา เทคโนโลยีการบริหารสิ่งแวดล้อม คณะ สิ่งแวดล้อมและทรัพยากรศาสตร์ มหาวิทยาลัยมหิดล มีความประสงค์ทำวิทยานิพนธ์เรื่อง “การจำลองการไหลของลมร่วมกับเขตความสบายของผู้ปฏิบัติงาน กรณีศึกษา สถานีขนส่งหมอชิต 2” ซึ่งประโยชน์ที่คาดว่าจะได้รับคือ ทราบศักยภาพของหลักการพลศาสตร์การไหลร่วมกับเขตความสบายและการถ่ายเทอากาศภายในสถานีขนส่งหมอชิต2 ซึ่งเป็นหลักประกอบการตัดสินใจของผู้บริหารในการจัดการพื้นที่จริงและใช้ประโยชน์จากธรรมชาติอย่างเต็มที่ ท่านได้รับเชิญให้เข้าร่วมการวิจัยนี้เพราะ ท่านมีการปฏิบัติหน้าที่ในส่วนที่เกี่ยวข้องกับการใช้ประโยชน์พื้นที่โดยตรง

ในการนี้ผู้วิจัยมีความจำเป็นต้องเก็บรวบรวมข้อมูลโดยใช้แบบสอบถามเรื่อง การจำลองการไหลของลมร่วมกับเขตความสบายของผู้ปฏิบัติงาน กรณีศึกษา สถานีขนส่งหมอชิต 2

ซึ่งประกอบด้วยคำถาม 2 ส่วน คือ

1. ข้อมูลด้านคุณลักษณะของสภาพอากาศเช่น ความเร็วลม ความชื้น และอุณหภูมิ ในสถานีขนส่งหมอชิต 2

2. ข้อมูลทางด้านความรู้สึก หนาว ร้อน ของผู้ปฏิบัติงาน ในสถานีขนส่งหมอชิต 2

ใช้เวลาในการตอบ 5 นาที ผู้วิจัยจะขอรับแบบสอบถามคืน

ขอความกรุณาให้ท่านพิจารณาตอบตามความรู้สึกของท่านให้มากที่สุดโดยข้อมูลและคำตอบทั้งหมดจะถูกปกปิดเป็นความลับ และจะนำมาใช้ในการวิเคราะห์ผลการศึกษาครั้งนี้โดยออกมาเป็นภาพรวมของการวิจัยเท่านั้น จึงไม่มีผลกระทบใดๆต่อผู้ตอบหรือหน่วยงานของผู้ตอบ เนื่องจากไม่สามารถนำมาสืบค้นเจาะจงหาผู้ตอบได้ ท่านมีสิทธิ์ที่จะไม่ตอบคำถามข้อใดข้อหนึ่ง หากท่านไม่สบายใจหรืออึดอัดที่จะตอบคำถามนั้น หรือไม่ตอบแบบสอบถามทั้งหมดเลยก็ได้ โดยไม่มีผลกระทบต่อการปฏิบัติงานใดๆของท่าน ท่านมีสิทธิ์ที่จะไม่เข้าร่วมการวิจัยก็ได้โดยไม่ต้องแจ้งเหตุผล

หากผู้เข้าร่วมวิจัยมีข้อสงสัยเกี่ยวกับการวิจัยหรือแบบสอบถาม สามารถติดต่อสอบถามได้ที่ ปาริสุทธิ์ สีทองดี สามารถติดต่อทางโทรศัพท์ที่เบอร์ 08-1729-7081 ได้ตลอด 24 ชั่วโมง

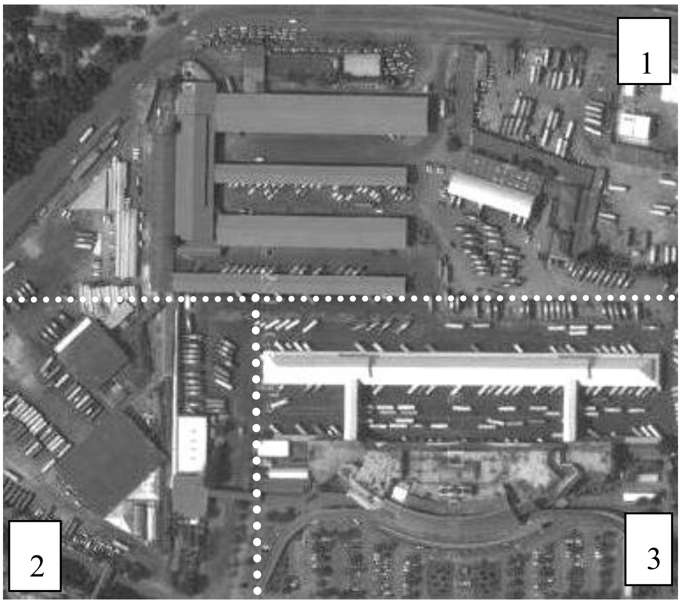
โครงการวิจัยนี้ได้รับการพิจารณารับรองจาก คณะกรรมการจริยธรรมการวิจัยในคนของมหาวิทยาลัยมหิดล สำนักงานอยู่ที่ สำนักงานอธิการบดีมหาวิทยาลัยมหิดล ถนนพุทธมณฑล สาย 4 ตำบลศาลายา อำเภอพุทธมณฑล จังหวัดนครปฐม 73170 หมายเลขโทรศัพท์ 02-849-6223-5โทรสาร 02-849-6223 หากท่านได้รับการปฏิบัติไม่ตรงตามที่ระบุไว้ ท่านสามารถติดต่อประธานกรรมการฯหรือผู้แทน ได้ตามสถานที่และหมายเลขโทรศัพท์ข้างต้น

ขอขอบพระคุณที่กรุณาสละเวลาในการตอบแบบสอบถาม

ขอแสดงความนับถือ

ปาริสุทธิ์ สีทองดี

Questionnaire of Thermal comfort



ตำแหน่งสถานที่ (Place) …………………….....

อายุ (Age) ……………………………………

เวลา (Time) …………………………………

อุณหภูมิแวดล้อม (Temperature) ……………..…

ความชื้นสัมพัทธ์ (%RH) ………………………

ชาย (Male) ( ) หญิง (Female) ( )

อาชีพ (Occupation) ....ระยะเวลาการทำงาน (During of work)........................…

วิธีการลดความร้อน................................

☐ อ่อนเพลีย (Exhausted) ☐ หงุดหงิด (Moody) ☐ กังวล (Anxiety)

Thermal Sensation Vote: PMV standard

-3	-2	-1	0	1	2	3
หนาว (Cool)	หนาวเล็กน้อย (Slightly cool)	พอดี (Neutral)	อุ่นเล็กน้อย (Slightly warm)	อุ่น (Warm)	ร้อน (Hot)	ร้อนมาก (Very hot)

Scale	-3	-2	-1	0	1	2	3
Sensation Vote							

The result of wind speeds by used Grid Dependence method.

Scale number2		Scale number3		Scale number4		Scale number5	
Length (m)	**Velocity (m/s)**	**Length (m)**	**Velocity (m/s)**	**Length (m)**	**Velocity (m/s)**	**Length (m)**	**Velocity (m/s)**
0	1.884926429	0	1.976544868	0	2.037155612	0	2.003249033
0.235227405	1.917269872	0.090883777	1.986790183	0.098537083	2.032495771	0.103198987	2.003899313
0.47045481	1.950169068	0.181767555	1.99729781	0.197074166	2.028272704	0.446533528	2.010196129
0.705682215	1.983596366	0.282991337	2.002746908	0.295611249	2.024479626	0.517264287	2.011189933
Length (m)	_1	0.38421512	2.008472918	0.394148332	2.021109978	0.587995045	2.012130432
0	2.026187645	0.485438903	2.014473478	0.492685415	2.018157445	0.658725803	2.013015308
0.124221932	2.021653747	0.536050794	2.017575953	0.591222498	2.015615971	0.729456562	2.013842473
0.248443864	2.017731506	0.66327436	2.019341887	0.711120634	2.013287693	0.802028907	2.015413249
0.372665796	2.014408569	0.705682215	2.020001733	0.8108743	2.011940538	0.874601253	2.016854488
0.496887728	2.011673164	Length (m)	_1	0.910627966	2.010673973	0.947173598	2.01816515
0.62110966	2.009514142	0	2.023998921	1.010381632	2.00948649	1.019745943	2.019344399
0.730513155	2.008326245	0.049044046	2.022346509	1.110135298	2.008376643	1.092318289	2.020391595
0.83991665	2.007238911	0.098088091	2.020764669	1.209888964	2.007343047	1.164890634	2.021306297
0.949320146	2.006251044	0.147132137	2.019252637	1.30964263	2.00638438	1.23746298	2.022088262
1.202432528	2.004998527	0.196176183	2.017809663	1.409396296	2.005499382	1.310035325	2.022737442
1.455544911	2.003873277	0.245220228	2.016435007	1.509149962	2.00468686	1.355714199	2.023203695
1.708657294	2.002870678	0.294264274	2.015127942	1.608903628	2.003945683	1.423201533	2.024219232
		0.34330832	2.013887754	1.708657294	2.003274785	1.490688868	2.025120041
		0.392352366	2.012713741	Length (m)	_1	1.558176202	2.025906093
		0.427032005	2.012014563	0	2.004409431	1.625663537	2.0265774
		0.520364717	2.010420337	0.253589535	2.006765688	Length (m)	_1
		0.613697429	2.008953755	0.33811938	2.007583502	0	2.0265774

The result of wind speeds by used Grid Dependence method (cont.)

Scale number2		Scale number3		Scale number4		Scale number5	
Length (m)	Velocity (m/s)	Length (m)	Velocity (m/s)	Length (m)	Velocity (m/s)	Length (m)	Velocity (m/s)
		0.707030142	2.007611813	0.43379762	2.011047333	0.062376937	2.024351605
		0.800362854	2.006391637	0.529475861	2.014225671	0.124753873	2.022243168
		0.84702921	2.005826348	0.625154102	2.017108152	0.18713081	2.020250804
		0.96945013	2.004672902	0.720832342	2.019686477	0.249507747	2.018373247
		1.010257103	2.004318658	0.816510583	2.021954381	0.311884683	2.016609254
		1.157286076	2.003336234	0.912188824	2.02390761	0.37426162	2.0149576
		1.304315049	2.002493409	1.007867064	2.025543907	0.415290263	2.014024959
		1.497093151	2.00167004	1.103545305	2.026862995	0.489036393	2.012741606
		1.593482202	2.001318659	1.199223546	2.027866573	0.562782523	2.01152809
		1.708657294	2.001051986	1.286438131	2.030352069	0.636528652	2.010383239
				1.371244482	2.032482603	0.710274782	2.009305915
				1.456050834	2.034326788	0.784020912	2.008295013
				1.540857185	2.035884454	0.857767042	2.007349463
				1.625663537	2.037155612	0.931513172	2.006468231
						1.005259302	2.005650318
						1.079005432	2.004894759
						1.242514159	2.003668379
						1.442289788	2.00269085
						1.642065417	2.001874927
						1.708657294	2.001637451

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