Surfacing Effects on Thermal Condition in Urban Open Space

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Abstract

Urban density has significant impacts in shaping the microclimatic condition of urban milieu. Studies related to global warming and environmental hazard effecting climate condition particularly in urban open space indicates constructive outcomes of escalating temperature caused by poor design strategies and adaptation. Hence, the aim of this study is to identify and assess the elements and prospects of existing open space towards outdoor thermal condition and discomfort of urban environments while preserving the ideal state of quality of life. Measures involve physical microclimatic parameters (radiant temperature, air velocity and relative humidity) and calculations of natural and manmade topographies in two identical open spaces. Meteorological assessments was conducted at designated zones for three (3) days in June at 1.1meter above ground level with five (5) and ten (10) minutes time interval.The preliminary findings revealed that the morphological characteristicsand total area of natural and manmadeelements affect the thermal condition of urban open spaces. However, further empirical research is required to include other associated parameters i.e. types of vegetation and materials promoting ideal thermal environments.

*Keywords:*morphological characteristics, open space, thermal condition

1.0 Introduction

By the end of 21st. century it is estimated that the global average temperature will increase by 2.6 to 4.8^{o}C due to greenhouse gases emission and global warming (The Royal Society and the US National Academy of Sciences, 2014). Intergovernmental Panel on Climate Change (Stocker et al., 2013)reported robust evidence of increased in global average temperature from 1951 to 2010 is actually caused by anthropogenic forces.Energy consumptions and carbon emissions is identified as the most influential factors to initiate carbon footprints and global warming (Stocker et al., 2013).A study ofrapid thermal progression and alteration of surface energy balance and microclimates revealed human activity and development as major factors(Elnabawi, Hamza, & Dudek, 2014). Moreover, excessive industrial growth and urban population’s expansion for the last five (5) decades has imprinted imbalance nature-manmade development due to limited renewable and non-renewable energy resources andabundant transportation movements (World Urbanization Prospects: The 2014 Revision).

United Nations Economic and Social Commission for Asia and the Pacific (Yearbook, n.d.)reported in 2014, Asia Pacific region represent 55% of urbanized world population. Malaysia is ranked first with the highest urban population for five (5) years projection between 2005 and 2010 (Urbanization Policy in Malaysia and its Impact, December 2012). Most of the research and observation concerning environmental hazard, human development and economic enhancement is circling around urban realms and developing countries.This is very common and indeed essential as rural-urban and urban-urban migration occurred. Consequently, these circumstances increased the demand of new settlements, transportations, sustenance, amenities and socio-economic prospectsalong with energy consumption and production.Thus, the effect of global warming and climate change is inevitable.

However, earlier study proven green infrastructure (Mansor, M. and Said, I., undated) and natural elements for instance a control mechanism to preserve urban space livability through microclimatic restraint and thermal discomfort mitigation(de Abreu-Harbich, Labaki, & Matzarakis, 2015; Nasir, Ahmad, Zain-Ahmed, & Ibrahim, 2015)Generally, the issue of thermal discomfort assessment is associated with the type of surrounding: outdoor, semi-outdoor or indoor enclosure (Rupp, Vásquez, & Lamberts, 2015)constrained by the local microclimatic conditions. This study bound the classification of outdoor environment on green infrastructure namely open space, hemmed in by building blocks around a city center of Ipoh, Perak. The aim of this paper is to explore the potential of morphological characteristics defining open spaceto improve heat stress and reduce thermal discomfort risk. Furthermore, preliminary findings in slightly different settings will assist on finding standardizationof methods and instruments assessments particularly for hot-humid climate. Thus, possibilities to develop and adapt regenerative design approach of open space will be obtainable once the understanding of urban outdoor microclimatic characteristics and thermal conditions is visible.

2.0 Study Area and Methodology

A comparative study of two identical open spaces obtains from the physiological elements of urban surfacing namely permeable surface and impermeable surface. It is limited to the density of vegetation and hardscape features with considerations of morphological aspects of site orientation, total areas and proportions of adjacent buildings. Preferred microclimatic parameters are Air temperature ($T_{A)}$, Relative Humidity (Rh) and Air Velocity (V_A) to determine thermal discomfort level based on PET index. A psychological aspect (behavioral, experience, perception and expectations) iseliminated.Other related independent variables contributed to the microclimate condition, geographical aspects, shaded constituent and user density will not be evaluated due to unpredictable weather and instrumentconstraintswhichwill be lack of the real time datafor solar radiation. However, to support the available data of selected microclimatic parameters,supplementary data is accumulated from Malaysia Meteorological Department for three (3)selected days in June for both sites. During the inspections of selected days, the sky was clear from clouds with no rainfall. This circumstance is important becauseitcanmanipulatethe meteorological reading.

Outdoor thermal assessment has various diversified characteristics to put in consideration compared to indoor or controlled environment (E. Johansson et al., 2014). Instruments and method recommendation need to distinctivelydefineurban morphological characteristics (physical and spatial components), microclimate condition and human physiological and psychological aspects (R.F. Rupp et al., 2015; E. Johansson et al., 2014; K. Villadiego& M.A. Velay-Dabat, 2014) even though several studies debated the effects of physiological approach alone towards outdoor thermal comfort (W. Yang et al., 2013).Urban morphology is characterized by location and orientation, manmade and green surface stratum, and height-to-width ratio of built-up area (E. Andreou, 2013; E. Johansson et al., 2014). Furthermore, microclimatic parameters involved instruments setupand time frame need to be carefully structured as it will determine recommended micrometeorological instruments model and influenced the end results.

2.1 Site Study

The study was carried out in Ipoh ($4^o35'02''$ N, $101^o04'58''$ E) the capital city of Perak, Malaysia. Identified open spaces is located within the commercial zones of Ipoh city center dominated by rows of shop-houses in two(2) storeys height and more with the frontage facing the main road. Both sites employed designers' imprintembroideredbya mixture of vegetation and man-made surface.Site 'A' is at par with road level with severalamounts of punctured concrete walls and a playground.Trees are fully grown providing natural shades scattered around. While site 'B' is 500mm higher from road level without playground or concrete walls.Trees arestill immature and mostly conquered by shrubs. Itexperiences a hot-humid climate with prolific solar radiation. In addition, the microclimatic conditions are constantly high in temperatures and relative humidity, light and irregular wind flow, long hours of sunshine, heavy rainfall and overcast cloud all year long. However, the highest temperature and hot weather is experienced between the months of March until June annually. Hence, site investigation was conducted on three (3) selected days in June whereby there is no obliteration from rain. Experimental study was performed at two identical open spaces with similar variables of vegetation and manmade elements as described in Figure 1.

Site 'A': Taman Kanak-kanak. Image Copyright, Wikimapia 2015

Site 'B': Birch Memorial Clock Tower. Image Copyright, Wikimapia 2015

Figure 1: Site Location and Characteristics.

Figure 2: Physical Characteristics

Figure 3: Physical Characteristics

Site ‘A’ (Figure 2) is notably recognized by locals as Taman Kanak-Kanak (TKK) Food Court with the total estimated area of 3888m^2. The site is located at 4^o35’46.5” N, 101^o5’5.1” Eenclosed by a block of ten (10) storey building on the left, a block of seven (7)storey building on the right, row of one (1) storey shop at the rear and facing rows of two (2) storey shop lots in front. Site ‘B’ (Figure 3) with the total estimated area of 1624$m^2$is well-known as Birch Memorial Clock Tower two times smaller than site ‘A’. The site is located at 4^o35’48.6” N, 101^o4’34.1” E surrounded by blocks of three (3) storey buildings. Site ‘A’ has more naturally shaded area compared to site ‘B’. Both sites has clock tower as focal point, applied different leveling and mostly covered with combinations of irregular hard surfaces and green cover. The distance between Site ‘A’ and ‘B’ is approximately five (5) minutes driving range without traffic congestion. Both sites are located at the city center with the frontal façade facing the main road.

2.2 Instruments and Measurements

Three (3) main aspects to consider before mapping thermal environment are buildings geometry (ground/façade and vegetation), meteorological parameters and time parameter (Lutz Katzschner). Preferred microclimatic parameters to analyze thermal condition are Air Temperature (Ta), Wind Velocity (v) and Relative Humidity (RH) respectively (RabiatulAdawiyahNasir et al., 2015; E. Johansson et al., 2014; N. Makaremi et al., 2012). The instrument (Figure 3) used to record related data is Air Velocity Meter Model 9555 Series TSI 9555-P 0747025. The sensor is set at the height of 1.1m from ground (Table 2) as recommended by the international standard ISO 7726:1998 with time interval of five (5) and ten (10) minutes depending on site location. Instruments specification is as stated in Table 3. Data was collected for seven (7) hours constantly from 10.00am to 5.00pm.

Figure 4: Air Velocity Meter Model 9555 Series TSI 9555. Image Copyright, Brandt Instruments 2002-2014

Site ‘A’

Site ‘B’

Figure 5: Instruments setup on site

Table 3: Instruments Specification. Source from Operation and Service Manual, TSI Incorporated 2011-2012.

Parameter	Response Time	Accuracy
Velocity	200 msec	± 3% of reading
Temperature	2 minutes (to 66% of final value)	± 0.3°C
Pressure	0.1 msec	± 2% of reading
Humidity	<1 minute (to 66% of final value)	± 3% RH

2.3 Constraints and Modifications

Numerous earlier study on outdoor thermal comfort agreed that meteorological parameters (physical data) to evaluate thermal conditions are Air Temperature (Ta), Wind Velocity (v), Relative Humidity (RH) and Solar Radiation (W. Klemm et al., 2015; S. Watanabe et al., 2014; K. Villadiego& M.A. Velay-Dabat, 2014; E. Andreou, 2013; N. Makaremi et al., 2012). However, since the instrument to record actual time of solar radiation on sites is unavailable, the data was retrieved from the nearest weather station (Malaysia Meteorological Department) in Ipoh located at 4°34’ N, 101°06’ E. In terms of wind speed (air velocity) readings, since the instruments used is restricted to one direction wind flow (horizontal) which is preferably measured by three dimensional (3D) measurements (horizontal and vertical) due to irregular wind direction (E. Johansson et al., 2014).

Another constraint was the amount of instruments located at each designated points. With one instruments in hand, data was separately collected for each sites. The first study was conducted at Site ‘A’ for three (3) days in June followed by Site ‘B’. To ensure a reliable reading, the height/width ratios need to be carefully justified to eliminate bias factor. In general, Site ‘A’ is almost two times larger than Site ‘B’. Hence, both were divided into segmentsasshown in Table 4. The approximate total area division is determine by a regular practice time frame factors from previous studies with a time interval between 10 – 15 minutes per reading (RabiatulAdawiyahNasir et al., 2015; S. Watanabe et al., 2014) preferred for Site ‘B’ which was fixed at 10 minutes time intervals between each portions and for Site ‘A’ a five (5) minutes time intervals (K. Villadiego& M.A. Velay-Dabat, 2014) applied. Each segment was measured using portable laser rangefinder Fluke Model 414D.

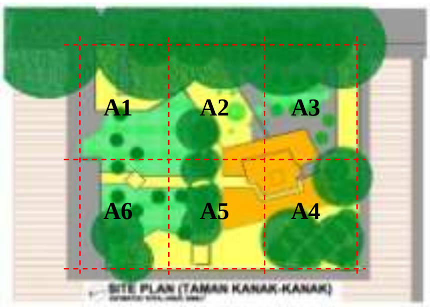

Image: Adapted from JabatanPerancang, MajlisBandaraya Ipoh (MBI)

Site ‘A’ Divided into six (6) segments
Time intervals: 5 minutes
Total area per segment: 740.97m²

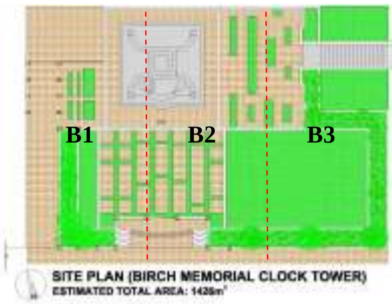

Image: Adapted from JabatanPerancang, MajlisBandaraya Ipoh (MBI)

Site ‘B’ Divided into three (3) segments
Time intervals: 10 minutes
Total area per segment: 541.33m²

Figure 6: Site Justification

3.0 Result and Discussion

Findings provided a better understanding of physical elements of both sites especially on the ratio of vegetation and non-vegetative (manmade) stretch. As shown in Table 5, site A has higher amount of non-vegetative surface (75.23%) compared to vegetative (24.77%) which covered three quarter of total area. In particular, zone A6 has the highest vegetative elements (67.42%) compared to other five (5) segments (Refer to Table 6a). Mostly, the speed of wind is low, with the lowest value of 0.01m/s but could reach up to 2.49m/s.Of temperature, the hottest is about 32.6°C and lowest at 27.8°C.Meanwhile, the percentage of relative humidity (RH) is between 65.2% (minimum) and 79.4% the most. Even though zone A6 has the largest amount of green surface, but the minimal point of heat was experienced at zone A2 (27.8°C).This signify that other related factors such as canopy and wind speed can very much alter the amount of heat gain and release around the site. Moreover, if last night was raining, any spots on ground with higher probability to absorb water will affect the condition of thermal sensation of the day after.

Correlation between thermal condition and morphological aspect is as shown in Table 5, 6a and 6b. Climatic parameters of ambience temperature and relative humidity show discrete evidence towards thermal comfort level. In general, it is proven that area with more vegetation (grass and trees) and shaded (trees canopy and buildings) provided less thermal stress. Site 'A' offernominallevel of heat stress compared to site 'B' as the amount of shaded area is higher. In addition, site 'A' is flanked by ten (10) and seven (7) storey buildings on both sides promoted higher comfort level. Temporarily, site B has significantly balance segregation of surfacing component, 51.32% vegetative and 48.68% non-vegetative. However, astonishingly the level of temperature is quite high (35.5^{o}C) and in average between the range of 31.6 – 34.5^{o}C with higher amount of green surfacingcompared to site A. This circumstance was affected by the physical and natural factors of building height and natural canopies available. Site B is very open towards heat penetration and lack of shield factor even though it is surrounded by three (3) storey buildings. Mainly, trees with larger canopies and nearer and higher adjacent buildings existed have significant impact on thermal level and local microclimatic condition.

Table 5: Total area of vegetative and non-vegetative composition (%)

Zone	Site A		Site B	
	Vegetative	Non-vegetative	Vegetative	Non-vegetative
A1	21.17	78.83	N/A*	N/A
A2	15.86	84.14	N/A	N/A
A3	11.06	88.94	N/A	N/A
A4	12.15	87.85	N/A	N/A
A5	20.94	79.06	N/A	N/A
A6	67.42	32.58	N/A	N/A
B1	N/A	N/A	20.57	79.43
B2	N/A	N/A	61.30	38.70
B3	N/A	N/A	72.09	27.91
Total Area (%)	24.77	75.23	51.32	48.68

**N/A:Non-applicable*

Table 6a: Meteorological Data in Summary – Site A

Parameter	Velocity (m/s)			Temperature (^{o}C)			Relative Humidity, RH (%)		
Zone	Ave	Min	Max	Ave	Min	Max	Ave	Min	Max
A1	.65	.11	1.87	29.4	28.0	31.2	72.7	65.2	78.3
A2	.62	.17	1.69	29.4	27.8	31.1	73.3	67.4	79.3
A3	.35	.08	1.31	29.7	28.1	32.6	74.6	62.3	79.4
A4	.53	.06	2.49	29.4	28.0	30.6	73.4	68.8	79.0
A5	.42	.01	1.38	29.3	29.0	29.9	74.3	71.8	75.9
A6	.24	.06	.41	28.4	28.4	28.5	77.5	76.9	78.1

Table 6b: Meteorological Data in Summary – Site B

Parameter	Velocity (m/s)			Temperature (^{o}C)			Relative Humidity, RH (%)		
Zone	Ave	Min	Max	Ave	Min	Max	Ave	Min	Max
B1	.54	.17	1.74	31.6	29.4	33.8	66.5	57.7	75.1
B2	.72	.29	1.50	34.5	33.7	35.5	50.9	48.7	54.0
B3	.45	.14	.90	33.7	31.5	35.1	66.5	57.7	75.1

4.0 Conclusion

Although the findings support that higher composition of vegetation elevate the possibility tomaximize the reduction of heat stress and thermal condition, uncontainable climatic factors such as rain, haze, sky factorsadding up with heat released within the neighborhoodtogether with drastic development, certain strategy such as regenerative design approach needed local microclimatic input to guide the implementation and improvement. In the future, the actual result on site and the data obtained from the nearest weather station should be compared to examine the diversion. It is compulsory to evaluate the readings because the spatial context of surroundings has potent influence on data retrieved. To optimize the positive effects of thermal condition in short term in constant is quite impossible. Thus, we should not merely implement sustainability approach by providing open concept landscape design without acknowledging short and long term effects on thethermal conditions(Hwang, Lin, & Matzarakis, 2011). Critical evaluation on types of vegetation, buildable surfaces and existing structure has to be the main concern when designing urban open space as it transmits higher threat towards thermal condition. This study is only a preliminary for further understanding of urban thermal microclimatic conditions. Method of evaluation and time allocation for each test conducted need to specifically justified. Longer duration of assessment equipped with flexible and up to date instruments will indisputably facilitate higher accuracy and reliability of end result.

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