Investigating the sans pareil streetscape configuration for creating thermal comfort urban place in Surabaya

A R Pattisina\textsuperscript{1} and F R Widayanti

Department of Civil Engineering, Faculty of Engineering, Universitas Negeri Surabaya, Jl. Ketintang unesa, Surabaya, Indonesia

*amandaristriana@unesa.ac.id

Abstract. The case of climate change expand accelerated than before caused by human-made emissions happened in the street. Coastal cities such as Surabaya are needed a thermal comfort urban place to be the solution. Through the sans pareil streetscape, we can understand which configuration are more (or less) effective for creating thermal comfort urban place. To explore this, we surveyed Raya Darmo Street, Polisi Istimewa Street, and Diponegoro Street Surabaya, Indonesia (N=25). The method using is micro climate analysis with software ENVImet which simulated the micro-scale interactions among urban surfaces, vegetation, and the atmosphere. In this method, it is necessary to measure the thermal comfort index by computing the Temperature Humidity Index (THI) from the data for each thermal station. In the results of this microclimate analysis, six color distributions produced, which showed the climate level. From the color distribution at 12 a.m., showed that no comfortable spaces found on all three streetscapes. There are as many as 90% of streetscape cuts included in the criteria for being uncomfortable on Diponegoro Street. On Raya Darmo Street and Polisi Istimewa Street are included in the requirements of being uncomfortable with a percentage of 49% while the rest are moderate criteria.

1. Introduction

UHI paradox expresses a situation in which urban areas are knowing have the more significant air and surface temperatures correlated to its rural environs [1,2]. The UHI effect in cities affects the wellbeing and social activities of inhabitant [3,4]. Moreover, the case of climate change expands accelerated than before caused by human-made emissions happened in the street. Coastal cities such as Surabaya, Semarang, and Jakarta, which are always close to the phenomenon of climate change, are used as a prior affected area of microclimate. Previous studies revealed that urban greenery in the street is the reproachfully solving suggestion for microclimate to scale down the temperature in tropical areas [5–8].

In urban design, vegetation not only upgrades the aesthetic value but also reduce the Urban Heat Island (UHI) and recover the climate. Concerning the urban microclimate, it has shown that urban place with vegetation has cooling effects; therefore, it becomes essential instruments to counteract the UHI effect urgent to develop [9–11] Nowadays, urban development and weather are both introduced as reasons for generating UHI [12]; regardless, if climate change impediment, urban areas are still encountering the UHI issue [13]. The effect builds upon the variety of public places; for example, the
cooling effect of urban parks is surpassing than of streetscape. Streetscape also determines the local climate and has cooling accoutrements, depending on their vegetation composition [10].

Hence, the potential of sans pareil cooling design on thermal comfort urban place is in the shadow of trees and superstructure under heated summer conditions. The words “Sans Pareil” itself means beyond normal, extraordinary, and unrivalled. We can deliver that if the sans pareil investigation of the exertion to weaken the burning temperature, by convenient urban design, air temperature at the street level can be solved and increase pedestrian during immense thermal circumstances [14]. In line with that, the effectiveness of street greenery is more measurable in hot climates generated by shading of the trees increased the streetscape thermal comfort efficaciously [15].

Furthermore, the characteristics of an area located in a tropical rain forest climatic zone, like Indonesia, is the relatively high evaporation between 77% and 88%. Moreover, the summary of the annual average air temperature is 20 to 34 °C [12] that provoke windily weather, and it has intermediate to ultimate sunshine emission. The thermal interdependence is depressed as a result of the development of evaporation [16]. The rainy and summer were two seasons, which started in September and March [17].

With regards to individuals, the UHI is generating uncomfortable circumstances in people's life. The UHI in the streetscape derives from the emission of private transportation regarding temperature in a streetscape. A streetscape that has a different configuration could have tremendous pollution and produce immense regional temperatures and backward with the order reversed [18]. Many climatic investigations have recorded that citizen was more laid back and dynamics with the base evaporation because of the rapid evaporation of perspiration. On the other hand, people sense fatigued when the relative evaporation hits 70% of the whole humidity [19]. Specifically, wide-ranging disclosure to extreme sunstroke not only giving the effect of people's physiology but also leading to hot severe weather exposure periodically, stress, and hot weather-affiliated death and depression [20].

Admittedly, based on its theory, heat interchange estimation might not be practiced rigorously to all environments, as people contribute to adjusting to a different climate situation or condition to their neighborhood [15]. This implies that people overcome their thermal discomfort through the adaptive design of their surroundings. Even though Surabaya has innumerable streets that design as thermal comfort, it is not immune to the phenomenon of UHI. Additionally, due to the rapid physical development of Surabaya, urbanism comes drastically, and the high utilization of private vehicles; is the reason why several factors that cause a decrease quality of the weather in the urban area of Surabaya.

Given the above, this study aims to investigate the sans pareil streetscape configuration for creating thermal comfort public place in Surabaya, identify and compare the level of thermal comfort based on climate distribution, and determine the effect of streetscape configuration on thermal comfort. There are three study areas used as research objects. The study area, namely Raya Darmo Street, Diponegoro Street and Polisi Istimewa Street.

2. Methods
Laboratory studies were carried out to know the quality of box culvert 2000 x 2000 x 1000 mm type, thus it can be known if box culvert technically can operate and meet the design specification.

2.1. Data and sampling methods
To test the streetscape thermal comfort model, three streets on the site were studied. There are three study areas used as research objects. The study area, namely Raya Darmo Street, which is the main corridor of Surabaya that connected the suburban and central business district (CBD); Diponegoro Street that has extensive use of office and public service; and Polisi Istimewa Street that has art deco colonial residential quartier as Table 1 bellow.
Table 1. Research measurement sampling

| Place | Street                  | Code | Street Cut | Total   |
|-------|-------------------------|------|------------|---------|
| East  | Diponegoro              | E1   | 7          | 15      |
|       | Polisi Istimewa         | E2   | 2          |         |
|       | Raya Darmo              | E3   | 6          |         |
| West  | Diponegoro              | W1   | 4          | 10      |
|       | Polisi Istimewa         | W2   | 1          |         |
|       | Raya Darmo              | W3   | 5          |         |

2.2. Micro climate analysis with software ENVI-met

The three-dimensional microclimate model ENVI-met (version 3.1) was used to study thermal comfort public place in Surabaya. ENVI-met software is a simulation system to determine the impact of strepscpe and urban planning on climate through a three or two-dimensional simulation process. The analysis fulfilled by processing the input data modeling the study area in the form of buildings and roads that simulated the ENVI-met software. There are four stages needed, namely the creation of areas, configuration settings, test models, and run models, then Leonardo stages that produce two-dimensional modeling.

The simulation carried out with the same parameters based on data from BMKG Perak I Surabaya Station. The aim is to be able to compare the conditions of the microclimate in the three street. This study executed based on the hottest month data during 2019 that occurred on May 26, 2019. The accuracy of ENVI-met model in simulating the thermal effects was validated by two sets of measured data collected in a street during 09:00–15:00, using the indicators configuration as Table 2 bellow.

Table 2. Indicators Configuration Data of ENVI-met.

| No | Indicator            | Model Value                  |
|----|----------------------|------------------------------|
| 1  | Simulation date      | May 26, 2019                 |
| 2  | Starting time        | 09:00                        |
| 3  | Finishing time       | 15:00                        |
| 4  | Duration (h)         | 6 hours (9 am;12 pm;3 pm)    |
| 5  | Temperature (K)      | 308.95 K                     |
| 6  | Wind velocity (m/s)  | 6 m/s                        |
| 7  | Direction of wind    | 72 (East)                    |
| 8  | Relative humidity above 2m (%) | 80%                      |

2.3. Thermal comfort index

The estimating of the thermal conditions has completed by measure the Temperature Humidity Index (THI) from the information for every station. The THI is the thermal comfort indicator ratio advanced by Thom [21]. The THI can be examined in this study is based on equation 1 as follows:

\[ THI = 0.8 + \frac{T + (RH \times T)}{500} \]  

T represents the air temperature (°C) and RH (%) represents the relative humidity.

It is significant to consider that more current indicator is accessible and are has used in human thermal comfort appraisal; nonetheless, the restraint of the existing data as an outcome of convenient appliance defined the calculation of the thermal conditions to the use of the two parameters and as a result of THI. This restraint is noticeable in the human thermal comfort examination given worldwide. The predicted THI principles have classified according to the particular thermal perception category [22] as Table 3 bellow.
Table 3. Thermal sensation classes corresponding to THI range.

| THI range (°C) | Thermal Sensation |
|----------------|-------------------|
| 22-24.6        | Neutral           |
| 24.6-27        | Slightly warm     |
| 27-30          | Warm              |
| 30-34          | Hot               |
| >34            | Very hot          |

3. Results and discussion

3.1. Microclimate analysis

3.1.1. Microclimate temperature. Temperature increases in the three streets occurred from 09:00 to 12:00. The maximum temperature is a rise that occurred at noon. Then a decrease in temperature occurs starting from 12:00 to 15:00. Meanwhile, when viewed from a temperature distribution map, it can be seen that the younger the red color in the temperature distribution area, the hotter the temperature, while the more concentrated blue color at the temperature distribution area, the lower the heat. Furthermore, 12 (48%) of the streetscape cuts at noon shown that microclimate temperature at three streets reaches more than 30.48°C; when the other street cuts are diversified from 27,48°C to 30,48°C as figure 1.

Figure 1. Microclimate temperature maps at 9 a.m. and 12 a.m.

3.1.2. Microclimate relative humidity. Relative humidity is always inversely proportional to temperature, due to the evaporation process. It can be concluded from the results of the temperature analysis that the results of the simulation of relative humidity at 12.00 lower than at 09.00 and 15.00.

3.1.3. Microclimate wind velocity. Wind velocity has an influence on thermal comfort, which helps the convection of the heat process. Based on the simulation results, there was no change in wind speed flow in the three streets.

3.1.4. Thermal comfort analysis. This analysis was conducted to determine the level of comfort in the streetscape based on the distribution of microclimate Thermal Humidity Index (THI). The unit of analysis in the calculation of thermal comfort analysis is the street cuts in the streetscape that have been divided and numbered based on the temperature distribution at noon. The time of day was chosen
because of the occurrence of the sun's equinox point which caused a significant increase in temperature at 09:00 to 12:00 in the study area of Diponegoro, Polisi Istimewa, and Raya Darmo Street; then depreciation starting at 13.00. In Diponegoro Street, these streetscapes are divided into 11 street cuts, Polisi Istimewa Street divided into 3 street cuts, while in Raya Darmo, they are divided into 11 pieces as Table 4.

Table 4. Thermal Humidity Index (THI) and thermal sensation analysist.

| Place  | Code     | THI Range | Thermal Sensation | Analyst          |
|--------|----------|-----------|-------------------|------------------|
| East   | E1 (1-7) | > 34      | Very Hot          | Uncomfortable    |
|        | E2 (1-2) | 27 – 30   | Warm              | Moderate         |
|        | E3 (1-6) | 30 – 34   | Hot               | Uncomfortable    |
| West   | W1 (1-4) | > 34      | Very Hot          | Uncomfortable    |
|        | W2(1)    | 30 – 34   | Hot               | Uncomfortable    |
|        | W3(1-5)  | 27 – 30   | Warm              | Moderate         |

As can be seen in Table 4, the level of thermal comfort in Diponegoro Street at noon at the highest percentage of 90% is a cramped streetscape due to high temperatures and low humidity levels. Then the lowest percentage of 10% is three pieces of street cuts that included in the moderate criteria. This means that there are no street cuts included in the criteria for comfort in Diponegoro Street. The absence of comfortable spaces formed indicates that too high an increase in temperature that occurs during the day resulting in a drier microclimate in Diponegoro Street as figure 2 below.

![Figure 2. Thermal comfort analysist configuration maps.](image)

Based on Figure 2, the lowest percentage of street cuts in Raya Darmo and Polisi Istimewa included in the uncomfortable criteria with a percentage of 49%. There are 14 pieces of streetcuts in Raya Darmo that are uncomfortable for humans to do activities. While the remaining 51% or as many as 5 street cuts in Polisi Istimewa at 12:00 are included in the criteria moderate. It could be recognized that the duplication of air temperature be expressed by the deliberate of thermal comfortable. Hence, the previous study found that trees are inadequate in the depreciate of air temperature in arid area [23], they
also are inadequate in enhancing thermal comfort accomplishment in the rainforest tropical area, like in streetscape Surabaya.

4. Conclusion

Subjective of this study is to investigate the sans pareil streetscape configuration for creating thermal comfort public place in Surabaya. There are three study areas used as research objects. In the microclimate temperature analysis, there were 12 (48%) of the streetscape cuts at noon shown that microclimate temperature at these streets reaches more than 30,48°C; when the other street cuts are diversified from 27,48°C to 30,48°C. Meanwhile, the level of thermal comfort in Diponegoro Street at noon at the highest percentage of 90% is cramped streetscape due to high temperatures and low humidity levels. Then the lowest percentage of 10% is three pieces of streets that included in the moderate criteria. This means that there are no street cuts included in the criteria for comfort in Diponegoro Street.

Moreover, the lowest percentage of street cuts in Raya Darmo and Polisi Istimewa included in the uncomfortable criteria with a percentage of 49%. There are 14 pieces of streets in Raya Darmo that are uncomfortable for humans to do activities. While the remaining 51% or as many as 5 street cuts in Polisi Istimewa at 12:00 are included in the criteria moderate. Hence, the previous study found that trees are inadequate in the depreciate of air temperature in arid area [23], they also are inadequate in enhancing thermal comfort accomplishment in the rainforest tropical area, like in streetscape of Surabaya.

References
[1] Oke T R 1982 OF THE Q. J. R. Meteorol. Soc. 108
[2] Farhadi H, Faizi M and Sanaieian H 2019 Mitigating the urban heat island in a residential area in Tehran: Investigating the role of vegetation, materials, and orientation of buildings Sustain. Cities Soc. 46 101448
[3] Feyisa G L, Dons K and Meilby H 2014 Landscape and Urban Planning Efficiency of parks in mitigating urban heat island effect: An example from Addis Ababa Landsc. Urban Plan. 123 87–95
[4] Wai K, Tan T Z, Morakinyo T E, Chan T and Lai A 2020 Reduced effectiveness of tree planting on micro-climate cooling due to ozone pollution — A modeling study Sustain. Cities Soc. 52 101803
[5] Ng E, Chen L, Wang Y and Yuan C 2012 A study on the cooling effects of greening in a high-density city: An experience from Hong Kong Build. Environ. 47 256–71
[6] Akbari H, Cartalis C, Kolokotsa D, Muscio A, Pisello A L, Rossi F, Santamouris M, Synnefa A, Wong N H and Zinzi M 2016 Local climate change and urban heat island mitigation techniques – the state of the art 3730
[7] Sun C, Lee K, Lin T and Lee S 2012 Vegetation as a Material of Roof and City to cool down the temperature 461 552–6
[8] Hien N, Chen Y, Leng C and Sia A 2003 Investigation of thermal benefits of rooftop garden in the tropical environment 38 261–70
[9] Section S 2016 The Bigger, the Better? The Influence of Urban Green Space Design on Cooling Effects for Residential Areas 145 134–45
[10] Mathey J, Rößler S, Banse J, Lehmann I and Bräuer A 2015 Brownfields As an Element of Green Infrastructure for Implementing Ecosystem Services into Urban Areas 4015001 1–13
[11] Koch A F, Bilke L and Helbig C 2017 Compact or cool? The impact of Brownfield redevelopment on inner-city micro climate Sustain. Cities Soc.
[12] Klerkx L, Esch M Van and Baldiri T 2012 Resources, Conservation and Recycling How to make a city climate-proof, addressing the urban heat island effect "Resources, Conserv. Recycl. 64 30–8
[13] Bokaie M, Zarkesh M K, Arasteh P D and Hosseini A 2016 Assessment of Urban Heat Island Based on the Relationship between Land Surface Temperature and Land Use/Land Cover in
Tehran Sustain. Cities Soc.

[14] Shashua-bar L, Tsiros I X and Hoffman M 2012 Passive cooling design options to ameliorate thermal comfort in urban streets of a Mediterranean climate (Athens) under hot summer conditions Build. Environ. 57 110–9

[15] Hamada S and Ohta T 2010 Urban Forestry & Urban Greening Seasonal variations in the cooling effect of urban green areas on surrounding urban areas Urban For. Urban Green. 9 15–24

[16] Peel M C, Finlayson B L and Mcmahon T A 2007 Updated world map of the Köppen-Geiger climate classification 1633–44

[17] Prianto E and Setyowati E 2015 Thermal comfort of wood-wall house in coastal and mountainous region in tropical area Procedia Eng. 125 725–31

[18] Tan Z, Dong J, Xiao Y and Tu J 2015 A numerical study of diurnally varying surface temperature on flow patterns and pollutant dispersion in street canyons Atmos. Environ. 104 217–27

[19] Tsutsumi H, Tanabe S ichi, Harigaya J, Iguchi Y and Nakamura G 2007 Effect of humidity on human comfort and productivity after step changes from warm and humid environment Build. Environ. 42 4034–42

[20] Aminipouri M, Jensen A, Krayenho E S and Zickfeld K 2019 Urban Forestry & Urban Greening Modelling the impact of increased street tree cover on mean radiant temperature across Vancouver’s local climate zones 39 9–17

[21] E. C. THOM 2010 The Discomfort Index 37–41

[22] Nieuwolt S 1982 Agriculture and Environment, 7 (1982) 135--148 Agric. Environ. 7 135–48

[23] Aboelata A 2020 Vegetation in different street orientations of aspect ratio (H/W 1: 1) to mitigate UHI and reduce buildings’ energy in arid climate Build. Environ. 172 106712