The Effect of Building Layout on Microclimate Characteristic in Settlement Area

Christian N Octarino

1 Department of Architecture, Universitas Kristen Duta Wacana, Jl. Dr. Wahidin Sudirohusodo No. 5-25 Yogyakarta, Indonesia

Abstract. Housing is one of human’s primary need, then it has an important role on human life. Not only the building, but also the environment of settlement. People need to have a good quality of settlement area, one of which is microclimate quality to provide health and comfort in living. As a tourism and education city, Yogyakarta has a rapid development which indirectly resulted in increased housing needs. In the era of climate change, it’s very important to consider the environmental aspects in regional planning, including the settlement area. This study aims to determine the characteristics of the microclimate in two different settlement typologies in the city of Yogyakarta. The difference is on the building layout, which is one of the factors that influence microclimate. The study was conducted in two districts, one is settlement in Baciro that represent planned settlement, and settlement in Suryatmajan to represent unplanned settlement. Direct measurement and observation used as a method, supported by simulation with Envi-Met software. The result will show how the building pattern can affect microclimate, so it can be considered in settlement development that can improve the quality of people’s life and also the environment.

1. Introduction

As one of the main tourist destinations and also known as student city in Indonesia, Yogyakarta attracts many people to come. The city has a rapid development on infrastructure, which led to increase the need of housing. At present, the phenomenon of climate change and global warming is a global concern, proving that environmental quality is declining. One factor that is believed to be the cause of environmental degradation is the development of infrastructure. Settlements become one of the areas that develops rapidly along with urban growth. The quality of settlement area will give a direct impact to the people who live inside. To be able to have good activities humans need certain physical conditions around them that are considered comfortable [1]. One of the comfort factors for humans is thermal comfort, both indoor and outdoor. Related to outdoor thermal comfort, it is important to consider the quality of microclimate. This study will be focused on microclimate in settlement area.

As a City with strong culture and history, Yogyakarta has a various typology of settlement. There are 5 elements forming settlement, namely nature, man, society, shell, and network [2]. These elements can be divided into two main factors, that is physical and non-physical factors [3]. Physical factors consist of geographical aspects, such as topography, climate, etc. Then non-physical factors related to social and cultural aspects of the local. Basically, in the term of physical factors Yogyakarta can be divided into two types, settlements that are planned and unplanned. Unplanned settlements will certainly lead to
the typology of the “kampung” settlement. Kampung Suryatmajan is one example of urban kampung that exist in the middle of the Yogyakarta city. Named by prince KRT Suryoatmojo, this kampung located in a very strategic area in the downtown of Yogyakarta, along to Malioboro on the west side and Code river on the east. Meanwhile, Baciro District will represent the planned settlement area. This area is known for its livable and comfortable environment even though it is located in the city center. Basically, this study aims to identify microclimate characteristic from both typology of settlement. The main focus is on building layout, which makes the difference between the two-settlement area. Building layout is one of the physical elements of outdoor space that can affect the thermal environment. Therefore, in settlement area planning, we need to pay more attention to the shape, dimensions, and spacing of the buildings [4]. About microclimate in the urban area, it will be related to urban heat island phenomenon. Urban heat island (UHI) is the condition that represent higher air temperature in the city center, compared to surrounding area. The main factor that cause UHI is urban infrastructure, which is dominated by dense building and less vegetation [5]. Generally, UHI factors divided to controlled factors (infrastructure, material, open space, etc) and uncontrolled factors (season, climate, weather, etc). Building layout included in factors that can be controlled by human, so that it is necessary to identify how the building layout effect the microclimate.

This study utilizes software simulation method using ENVI-met. ENVI-Met is a modelling tool of computational fluid dynamics (CFD), evaluating some relevant meteorological parameters. This software allows us to conduct simulation on microclimate based on physical elements as an input data, such as building mass, surface materials, and vegetation. Although it has limitation in coverage area to simulate, the use of this software still can provide the appropriate information about characteristic of microclimate in specific area.

2. Research Methodology

This study is divided into three phases: preparation, observation, and analysis. Analysis phase carried out with ENVI-Met software, to identify microclimate in the specific area. This software will take consideration about the interplays between building, surface, and vegetation as microclimate factors [6]. Data input is obtained through observation phase by both aerial image and direct observation. The data used as input are as follows: Building pattern, ground cover material, and vegetation. Output from the simulation process are data related to atmospheric such as temperature, humidity, also wind speed and direction. The data will be linked to physical factors in both settlements, so that a correlation can be found between the physical elements of the area, especially the pattern of building mass, and the quality of the microclimate formed.

As mentioned in the background, this study take place on two settlements in Yogyakarta, that represent planned and unplanned settlement. The settlement in Baciro, Gondokusuman, has a planned building layout and also represent a good environment although located in the city center. In addition, this area is also included in one of the heritage areas proposed as a cultural preservation. This study take place on an area consists of several cluster of building, separated by the road. The area is approximately 2 hectares, and considered to represent the overall settlement with the open space inside.

![Figure 1. Location of the case study](image-url)
The second location that represent unplanned settlement is Kampung Suryatmajan, Danurejan. There is no clear border inside the settlement, shows unplanned housing development. As an urban kampung, the people still maintain the spirit and culture of kampung living in the middle of urban living. Interesting to explore about performance of the environment to provide an adequate place to live.

3. Results and Discussion

Baciro settlement area is one of the residential areas in the middle of the city with a fairly green environment, can be seen from the amount of vegetation that exists. Some of them is a big tree with a wide shade, that can provide convenient shading for the settlement. Basically, there is no certain building pattern and layout like found in the modern residence, but they spread in clusters separated by circulation paths in the form of asphalt roads. Most of the building are residential function, with 1-2 floors height, dominated by tropical houses typology. Circulation path is a roadway with approximately 3-3.5 m width, covered with asphalt material.

![Figure 2. Observation data of Baciro settlement](image)

Meanwhile, Suryatmajan settlement area represent the characteristic of kampung-typology settlement, although located in the middle of the city. Each building has an adjacent position, with the narrow street as circulation path that exist between buildings. Not too much vegetation exists in this area, but the surface shading is quite wide due to the narrow distance between buildings. Circulation path is approximately 1.5 - 2 m width, covered by paving and only possible to crossed by motorcycle. There are no clear boundaries for pedestrians, in fact there are no clear boundaries of land ownership, which is one of the characteristics of Kampung settlements.

![Figure 3. Observation data of Suryatmajan Settlement](image)

Based on observation, it can be known that there are significant differences between the two settlements, namely:

1. Different building layout
2. Circulation path has a difference about width, material, and uses
3. Variety and size of vegetation

The next phase is microclimate analysis with ENVI-Met. To run simulation with ENVI-Met there are two main steps. The first is using existing data, both physical and climatic data, as simulation input. The physical elements of the study area are modelled based on observation. For this task, one needs the horizontal and vertical dimensions of the architectural environment along with any specific design features such as open breezeways, overhangs, horizontal surface materials, ground cover, vegetation size and coverage, etc. [7].

For regional climate data input, this study used published data from Statistic of Yogyakarta Municipality (BPS). Based on Yogyakarta Municipality in Figures 2018, the average temperature is maximum 34°C and minimum 22°C, the average wind speed is 1 m/s, from the southeast side.

The second step is running the simulation and then visualize with LEONARDO. In this case, the discussion of the simulation output data will focus on the comparison of temperature, wind movement and also wind speed between the two settlement areas. The simulation is carried out in the time range of 1 pm – 2 pm, assuming the time with the highest temperature on the day.

![Figure 4. Modelling area on ENVI-Met for Baciro Settlement (left) and Suryatmajan Settlement (right)](image)

In Baciro settlement, as seen in figure 5, there is a various kind of temperature data on several nodes. It discovered that inside building cluster the temperature is lower, about 30 - 31°C. Meanwhile, along the circulation path showed highest temperature among the area, reach more than 32°C. This indicates that surface material has a significant influence on air temperature. Asphalt material contained in the circulation path is known to have a small albedo value (about 0.1) so that the solar absorption is quite high. The lower temperature inside building cluster is caused by the density of building mass, that minimize the solar heat reaching ground level. Moreover, ground cover material in this area are dominated by softscape material, such as soil and grass, so the heat absorption is low.

The combination layout between building cluster and open spaces also has an impact on wind movement. Simulation result indicate that the open space has higher wind speed, about 0.9 – 1.1 m/s, then inside building cluster the wind speed is only below 0.5 m/s. The dense of building cluster caused the air flow spread and reduce the wind speed.
Simulation results in the Suryatmajan settlement area show relatively similar temperatures throughout the section (as seen on figure 6). The difference is not too significant, just in range of 30-31°C. With the similar character of physical elements, such as typology of building mass layouts that are dense for the entire region, then the conditions of the microclimate formed also tend to be minimal variations. Building density causes the ground surface to be shaded by the height of the building. In addition, there is no large open area that is directly exposed to the sun, so the air temperature in the area is evenly distributed in all section. The temperature difference is only found in the eastern side of the residential area, which is side by side to the Code River.

Wind speed in Suryatmajan settlement is quiet low. Although there is a high flow from the east side, but the density building mass make it spread and decreases the speed. Simulation results show the wind speed inside the settlement area is not more than 0.6 m/s.

Through this data, it can be seen that the two settlement have a common average temperature with a slight difference (just about 1°C). Temperatures in Bacro settlements are more variable at several points, compared to Suryatmajan settlements which are relatively evenly distributed throughout the area. This happens because of the higher variation of surface material, so that it also influences temperature. As known, each material has certain thermal properties (such as albedo, emissivity, and thermal storage) that can affect the thermal environment [8]. As for the Suryatmajan area, air temperatures tend to be stable and evenly distributed at all points. This is due to lack of material variations in the surface.

Differences are also found in the simulation results related to wind speed and wind movement. The open space contained in the settlement of Bacro causes faster movement of wind, in addition to the wide circulation of the road is also become a breeze way in the area.
Regarding the thermal comfort of outdoor space, conditions in the area will be observed using the Tsp (Thermal Sensation Perception) comfort index proposed by Monteiro and Alucci (2009). Although used in sub-tropical climate case, this index is considered quite close to the criteria in locations with humid tropical climate [9]. The Tsp index calculation uses the following equation:

\[
Tsp = -3.557 + 0.0632 \cdot t_a + 0.0677 \cdot t_{mrt} + 0.0105 \cdot RH - 0.304 \cdot V
\]

- \( t_a \) = air temperature
- \( t_{mrt} \) = mean radiant temperature
- \( RH \) = relative humidity
- \( V \) = wind speed

The Tsp index uses a scale of 3 (very hot), 0 (comfortable), and -3 (cold). Based on the simulation results in both locations, it is known that the average data is air temperature of 30°C, average radian temperature of 58°C, relative humidity of 55%, and wind speed of 0.6 m/s. Using the previous equation, the index will be on 2.6. This means that during the daytime conditions in both locations are still classified as uncomfortable. However, the level of thermal comfort in outdoor space is declared to have a wider tolerance than indoor. For humid tropical climate comfort can be in the range of 27.5°C - 32.5°C at 50-75% humidity with low-speed winds [10].

4. Conclusion

Based on observation and analysis, the following conclusions are obtained:

1. Two settlements with different building layout typologies apparently did not have a big difference in terms of the average air temperature. The simulation results on both settlements show the average temperature is at 31°C.
2. Shading is a factor that affects microclimate conditions [11]. In Baciro, shading is created by the presence of large trees in the Zone. While in Suryatmajan, shading is formed from the dense existing buildings, thus minimizing radiation reaching the surface.
3. The main difference between the two Regions is the variation of spatial pattern and ground cover material. In the Baciro settlement there is an open space and also a wide circulation path that causes variations in surface temperature. This also affects the movement of wind in the area. Whereas in Suryatmajan there is no variation in the spatial pattern so that the temperature is almost the same in every area and lack of wind movement.
4. Based on the calculation of the outdoor comfort index, the two locations are still classified as an uncomfortable condition.

Generally, it can be concluded that a settlement area needs to create variations on spatial patterns, between building and open space. This aims to create a pathway for air movement so the air change will be better. The existence of green open space is an approach to create an ecological and comfortable settlement for residents [12]. In term of climate change phenomenon, good air quality in the outdoor space also improve indoor air quality to maintain people’s health and building energy efficiency, which aims to achieve a comfortable, eco-friendly, and sustainable environment.

The analysis in this study still has several limitations, one of which is ENVI-Met software has a grid-style area in modelling interface. This makes it quite difficult to get the real shape and orientation of the original building, especially if the condition of the building is very dense. Thus, it needs to be enriched with the results of field measurements as a comparison from simulation data. Moreover, this study limits the analysis only on the physical aspects of the environment. Subsequent studies can reach more about activities and social aspects, considering that different types of human activities will also affect the quality of the urban environment [13].
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