The Study of Thermal Comfort in Transforming Residential Area in Bandung using ENVI-met Software. Case Study: Progo Street

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Abstract. Bandung has a high potential in attracting tourists. This potential impact on building function near tourist attraction that can transform residential uses into commercial uses. Progo Street and its surrounding area used as the case study, which is close to Gedung Sate and Riau Street as tourist destinations in Bandung. Moreover, this transformation is also reinforced by the spatial planning policies in Bandung, known as RTRW and RDTR, said that this area will be fully non-residential area. This condition in some cases could affect thermal comfort. This paper provides the changes of thermal comfort phenomenon that occurs using EnviMet software. The study compares Predicted Mean Voted (PMV) as thermal comfort indicator between existing and Bandung detailed spatial plan (RDTR) condition. The result shows that the PMV value of current condition is higher than future planning, nonetheless the planned area will be changed into higher non-residential buildings and less greeneries. Some environmental factors that are used to calculate PMV such as air temperature, mean radiant temperature, humidity, and wind speed are also examined to find out what makes the plan more comfortable than the existing. Simulations using ENVI-met software could be considered in making more objective planning policy in the future.

1. Introduction
Bandung city development as one of tourist destinations in Indonesia has encouraged the provision of additional facilities to accommodate the tourists or visitors, both from other cities and from abroad. Data from the Central Bureau of Statistics (BPS) shows that there is an increase number of tourists visiting Bandung and has reached its peak in 2011 with more than 6.7 million people. This phenomenon encourages the transformation of building functions or land uses from residential uses into commercial uses in some strategic corridors. Irregular city growth could make each area within the city develops based on the economic potential that can generate the area. As a result, space for development is getting bigger and wider to accommodate the needs of the visitors. This growth will affect the microclimate of the region, for example more pavement areas for car parking in commercial use will give an increase temperature in the area. The phenomena of Urban Heat Island (UHI) is a result of city development that modify the regional atmosphere situation [1] and not considering the capacity of the environment. To overcome its negative impact, it is necessary to study the area on achieving thermal comfort, which can be affected by several factors such as air temperature (Ta), humidity, level of radiation (Tmrt), and wind speed.
This study proposes an engineering approach that discovers the level of thermal comfort in a transformed residential area in Bandung, so it can be the information base on how the spatial plan can be used to make better space.

2. Case Study

Area between Gedung Sate building as one of tourist destinations in Bandung and LL RE Martadinata Street (known as Riau Street) is used as case study area, particularly Progo Street and surrounding area.

Progo Street is used to be a residential district in the colonial era, which has similar architectural style for all buildings along the corridor – one floor villa type with green terrace and innercourt. It is the second layer street after Riau Street, which serve as primary collector road, and parallel with Cimandiri Street in the North of the case study area. These streets have the same orientation, West-East, but different land uses and road width.

![Figure 1. Current Condition of Progo Street, mixed of residential plots and commercial uses along lush corridor.](image)

Nowadays, Progo Street and its surrounding area has gradually transformed. Some of the land uses have changed from residential to commercial, building height become higher, façade design began vary, and green terraces become pavements for parking lots. Although the area partly altered into commercial uses and become more public, the infrastructure is not supported yet with pedestrian path along the streets. Moreover, the streets are more crowded with vehicles that parking along the street, since the parking space inside the lot is limited. However, this area is mostly still has lush trees that give shades and comfort.

2.1. Planned

To find out the comparison on how comfort the area of the case study, this research uses the Detailed Spatial Plan (draft) of Bandung City 2015, known as RDTR, for simulation. By simulating the spatial plan, elements or factors for consideration in making ke plan in the future can be found.

![Figure 2. Spatial Plan Map of Cibeunying District with enlargement map of case study area, from Draft Detailed Spatial Plan (Rencana Detail Tata Ruang - RDTR) of Bandung City 2015.](image)

In RDTR, it can be seen that the case study area will be mostly commercial uses, facilities, and offices. No more residential uses within the area.
From the spatial plan, information about Building Coverage Ratio (BCR), Floor Area Ratio (FAR), Land Uses, and Setback are taken from the document for simulation.

2.2. Development Changes
There are several differences between the existing condition of the study site and the projected/detailed spatial plan. The most significant change is the building configuration and intensity. Based on Draft Detailed Spatial Plan document, the buildings along Progo Street will be higher than current condition, with average about 3 floor height (based on calculation of Building Coverage Ratio and Floor Area Ratio taken from Detailed Spatial Planning of Bandung 2015). Moreover, the building coverage is maximized on the first floor without expanded over the setback.

![Figure 3. 3D Illustration and land material plan of case study area with 2 conditions: current condition and based on future plan (RDTR), created using EnviMET software.](image)

Second change that can be seen from Figure 3 is the material in front of the buildings, which is changed into pavement (light grey) and concrete (dark grey). This is to accommodate the parking area in front of the commercial uses.

In this study, the trees are kept the same for both plan, the building material is also assumed to be the same since the simulation is taken in wider or urban context.

3. Thermal Comfort Assessment Using Envi-Met Software
In several research or studies, thermal comfort assessment is usually associated to ENVI-met software. One of the studies has been conducted by Kurniawan and Gao [2], where the thermal comfort of urban open spaces in tropical city (Jakarta) was assessed using this software. ENVI-met Simulation Software itself is a three dimensional computer model that can evaluates environmental conditions, especially related to thermal condition in urban context [3]. Microclimate and air quality in open spaces and urban structures will be calculated with this software, consisting of dozens of dynamic subsystems ranging from atmospheric dynamics, over soil physics, vegetation response, to building indoor climate. Among all environmental factors that analysed in this software, Predicted Mean Voted (PMV) will be the main factor used as thermal comfort index.

3.1. PMV
Predicted Mean Voted (PMV) can be obtained from ENVI-met simulation result and used as thermal comfort index. It is one of the most widely used thermal comfort index nowadays. In ENVI-met software, PMV is calculated from personal factors (metabolic rate (met) and clothing insulation (clo)) and environmental factors (air temperature (Ta), radiant temperature (Tmrt), air velocity, and relative humidity).
The thermal scale for PMV based on Fanger’s thermal comfort model (1972), range from Cold (-3) to Hot (3). This comfort sensation scale is also adopted as an ISO standard, particularly in ISO 7730 [4]. If the result is out of the range, the area will be considered as uncomfortable zone and need to conduct further study to make the area more comfortable.

![Aerial Satellite View](image1)
![CAD Map](image2)
![Area Input File to the ENVI Met](image3)

**Figure 4.** Images of the selected area: (1) aerial satellite view picture; (2) CAD map of building footprints including trees and their type of height; (3) Input file images for EnviMet simulation, based on the aerial satellite view pictures. Source: Google Maps, GIS Map, and EnviMet

4. METHODOLOGY

As shown in Figure 4, the selected area in Progo Street and its surroundings is traced from aerial satellite view (Google maps) and defined through CAD map. The map then digitized on EnviMet software with 90 x 90 grids of 5 m resolution, so the model represented 450 x 450 m² of the selected area for study. The buildings are assumed have the same material but different heights, in accordance with the existing and future plan. Meanwhile the ground surface is mostly covered by asphalt road, except the area in front of the buildings within the plots. The trees are also mapped with various heights and diameters.

The simulation conducted on June 21st, one of the typical hottest day in Indonesia, between 1am and 12am (24 hours).

As can be seen in Table 1, the initial condition of simulation into 4 parts: basic settings, meteorological settings, soil temperature, and PMV settings. The basic settings contain information regarding the time and location taken for simulation, while meteorological basic settings represent the real condition of the existing location.

To calculate the PMV model, or known as biomet model in EnviMet, some information about personal parameters should be set first, as the energy balance of human body is related to the personal comfort to surrounding environment.

| Basic Settings          |
|-------------------------|
| Boundary Model          | 450x450 m |
| Grids                   | 90x90     |
| Simulation Date (DD.MM.YYYY) | 21.06.2017 |
| Start Simulation at Time (HH:MM:SS) | 06:00:00 |
| Total Simulation Time in Hours | 23        |
| Save Model State each 60 min | 60        |

| [Meteorology] Basic Settings |
|-----------------------------|
| Wind Speed in 10 m ab. Ground [m/s] | 3.12 |
| Wind Direction (0=N, 90=E, 180=S, 270=W) | 200 |
| Roughness Length z0 at Reference Point | 0.01 |
5. Results

As the main factor for thermal comfort index that considered in the study, the distribution map of PMV values for both existing condition and based on spatial plan are presented in Figure 5. It can be seen that at first glance there is no significant changes, even though the building layout considerably changed. To some points, the decline of PMV value occurred from above 4 to lower than 4. To be more exact, Figure 6 presents the comparison of PMV value composition between two conditions. It shows that in general the future plan has lower PMV index (more comfortable) than current condition. Nevertheless, overall result in both conditions are not in an ideal comfort zone as most of the area have value over than 3 – more than ideal thermal comfort range.

To find out the cause of the lower value, the environmental factors of thermal comfort have been analyzed through the same simulation software. In Figure 7, it shows the air temperature of current condition in several area are higher than in Detailed Spatial Plan, particularly on Progo Street and Riau Street, with 1-20 C difference. This trend is also proved in Figure 8, where air temperature in existing condition mostly higher than in Detailed Spatial Plan in a day (23 hours).

Figure 9 shows the simulation result of mean radiant temperature (Tmrt). In general, there is no significant changes of the Tmrt, but the temperature range in Detailed Spatial Plan (36.1-66.6oC) is lower than in current condition (37.3-67oC). More clearly can be seen in Figure 10, the radiant temperature level between both conditions has a gap during the day (10am-2pm).

Meanwhile from Figure 11 and Figure 12, relative humidity in Progo Street and its surroundings generally decreased. During the day, the humidity for both conditions are comparatively the same, but at night the future plan has less humid compared to the existing condition.

Wind speed as the last environmental factor also simulated with the result in Figure 13. Similar trend with the other factors, wind speed in Progo Street and its surroundings will be decreased in the future, with 1 m/s in average. The gap is clearly wide, although the future plan has higher buildings than now.

Although the future plan has higher buildings, more building area, and less green surfaces, they do not affect the thermal comfort. However, the future plan is still need to be reviewed since the overall PMV value is still over the thermal comfort standard.
Figure 5. PMV Simulation for current condition and Detailed Spatial Plan

Figure 6. Comparison of PMV Value on Progo Street and surrounding Area (at 1pm)

Figure 7. Air Temperature simulation result for current condition and Detailed Spatial Plan
Figure 8. Diurnal air temperature change at human height level (1.5m) on a typical hottest day, from 1 am to 11 pm on June 21st.

Figure 9. Mean Radiant Temperature (Tmrt) simulation based for current condition.

Figure 10. Diurnal mean radiant temperature change, from 1 am to 11 pm on June 21st.
Figure 11. Relative Humidity simulation for current condition and Detailed Spatial Plan

Figure 12. Diurnal relative humidity at human height level (1.5m) on a typical hottest day, from 1 am to 11 pm on June 21st

Figure 13. Wind Speed simulation for current condition and Detailed Spatial Plan
6. Conclusions
Overall, the thermal comfort index values (indicated by PMV value) on both existing and planned conditions of Progo Street and surrounding area are over the standard index for hot humid climate countries. Although there are a lot of lush trees and relatively low height buildings, the thermal comfort is still not reached yet.

Compared to each other, the existing condition has higher thermal comfort index values than the projected condition. Based on this research and literature study, it is clearly seen that several factors such as building heights, building area or configuration, and terrace materials have an impact to the thermal comfort.

This research has collected limited data to find out more exact and objective causes of the high thermal comfort index. If more accurately variables and causes can be gathered through other research methods, factors for considerations on making spatial planning policy can be determined. Therefore, further research is needed.

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8. References
[1] Kuttler, W. 2010. Urban climate, Part I. Gefahrstoffe – Reinhaltung der Luft, 70(7/8), pp 329–340.
[2] Koerniawan, M. D., Gao, W. 2014. The Simulation Study of Thermal Comfort in Urban Open Space of Commercial Area Using EnviMet Software, a conference paper, January 2015.
[3] Wang, Y., Akbari, H. 2016. The Effects of street tree planting on Urban Heat Island mitigation in Montreat. Journal of Sustainable Cities and Society, 27: pp 122-128
[4] ISO 7730. 1994. Moderate Thermal Environments – Determination of the PMV and PPD Indices and Specification of the Conditions for Thermal Comfort. International Standard.
[5] Fanger, P.O. 1972. Thermal comfort. Analysis and applications in environmental engineering. New York: McGraw-Hill
[6] Bandung Local Regulation no. 10 of 2015 about Detailed Spatial Planning of Bandung 2015-2035. Spatial Planning Department of Bandung.
[7] Central Bureau of Statistics (BPS). 2017. *Jumlah Wisatawan Mancanegara dan Domestik di Kota Bandung*, 2016. Cultural and Tourism Department of Bandung.