Spatial Configuration of Optimization Model at Fort Oranje Area in Ternate City to Create Thermal Comfort

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Abstract. Ternate's geographical condition as a coastal city with a volcanic mountain and on the equator makes this city potential for the phenomenon of urban heat island. This condition causes the air temperature in Ternate to be quite hot around 26-34°C. Consequently people feel reluctant to conduct activities in the public space during the day. This situation occurs at Fort Oranje public space area, where people visiting this place are not so crowded. It occurs because thermal condition is inconvenient for people to conduct any activities. This research aims to optimize the configuration of both the building and vegetation space to obtain a convenience thermal condition at Fort Oranje. The method used empirical measurement and modelling/simulation (engineering of area) using Envi-MET software. This method was used to conduct a simulation of thermal optimization at Fort Oranje. The results indicated that the engineering of spatial configuration with the intervention on the building by utilizing the vent and the use of vegetation could improve thermal comfort at Fort Oranje compared to the existing condition.

Keywords: thermal comfort, space configuration, urban public space, Envi-MET.

1. Introduction
Thermal comfort at Fort Oranje public space in Ternate is quite impossible to be created with solid building mass configuration minimum vegetation. Solid building mass configuration causes uneven wind movement patterns, so that it increases air temperature and decrease humidity, therefore it cannot create thermal comfort [1]. Thermal comfort in outdoor area will affect the townspeople to conduct outdoor activities [2]. Urban microclimate causes specific changes such as slowing down the wind speed or storing solar radiation by the construction material used [3]. To control the rate of increase in temperature, people must pay attention to the duration and intensity of sun exposure as well as the sun angle [4]. In addition, air movement is also very helpful in controlling the existing temperature. This is a parameter caused by building and environmental interaction [5]. Considering these parameters, thermal comfort in the urban public space is possible to be created. Monitoring the thermal comfort is an indicator for identifying the environmental condition in the area [6]. This research aims to optimize the configuration of both the building space and vegetation to create thermal comfort in the Fort Oranje public space area.
2. Methods
The study focused on the optimization by engineering Fort Oranje area that was divided into several area models according to the study variables to see the effect on thermal comfort and Fort Oranje public space area sustainability. This study used experimental method with the simulation using computer application and field measurement. Simulation was a controlled study method in real context with the purpose of studying dynamic interaction in an arrangement [7]. There were three simulation processes, i.e.:

1. Empirical measurement, to show thermal condition and thermal analysis result using data that measured on site with specific measuring instruments.
2. Simulation used ENVI-met system software to determine the effect of existing space arrangement on thermal condition.
3. Optimization simulation with space configuration engineering using ENVI-met software to the better thermal comfort condition.

3. Discussion
The analysis process of Fort Oranje thermal comfort was conducted through some stages:

1. Making changes to some Fort Oranje areas according to the research variable (space variable), namely vegetation and building to achieve optimal thermal comfort in the area.
2. Making models (3 models) of the area according to the space variable (building and vegetation).
3. Conducting an analysis of thermal condition in each model using a micro-climate simulation model with ENVI-met software system with fixed climate data (measurement result) as in the simulation of the existing condition. Simulation data of each model was taken to represent the 3 different times morning, noon, and afternoon.
4. Analysing the Fort Oranje Area Model Optimization Simulation

3.1. Analysis of Fort Oranje Area Model Optimization Simulation
The analysis was performed on the elevation of 1.20 meters with the assumption that in this elevation the user will strongly experience the thermal comfort. The climate data used for the simulation was fixed meaning that there was no change in climate data in the existing model simulation or the three models created.

The optimization simulation was conducted using ENVI-met system software to determine the effect of spatial configuration change (which was divided into 3 models) on the thermal condition of Fort Oranje area and to obtain a better thermal comfort compared to the existing condition. Using the optimization simulation, it is discovered that there is a relationship between the spatial configuration and area microclimate. Spatial configuration at Fort Oranje area is various and it appears on the different existing thermal comfort.

Optimization simulation was conducted with the consideration that the area:

1. Has a high building density
2. Lack of vegetation in the area

The condition above allows the set of spatial based on the variables of the building and its vegetation so that there are changes in the thermal variables. The simulation was conducted on 4 created models using ENVI-met Eddi, namely:

1. Existing Model, this model represents the existing condition of Fort Oranje area without making any changing to its variables.
2. Model 1st (Vegetation), this model is Fort Oranje model with a setting/change on the one of the spatial configuration variables namely vegetation. The change in this model includes adding trees (see figure 1. number 1,2,3,4 & 6) and grass (see figure 1. number 5) in certain areas based on the result of the existing simulation.
3. Model 2nd (Building), this model is Fort Oranje model with a setting/change on the one of the spatial configuration variables namely building. The change in this model includes making a wind tunnel (see figure 1 number 2) and set back the building that is close to the road (the building uses an arcade).

4. Model 3rd (Vegetation and Building), this model is a combination of model 1 and 2. The changes were performed to the two space variables, namely building and vegetation (see figure 3.). The building changes in this model are indicated in figure 3. numbers 3 and 8, while the changes in vegetation are indicated in figure 3. number 1,2,4, & 5 (trees) and figure 3. number 6 for grass.
3.2. **Thermal Comfort Analysis on Fort Oranje area Model 1st**

The change performed in this model was by adding vegetation to the area as previously explained (see figure 1). After simulating the model 1 using the ENVI-met system, and there was a change in the temperature and humidity in the area changed (see figure 4). The temperature condition in the morning (at 9:00 a.m.) clearly indicated a decrease in the corridor area with trees, indicated by the colour changing in the visualized simulation result (see figure 4, temperature, figures 1,2,3,4 & 6). The area in Fort Oranje did not indicate any significant changes (see figure 4, temperature, number 5 at 9:00).

The decrease in the temperature was also followed by humidity increase. Humidity increase is clearly indicated in the front area of Fort Oranje (see figure 4, moisture, number 6).

During the day (at 1:00 p.m.), the difference in temperature and humidity between the existing model and model 1 was clearly visible. The air temperature in the existing model looked high (see figure 4. Existing temperature, number 1,2,3,4,5 & 6) but different condition was indicated in model 1, where at the same time the model 1 air temperature was lower than the existing condition (see figure 4, temperature model 1, number 1,2,3,4,5 & 6). This condition also occurred in the humidity, where at the same time the humidity of model 1st was higher than the existing condition (see figure 4, humidity, number 5 & 6). The temperature and humidity condition in the afternoon (at 4 pm) were not much different from the morning and noon, in which the temperature condition was lower than the existing condition and the humidity was higher than the existing condition.

Wind movement in the existing area and model 1 was not much different. This appears in some areas intervened (see figure 5, number 1,2,3, & 4). However, different condition occurred in the inner and front area of Fort Oranje (see figure 5, figure 5 & 6) in which the wind speed was lower than the existing condition. This situation occurred because the added vegetation reduced the wind movement passing through it (see figure 10, existing and model 1st).
Figure 4. Result of Temperature and Humidity Existing and Model 1st
3.3. Thermal Comfort Analysis on Fort Oranje area Model 2

In this model, the intervention was conducted only in 2 areas (as indicated in Figure 2). The intervened variable was the building whereas the vegetation was the same as the existing condition. Climate data used for the simulation was the same as the existing condition and model 1. Based on the simulation, in the morning (9 am) the temperature change occurred in the area (see figure 6, temperature, number 1 & 2) was not significant, but if it was compared with the existing condition, the air temperature in model 2 was lower than the existing condition. Temperature changed was evidenced during the day (at 1 pm) where the air temperature in the area with the intervened building mass was lower than the existing condition. In addition, the changes made in the area affected the temperature decrease around it (see figure 6, temperature, number 1 & 2). This condition was caused by the unobstructed wind movement as it passed through the changing area. As in the morning and noon, in the afternoon the condition of air temperature in the existing model was higher than the model 2 (see figure 10, existing & model 2).

The decrease in temperature was followed by increase in humidity. From the three times, only during the day where the condition of air humidity in model 2 was clearly seen as higher than existing condition (see figure 6, humidity, number 1 & 2). The wind movement area that experienced change in its building mass was more dynamic than the existing. Here, the moving wind could go through wide road corridors, and the existing condition did not allow the wind to move freely through the road corridor because the building was too close to the road. The buildings that were too close to each other also affected the wind movement through the area. (see figure 7, item 1 and picture 10 of existing & model 2). The existence of corridor that cut the direction where the wind came (see figure 7, number 2) greatly affected the wind movement to the public space of Fort Oranje because the wind that moved toward the area was blocked by the existence of the buildings on the side of the corridor. With the creation of wind tunnel in a building, the wind could move through the space without move up to pass the building (see figure 7, number 2 and figure 10, existing and model 2).
Figure 6. Result of Temperature and Humidity Simulation Existing and Model 2
3.4. Thermal comfort analysis on Fort Oranje area model 3

This model is a combination of model 1 and model 2. Changes were made to both space variable namely building and vegetation (see figure 3). Change in spatial configuration affected the decrease in temperature and increase in humidity in the area. Temperature changes occurred in all changed areas. This condition was clearly seen when compared to its existing. Significant air temperature changes occurred during the day (at 1 pm) (see figure 8, temperature, number 1, 2, 3, 4, 5, 6, 7 & 8). The addition of grass (see figure 1, model 1 number 5 and figure 3, model 3 number 6) at Fort Oranje that served to reduce the area exposed to direct sunlight could decrease air temperature at Fort Oranje (see figure 8, number 6). The decrease in air temperature was directly proportional to the increase in air humidity in the changing area (see figure 8, humidity, 1, 2, 3, 4, 5, 6, 7 & 8). As with air temperature, significant increase in humidity occurred during the day (13:00).

Wind movement occurred in this model also experienced change. In certain areas the wind speed increased, (as indicated in Figure 9, item 3). This increase was caused by the changes in building mass by creating arcades in the building. In addition, there was a decrease in the wind speed (see figure 9, number 7). This was due to the existence of trees added to the area that reduced the wind speed passing through it (see figure 10, model 1 and model 3).
Figure 8. Result of Temperature and Humidity Simulation Existing and Model 3rd
Figure 9. Result of Wind Speed Simulation Existing and Model 3rd

Figure 10. Wind Speed Existing, Model 1st, Model 2nd and Model 3rd
Figure 11. Air Movement of the Fort Oranje Area

Figure 12. Wind Movement Existing, Model 1st, Model 2nd, and Model 3rd
In conclusion, based on the simulation with the three models, the intervention on the building by adding the existing ventholes (see Figure 11, building intervention signs with red lines) could improve thermal area because wind movement was not hindered by the building.

4. Conclusion
The spatial configuration affected the thermal comfort of the Fort Oranje area, where the distance between buildings reduced the wind speed, increased temperature and caused low humidity. Excellent materials that increased and reflected heat from direct sunlight as well as the building height that blocked the wind movement dominated condition of the surface area. The presence of vegetation could block direct light from the sun to the surface of these materials also affect the condition. It could also reduce heat and maintain moisture in the urban spaces.

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6. References
[1] Muhammad A, Marasabessy F, Kusumawanto A, and Nareswari A 2017 The effect of spatial configuration in the thermal area of Fort Oranje public space in ternate city Journal of Architecture and Urbanism 41(4) pp 253-259.
[2] Li L, Zhou X, and Yang L 2017 The Analysis of Outdoor Thermal Comfort in Guangzhou During Summer, Procedia Engineering 205 pp 1996–2002.
[3] Mestayer P.G, and Anquetin, S 1994 Diffusion and Transport of Pollutants in Atmospheric Mesoscale Flow Fields Atmos. Sci. Libr, Kluyer Academic Publishers.
[4] Satwiko, P 2004. Building Physic 2 (Penerbit Andi: Yogyakarta)
[5] Younsi S, and Kharrat F 2016 Outdoor Thermal Comfort: Impact of The Geometry of an Urban Street Canyon in a Mediterranean Subtropical Climate – Case Study Tunis, Tunisia Procedia Social and Behavioral Sciences 216 pp 689-700.
[6] Kusumawanto A, and Astuti B 2014 Green Architecture on Cities Innovation, (Yogyakarta: UGM Press)