Perception of Thermal Comfort Level in Outdoor Space on Urban Public Space (Case Study: Lumintang Park in Denpasar)

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Abstract. For the sake of their needs, humans try to condition the environment to provide thermal comfort for their bodies. Outdoor space is one of the environments in which humans move and is always influenced by climatic conditions, so the comfort that humans feel is highly dependent on the thermal conditions of the environment. The thermal comfort needed by the human person is not only influenced by thermal factors but also by the type of activity and clothing of the human person. The object of outer space in this study is a built environment in the form of a city park as a comfortable recreation facility for the city community, both from visual comfort and from thermal comfort. So it is important to conduct research on the level of thermal comfort and the sensation felt by city park visitors to then become a consideration for architects to develop an optimal urban garden design. The focus of this research is the condition of the level of thermal comfort in Denpasar City Park in Lumintang and elements of the outer space of the City Park. In 2016 a similar research was carried out in I Gusti Made Agung Field (Puputan Field) and this year it is continued with Lumintang City Park which is also one of the city parks in Denpasar. The purpose of this study is to determine the existing thermal conditions that provide thermal comfort and the sensation felt by visitors, then it can be used to find out what elements of outdoor space affect the level of thermal comfort in the city park. So that the results of this study can be used as a basis for architects in developing and designing city parks that can function optimally. So to achieve these objectives in this study using comparison and simulation methods, by combining the simulation results of the Comfort Calculator and the sensation of thermal comfort felt by visitors at each function zoning point in the city park. These results will show a mapping of the distribution of thermal comfort levels in each zoning. So, by mapping the distribution of the level of thermal comfort, it can be seen that the Hard Scape and Soft Scape elements that affect each zoning function of the city park.

Keywords: Thermal Comfort; City Park; Outdoor space

1 Introduction

Thermal comfort is an absolute necessity for the human body, and with its ability, humans also create a built environment to meet their comfort both outside and inside a building. The ability of humans to process the environment to achieve the level of thermal comfort the human body needs can be seen from the design of a city park. City parks as good public areas are certainly expected to meet the various needs and demands for the comfort of each of the various users.

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In the process of designing a city park that meets all aspects of thermal comfort for its users, of course considering various elements of outdoor space in the form of Hard Scape and Soft Scape elements. By determining the elements of Hard Scape and Soft Scape and their proper placement, it is hoped that the creation of a comfortable city park is expected. In fact, it is often found that a city park cannot function optimally in providing comfort for its users. This condition can easily be seen with observations in the field with unequal use in every city park area, such as in several city park points that are not visited by visitors.

The same thing is also found in Denpasar City Park in Lumintang, with various functions and facilities in it such as a children's playground, stage, garden pool, jogging track, etc. But in reality, these various facilities do not fully function optimally as seen from the uneven activity in each of the existing functions. This condition is important to know what causes and how to overcome it in order to provide a sense of comfort for visitors to the city park.

Seeing the importance of the existence of city parks, it is necessary to make a clear mapping of how the thermal comfort conditions in city parks and what components influence it. So that later these findings can be used as evaluation material for designers in planning another city park. So that to further optimize the existence and role of city parks, it is necessary to conduct research to improve previous research using a comparative method between identifying the level of comfort using the help of Comfort Calculator software and the sensation felt by visitors through questionnaires.

From the above background, the research problems that arise are: What is the condition of the thermal comfort of Denpasar City Park in Lumintang, Denpasar? How is the perception of thermal comfort felt by visitors to Denpasar City Park in Lumintang, Denpasar? To what extent does the application of spatial elements affect the comfort of Denpasar City Park in Lumintang, Denpasar?

2 Literature Review

Thermal comfort is a state of mind that expresses satisfaction with its thermal environment [1]. In creating thermal comfort, there are six variables that must be considered [2], namely: (1) Air temperature, (2) Average radiant temperature, (3) Relative air velocity, (4) Relative humidity, (5) Activity level, (6) Thermal resistance of clothing.

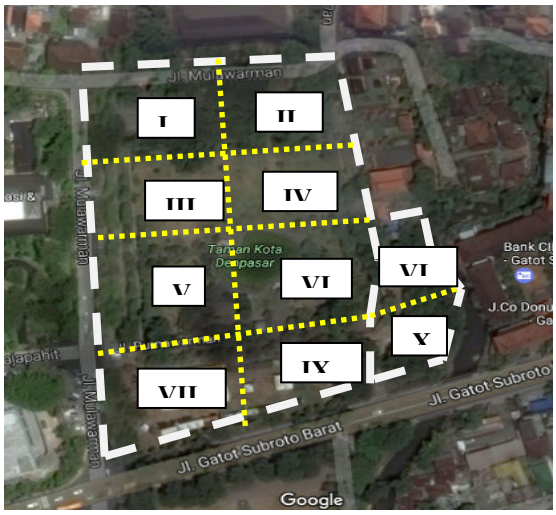
The PMV (Predicted Mean Vote) Index was first proposed by [2] was then ratified by the international community and received ISO 7748. This index scale is the standard for calculating the level of comfort for temperate regions. The PMV index scale is a prediction of the average thermal sensation, which relates thermal sensation to a combination of two personal variables and four climate variables [1]. Thermal sensation is scaled using the seven-point psychophysical scale from ASHRAE, namely: -3, -2, -1, 0, 1, 2, 3 which have conditions of “cold, cool, slightly cool, neutral or comfortable, mildly warm, warm, and hot". The two personal variables referred to are metabolic rate as seen from activity and insulation level as seen from the way of dress. Meanwhile, the four climate variables are air temperature, radiation temperature, humidity, and wind movement [1].

3 Method

In this study, to determine the quality and sensation of thermal comfort, as well as mapping of outdoor elements and their effect on thermal comfort in city parks, the method used in this study is the comparative method through simulation with a computer application, namely the Comfort Calculator which is supported by a questionnaire for knowing the sensation of thermal comfort felt by visitors to the city park of Lumintang, Denpasar.

Data collection was carried out by means of field observations to obtain field measurement data such as thermal conditions and physical conditions of the research object. Field observations will be carried out for three days to observe the existing conditions of the outer rung elements, measuring the thermal conditions for three time periods every day, and distributing questionnaires by taking 10 samples of visitors in each function zoning in the city park. The three measurement periods are; morning (07.00 - 09.00), noon (11.00 - 13.00), and evening (15.00 - 17.00). Within three days the measurements were also carried out at three different points, in order to obtain an overview of the thermal conditions which could represent the thermal conditions at the location.

For the measurement point, the thermal conditions in each zone are two measurement points. Two measurement points were chosen to represent the variable range of thermal conditions in each zone. This is because the characteristics of forming the outer space in each zone are different. Some are full of large and shady vegetation, especially on the sides of the field and some are in a position of less shade trees (an area closer to the center of the field). Then there are 12 measurement points in total. In accordance with the distribution of zones for measuring thermal conditions, questionnaires were also distributed to these 10 zones.



Information :

I. Parking Zone northwest side
II. Northeast side Parking Zone
III. West Zone (jogging track area)
IV. The center zone in front of Pura Agung Lokanatha
V. West Zone (open space and dove house)
VI. Middle zone (fountain pool and children's play area)
VII. Youth park area north zone
VIII. Southwest Zone
IX. South side central zone
X. South zone of Youth Park area

Figure 1. Division of Measurement Zones

Source: www. Googlemaps.com and summarized from various sources

Analysis of the empirical measurement data in the field using the Comfort Calculator and the sensation felt by visitors from the questionnaire results to map the sensation of thermal comfort based on the PMV thermal comfort index theory. From the results of this analysis, it

will be known the range of thermal comfort in the research object. Then with this result it will be known in each zoning of city parks, what elements of outdoor space affect thermal comfort.

4 Result and Discussion

In the discussion and analysis, the data and the process of data collection and analysis in each zone will be presented. The data is processed and displayed with a table of measurement results and methods in accordance with the research method described in the previous chapter. For the zoning can be seen in the image below.

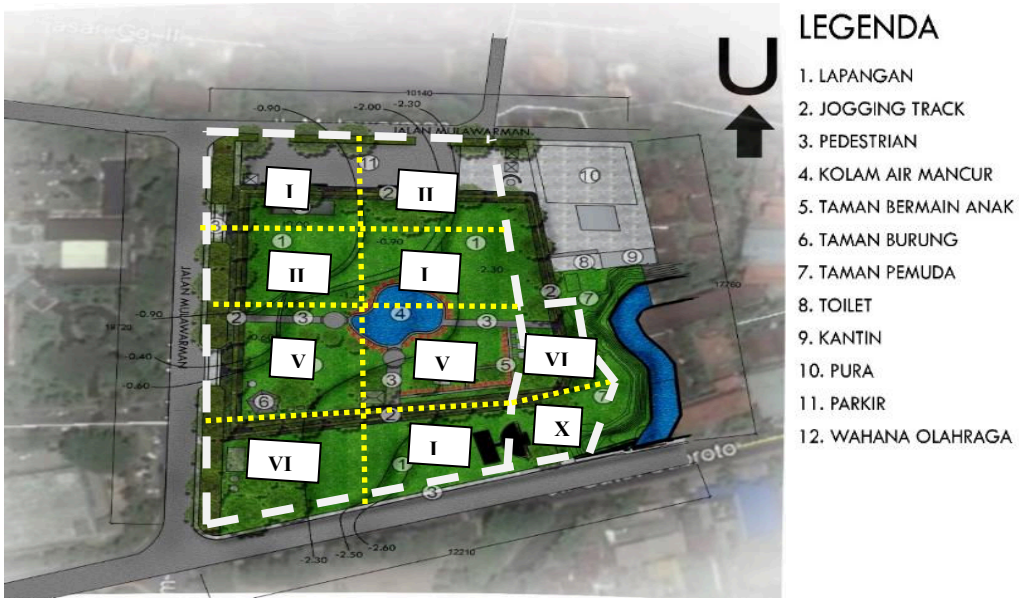


Figure 2. Division of Measurement Zones

Source: Research Team Documentation, 2020

4.1. Observation and Questionnaire Stage

This stage aims to determine the perception of field users about the level of thermal comfort in this field. Observations were made in three times adjusted to the time of thermal comfort measurement. Types of activities carried out in the Lumintang field (Denpasar City Park) in each observation zone (Zone I-X), the dominant activities carried out in this field are sitting and walking leisurely. The types of clothing that are widely used are cloth shirts with short sleeves and cloth pants, both short and long.

Figure 3. Jogging Track Zone I

Source: Personal Documentation, 2020

Table 1. Conclusion Table of Perception of Thermal Comfort

Zona	07.00 - 09.00			11.00 -13.00			15.00 - 17.00		
	R1	R2	R3	R4	R5	R6	R7	R8	R9
1	Slightly Cool	Neutral	Neutral	Neutral	Slightly Warm	Slightly Warm	Slightly Warm	Neutral	Neutral
2	Slightly Cool	Slightly Warm	Slightly Warm	Neutral	Slightly Warm	Slightly Warm	Slightly Warm	Neutral	Neutral
3	Neutral	Neutral	Neutral	Slightly Warm	Slightly Warm	Slightly Warm	Slightly Warm	Slightly Warm	Neutral
4	Neutral	Neutral	Slightly Warm	Slightly Warm	Slightly Warm	Neutral	Slightly Warm	Neutral	Neutral
5	Slightly Cool	Slightly Cool	Neutral	Neutral	Slightly Warm	Neutral	Neutral	Neutral	Neutral
6	Neutral	Slightly Cool	Slightly Warm	Neutral	Neutral	Slightly Warm	Neutral	Neutral	Neutral
7	Slightly Cool	Slightly Cool	Neutral	Neutral	Neutral	Slightly Cool	Neutral	Neutral	Neutral
8	Slightly Cool	Slightly Cool	Slightly Cool	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral
9	Neutral	Neutral	Slightly Warm	Slightly Warm	Slightly Warm	Slightly Warm	Slightly Warm	Neutral	Neutral
10	Slightly Cool	Neutral	Neutral	Slightly Warm	Slightly Warm	Slightly Warm	Slightly Warm	Slightly Warm	Neutral

Source: Questionnaire Results, 2020

The data conditions of this questionnaire, the first three factors (temperature, humidity and wind speed) are the driving factors for the sample of visitors to understand that thermal comfort is influenced by these three factors. Meanwhile, the perception of thermal comfort will be calculated from their choice of the fourth factor component, namely the thermal comfort scale. The trends in their perceptions are as follows:

- In zone I, the tendency for the perception of thermal comfort by the user is comfortable at the three measurement times. It is only during the day that users generally expect to perceive slightly warm conditions.

- In zone II, the trend in the perception of thermal comfort by the user was slightly warm at the three measurement times. Dominant in the afternoon, users generally lead their perceptions to comfortable conditions.
- In zone III, the trend in the perception of thermal comfort by the user is Slightly Warm at the three measurement times. Only in the morning the user generally leads to a comfortable perception.
- In Zone IV, the user's perceived thermal comfort tendency is comfortable across the three measurement times. Only near noon the user generally leads to his perception of warm conditions.
- In Zone V, the user's perceived thermal comfort tended to be comfortable across the three measurement times. Only in the morning the user generally leads his perception to slightly cool conditions.
- In Zone VI, the tendency of the user to perceive thermal comfort is comfortable across the three measurement times.
- In zone VII, the tendency for the perception of thermal comfort by the user is comfortable at the three measurement times. Only in the morning the user generally leads his perception to slightly cool conditions.
- In zone VIII, the user's perceived tendency of thermal comfort is comfortable across the three measurement times. Only in the morning and evening the user generally leads his perception to slightly cool conditions.
- In zone IX, the trend in the perception of thermal comfort by the user is Slightly Warm at the three measurement times. Meanwhile, in the morning and evening users generally point their perceptions to a comfortable condition.
- In Zone X, the trend in the perception of thermal comfort by the user is Slightly Warm at the three measurement times. Only in the morning and evening the user generally leads to a comfortable perception.

4.2. Simulation Stage

The data from thermal measurement results are used in making the Comfort calculator simulation. Other factors besides the above measurement results are the activity rate and the type of clothing. To facilitate the calculation of the simulation, a simplification is carried out by selecting the type of activity and the type of clothing that is dominant in each zoning. The dominant type of activity is casual walking (Met value = 1.9) with the type of shirt, short-sleeved cloth and short cloth pants (total value of Clo = 0.5). Even though it is widely seen, it is not used because people tend to choose to sit in a comfort zone.

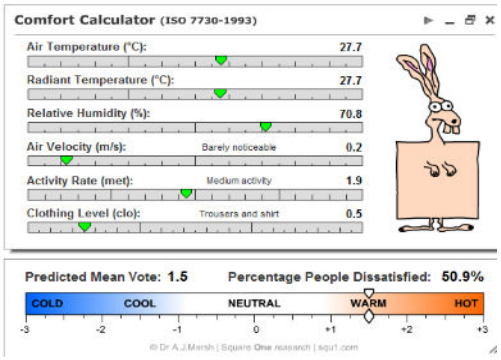


Figure 4.Examples of Zone 1 Morning Comfort Calculator Simulation

Source: Questionnaire Results, 2020

Estimation of average thermal comfort or Predicted Mean Vote (PMV) in the simulation above is arranged in a simpler form and shows the conditions of thermal comfort for each zone as follows:

Table 2. Thermal comfort according to simulation standards

Zona	07.00 – 09.00	11.00 – 13.00	15.00 – 17.00
I	1,5 (Slightly Warm)	2,4 (Warm)	1,4 (Slightly Warm)
II	1,6 (Warm)	2,4 (Warm)	1,3 (Slightly Warm)
III	1,7 (Warm)	2,5 (Warm)	1,4 (Slightly Warm)
IV	1,5 (Slightly Warm)	2,5 (Warm)	2,3 (Warm)
V	1,6 (Warm)	2,6 (Hot)	2,2 (Warm)
VI	1,9 (Warm)	2,7 (Hot)	2,1 (Warm)
VII	1,5 (Slightly Warm)	2,5 (Warm)	1,3 (Slightly Warm)
VIII	1,3 (Slightly Warm)	2,3 (Warm)	1,3 (Slightly Warm)
IX	1,7 (Warm)	2,4 (Warm)	1,1 (Slightly Warm)
X	1,6 (Warm)	2,2 (Warm)	1 (Slightly Warm)

Source: Researcher's Documentation, 2020

The table above shows the level of thermal comfort from the simulation results which shows that in the morning there is a warm and slightly warm range. The daytime trend is predominantly warm, while the afternoon conditions tend to be slightly warm.

4.3. Analysis of Thermal Comfort Conditions from Observation and Simulation

At this stage an analysis will be carried out to compare the trends in user perceptions based on the questionnaire with thermal comfort conditions based on measurements and simulations. As previously explained, the stages of the research have been explained and the trends obtained from each stage have been concluded. From the conclusion of each of the above stages, then the results between user perceptions obtained from the questionnaire results and the simulation results can be concluded that the trend of thermal comfort conditions in Lumintang City Park is as follows:

Table 3 Comparison of Thermal Comfort based on perception with Simulation

Zone	The result	07.00 – 09.00	11.00 – 13.00	15.00 – 17.00
I	User perception	Neuteral	Slightly Warm	Neuteral
	Simulation	Slightly Warm	Warm	Slightly Warm
II	User perception	Slightly Warm	Slightly Warm	Neuteral
	Simulation	Warm	Warm	Slightly Warm
III	User perception	Neuteral	Slightly Warm	Slightly Warm
	Simulation	Warm	Warm	Slightly Warm
IV	User perception	Neuteral	Slightly Warm	Neuteral
	Simulation	Slightly Warm	Warm	Warm
V	User perception	Slightly Cool	Neuteral	Neuteral
	Simulation	Warm	Hot	Warm
VI	User perception	Neuteral	Neuteral	Neuteral
	Simulation	Warm	Hot	Warm
VII	User perception	Slightly Cool	Neuteral	Neuteral
	Simulation	Slightly Warm	Warm	Slightly Warm
VIII	User perception	Slightly Cool	Neuteral	Neuteral
	Simulation	Slightly Warm	Warm	Slightly Warm
IX	User perception	Neuteral	Slightly Warm	Neuteral
	Simulation	Warm	Warm	Slightly Warm
X	User perception	Neuteral	Slightly Warm	Slightly Warm
	Simulation	Warm	Warm	Slightly Warm

Source: Researcher's Documentation, 2020

The comparison table above shows the general user's perception, in the morning, the user's perception is in the cool or comfortable range, while the simulation is in comfortable and slightly warm conditions. The trend of daylight, the user's perception is dominated by comfortable and the simulation is rather warm and warm. Meanwhile, the condition in the afternoon, the perception is at the level of comfort and a bit warm, whereas from the simulation it is rather warm and warm.

When comparing the level of thermal comfort from the perceived results, the standard of thermal comfort from temperature, and the simulation results, it can be seen that in general the trend of thermal comfort that occurs in Lumintang City Park is that the user's perception is one level lower than the results that arise from the simulation. The above trend can be seen from several factors that influence the thermal comfort conditions in this city park and the extent of their influence. The factors are as follows:

- Climatic factors (temperature, humidity and wind speed).

The simulation results in general, in terms of climatic factors such as temperature, in the morning, conditions in all measurement zones tend to be slightly warm. One level below the perception level, it also shows consistency between measurement results and simulation results. Meanwhile, during the day and evening, temperatures are dominated by warm conditions.

The existing positions of zones I, VII and VIII are indeed in a condition with fairly organized vegetation and cover the activities in the zone. The existing vegetation also has a relatively high altitude so that it maximizes its shading function and increases humidity. This really supports the perception of comfort and coolness that exist in the area. Especially in the afternoons, the shading function on the west side gives users the comfort needed.

- Personal factors (type of activity and clothing)

Personal factors related to body metabolism and are influenced by activity and clothing resistance. In this study, from the observation that the dominant type of activity is sitting and walking leisurely. The sitting area is more concentrated in zones I and VII and VIII and this is probably because this area is considered more comfortable and shaded by field vegetation (especially during the day). In the morning, the activity tends to be on the north side of the field (which is indeed a lower temperature condition) while in the afternoon the activity tends to spread out with more users in zones I, VII, VIII and X. Zones VII and X are in the eastern part of the site with lower position, during the afternoon it is more shaded by the surface of the site on the west side and vegetation so that conditions are also more comfortable.

For clothing types, in general, choosing clothes that are for outdoor activities does not significantly affect the perception of thermal comfort in field users.

- Adaptation to thermal comfort by open space users.

From the user's perception, in general the thermal comfort in this field is at a neutral / comfortable level. However, the actual field area is dominated by conditions that are above comfortable conditions (rather warm or warm). This shows the tendency of the user to adapt to conditions that may not be in accordance with his perception. According to [3], a person accustomed to a tropical climate will feel comfortable in a zone that is several degrees warmer than the maximum effective temperature that someone from England is comfortable experiencing.

This theory can explain the conditions that we see in the comparison results above where the user's perception of thermal comfort is one level lower than the conditions obtained from the simulation results. People living in Denpasar, which is a tropical region, have been exposed to thermal conditions that are above thermal conditions in Europe from birth and have a certain degree of adaptation to these thermal conditions. Meanwhile, the measuring parameters used in the Comfort calculator simulation are parameters in European conditions with four seasons and in sub-tropical areas with relatively lower temperatures.

5 Conclusion

This research on Thermal Comfort in Lumintang City Park aims to see the comfort condition with measurement and simulation methods and to compare the results of these stages. The conclusions obtained from this study are as follows:

According to simulations, the thermal comfort conditions in Lumintang City Park generally range from slightly warm to hot. The predominant level of thermal comfort is slightly warm. There is a difference in thermal comfort based on thermal perception with the simulation results where the simulation results show the comfort level one level below the simulation results. It can be concluded that conditions in the morning are relatively comfortable because the results obtained are in the range of comfortable to slightly warm. Meanwhile, the afternoon and evening are also relatively comfortable, although the level of comfort has risen to the level of a little warm and warm.

The existence of vegetation in several zones, especially zones I and VII and zones VIII and X is also quite helpful to provide shade for users who are active in this field. Whereas in zones III, IV, and V are relatively more open and exposed to direct sunlight, so that the measured thermal comfort conditions are in the warm and warm ranges, but users will directly choose not to do activities in these areas and select areas. others are more comfortable.

The influence factor of thermal comfort conditions and the perception of this field user is formed in such a way because of the influence of several factors such as climate factors (temperature, humidity and wind speed), personal factors (type of activity and type of clothing) and the most important factor is user adaptation. to certain thermal comfort conditions.

Field conditions are actually somewhat warm or warm, perceptually they are still accepted as comfortable conditions and are still considered good thermal conditions for outdoor activities in public open fields. As mentioned above, the background factor of the tropical environment of field users has made the body adapt to higher temperatures and thermal comfort while still feeling comfortable.

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