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ROAD USERS' PERCEPTIONS OF VISITORS' THERMAL COMFORT AND ITS RELATIONSHIP WITH THERMAL COMFORT ATTRIBUTES IN STREET CANYON, MH THAMRIN STREET, CENTRAL JAKARTA

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ABSTRACT

MH Thamrin is a street canyon area experiencing global warming, and impact on the level of thermal comfort. This study aims to provide an overview of thermal comfort attributes and user perceptions of thermal comfort in Street Canyon, Jl. Based on the measurement results, it was found that the air temperature in the non-dense green space segment was higher than the dense green space segment, with a total average of 31.12°C and 30.27°C. Air humidity is more humid in the dense green space segment (62.69%) than the non-dense green space segment (62.16%). The amount of wind speed in the dense greenery segment is 1.41m/s, while for the non-dense greenery segment it is 0.99m/s. The lowest surface temperature in the non-dense greenery segment is around 26.95°C, and the highest is 39.1°C. The maximum surface temperature of the dense greenery segment is 33.9°C with a minimum surface temperature of 26.1°C. Through the results of road user perceptions, it was found that user perceptions in the dense green spaces segment fell into the moderate category (15.67≤X<19.33). Meanwhile, the level of thermal comfort in the segment of non-dense green spaces on MH Thamrin Street also in medium category. Spearman rank correlation analysis results show the entire thermal comfort attributes associated with user perceptions. Air temperature with user perception has a strong correlation and unidirectional relationship direction (correlation coefficient -0.853). Surface temperature and user perception is also strongly correlated with the direction of the relationship is not unidirectional (correlation coefficient -0.928). In contrast, air humidity and user perception also have a strong correlation, but the direction of the relationship is unidirectional (correlation coefficient 0.911). Wind speed and road user perceptions are strongly correlated and the direction of the relationship is unidirectional (correlation coefficient 0.893).

***Keywords**: Green Open Space; Jl. MH Thamrin; Perception; Street Canyon; Thermal Comfort,*

ABSTRAK

Jl. MH Thamrin merupakan kawasan street canyon yang mengalami pemanasan global, serta minim vegetasi untuk menaungi pengguna jalan yang berdampak pada tingkat kenyamanan termal. Penelitian ini bertujuan memberikan gambaran atribut kenyamanan termal dan persepsi pengguna terhadap kenyamanan termal di Street Canyon, Jl. MH Thamrin pada kerapatan RTH yang berbeda, serta memperlihatkan hubungan antara kedua aspek tersebut. Pengambilan data dilaksanakan menggunakan thermohygrometer, anemometer data logger, Drone Thermal DJI, mini weather station, dan kuesioner ASHRAE modifikasi. Analisis pada penelitian ini ialah analisis skala likert untuk data persepsi, dan analisis korelasi rank spearman. Berdasarkan hasil pengukuran didapatkan suhu udara di segmen RTH non lebat lebih tinggi dibandingkan segmen RTH lebat, rata-rata total 31,12°C dan 30,27°C. Kelembapan udara lebih lembab di segmen RTH lebat (62,69%) dibandingkan segmen RTH non lebat (62,16%). Besaran kecepatan angin di segmen RTH lebat yaitu 1,41m/s, sedangkan untuk segmen RTH non lebat yakni 0,99 m/s. Suhu permukaan paling rendah di segmen RTH non lebat berkisar 26,95°C, dan tertinggi yaitu 39,1°C. Suhu permukaan maksimal segmen RTH lebat yakni 33,9°C dengan suhu

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permukaan minimal 26,1°C. Melalui hasil persepsi pengguna jalan, didapatkan bahwa persepsi pengguna di segmen RTH lebat masuk ke dalam kategori sedang (15,67≤X<19,33). Adapun, tingkat kenyamanan termal di segmen RTH non lebat pada Jl. MH Thamrin juga masuk ke dalam kategori sedang namun cenderung rendah (14,7≤X<19,33). Hasil analisis korelasi rank spearman menunjukkan seluruh atribut kenyamanan termal berhubungan dengan persepsi pengguna. Suhu udara dengan persepsi pengguna memiliki korelasi yang kuat dan arah hubungan yang tidak searah (correlation coefficient -0,853). Suhu permukaan dan persepsi pengguna juga berkorelasi kuat dengan arah hubungan tidak searah (correlation coefficient -0,928). Berbeda dengan kelembapan udara dengan persepsi pengguna yang juga memiliki korelasi kuat, namun arah hubungannya searah (correlation coefficient 0,911). Kecepatan angin dan persepsi pengguna jalan berkorelasi kuat dan arah hubungan yang searah (correlation coefficient 0,893).

***Kata Kunci**: Jl. MH Thamrin; Kenyamanan Termal; Ngarai Jalan; Persepsi; Ruang Terbuka Hijau*

A. INTRODUCTION

Comfort is a basic need of every human being. Comfort can also be felt physically and non-physically. Physically based on standard needs, while non-physically refers to human perception. Physical comfort according to Mangunwijaya (1997) in Oktavia's research (2021), consists of space comfort, visual comfort, audial comfort, and thermal comfort. One level of comfort that affects human activity is thermal comfort (Suyono & Eddy Prianto 2017). According to Karyono (1996) in Hadinata's research (2019) thermal comfort is the human response to temperature stimuli received from the environment. The comfort can be studied indoors and outdoors. Thermal comfort outdoors such as road corridors, city parks, and other open spaces are influenced by many factors, one of which is the air temperature of an area (Sangkertadi 2013). This factor has a major influence on the comfort of outdoor spaces. It is also conveyed by Aynsley, R.M. (1997) in Rahmania & Shiva Virly (2019) that thermal comfort is influenced by the physical environment, including air temperature, relative humidity, and wind speed. In addition, according to Auliciems, A., & Szokolay (2007) in Prasetya and Yayi's research (2022) the main factors affecting thermal comfort are the body's metabolic rate, clothing insulation, air temperature, surface temperature, wind speed, and air humidity.

The density of an area characterized by the presence of tall buildings has the potential to reduce the quality of the microclimate of the area. The geometric nature of the blocks of urban areas along with the type of material of building construction is one of the factors in the increase in air temperature due to the density of development (Falasca et al., 2019; Kantzioura et al., 2015) In addition, infrastructure development, especially in urban areas, tends to present towering vertical buildings due to limited land in big cities. This situation has led to the emergence of an area in the form of a street canyon commonly referred to as a street canyon, which is a place where a road is flanked by buildings on both sides and creates a canyon-like environment. Street Canyon affects various local conditions such as temperature, wind, light, and air quality (Hang & Guanwen Chen 2022). Research results from Wang et al. (2020) conducted on the Jianghuai plain showed that street canyons have high temperatures and also have an impact on the UHI (Urban Heat Island) effect. Buildings, roads, and vegetation are important components of the street canyon. In line with the research results from Deng & Wong (2020) who argue that the geometric shape of the street canyon affects environmental conditions such as solar access, wind speed, air and surface temperatures. The existence of a high temperature street canyon certainly affects the level of thermal comfort for road users (Wang et al. 2022). Moreover, the street canyon is dominated by building density rather than balancing it with the presence of vegetation through road greenways and road medians.

In fact, the availability of Green Open Space is very important for a city because it affects the environmental conditions and microclimate around the area. According to Gómez et al (2004) in the research of Ningrum et al. (2020), vegetated areas such as green spaces have an important role in influencing the albedo and value of solar radiation reaching urban areas. Green space areas are also able to neutralize the increase in surface temperature and provide a cooling effect. This is because vegetation performs evaporation and transpiration processes, thereby reducing the surrounding air temperature (Arifah, N., & Susetyo 2018). Regulation of the Minister of Public Works Number: 05/PRT/M/2008 concerning Guidelines for the Provision and Utilization of Green Open Space in Urban Areas states that the provision of green open space in the scope of the city is one of them to ensure the availability of sufficient space for the creation of microclimate in urban areas. According to Zhang et al (2018), increasing urban albedo to 0.7 through building engineering has the same effectiveness as providing a variety of vegetation. Salata et al (2015) have also proven that the combination of sidewalks and vegetation can significantly increase the comfort index by up to 60%. Gill et al (2007) and Byrne et al (2008) in Abdollahzadeh and Nimish (2021) stated that the use of greenery can reduce the UHI effect and change the state of air temperature, wind speed, and relative humidity.

Similar conditions are also experienced in Indonesia, precisely on Jl. MH Thamrin, Central Jakarta. This road is one of the main roads in Jakarta which is the center of business. Based on the results of research from Khuluk (2016) related to perceptions and preferences of user comfort aspects on Jl. MH Thamrin and Jl. Jendral Sudirman, it was found that as many as 80 respondents (62%) felt that the air temperature on the road was quite hot. Each respondent wants vegetation and shade facilities for shade, because the hot air temperature results in physical activity that quickly feels tired. Road users certainly want ideal comfort including thermal comfort. Moreover, DKI Jakarta as the capital of Indonesia has experienced a very intensive increase in urban development. The development of urbanization megacity Jakarta certainly affects the air temperature due to the phenomenon of urban heat island (UHI) such as an increase in temperature in the city center and decreased towards the sub-urban both north, south, west and east (Wati & Nasution, 2018). Ideal thermal comfort can be obtained through air temperatures that suit the Indonesian population. According to Mom & Wisebrom (1940) in research by Alkausar & Susetyarto (2019) there are 3 categories of comfortable temperatures for indigenous Indonesians, namely 20.5°C-22.8°C (cool comfortable), 22.8°C-25.8°C (optimal comfortable), 25.8°C-27.1°C (warm comfortable). In line with the standardized PET values by Matzarakis et al. (1999) in Haddid & Karam (2022) that temperatures between 18°C-23°C fall into comfortable climate conditions without heat stress. The second indicator is air humidity, the level of air humidity that can be enjoyed by the body ranges from 40-70%. In addition, wind speed also affects, as for the wind speed for comfort is in the limit of 0.1 m / sec to 0.5 m / sec. In fact, this is still difficult to obtain, especially since Jl. MH Thamrin is located in the city of Jakarta, which is also experiencing global warming and lack of vegetation and shade facilities to shade road users. Referring to the above problems, this study aims to provide an overview of thermal comfort attributes (air temperature, surface temperature, wind speed, and air humidity) and road users' perceptions of thermal comfort in Street Canyon, Jl. MH Thamrin on different green space density. This study specifically examines users’ perceptions of thermal comfort within the street canyon of MH Thamrin Street, Central Jakarta. The survey was conducted in two contrasting segments—one characterized by dense vegetation and another with sparse vegetation—to assess how variations in greenery influence microclimatic conditions and perceived thermal comfort. This comparative approach provides a clearer understanding of the moderating role of roadside vegetation in shaping outdoor thermal environments within dense urban corridors. Unlike previous studies that primarily investigated street canyons from a building geometry perspective without considering users’ perceptions or the presence of vegetation, this research integrates both human and environmental dimensions. Moreover, empirical studies on street canyons remain limited in Indonesia, highlighting the novelty and contextual significance of this work. In addition, this study will also show the relationship between thermal comfort attributes to the perception of thermal comfort of road users.

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B. MATERIALS AND METHODS

Data Collection Method

The research was conducted along Jl. MH Thamrin, which stretches 2.5 km from Bank Indonesia Fountain, Gambir, to Dukuh Atas. The area observed was part of Jl. MH Thamrin with 2 different characteristics of street green space seen from the level of green space vegetation density. This research uses tools and materials, which will support the research objectives. The tools and materials used can be seen in table 1. In addition, climate data collection was carried out for 3 days, in the morning (09.00-10.00 WIB), afternoon (12.00-13.00 WIB), and evening (15.00-16.00 WIB).

Table 1. Research Tools and Materials

No	Activity Type	Tools	Materials	Functions
1	Characteristics of thermal comfort attributes	Camera GPS Google Earth Pro DJI Thermal Drone Thermo Hygrometer Anemometer Data Logger Mini Weather Station Laptop	Primary and secondary data	Taking pictures Determine the location point Display the area virtually Detect surface temperature Measuring air temperature and humidity Measuring air velocity Additional tools Processing measurement data
2	Perceived thermal comfort level of users	Questionnaire Sheet Camera Laptop	Primary and secondary data	Getting respondents' perceptions Documentation Processing questionnaire results
3	Correlation between thermal comfort attributes with perceived thermal comfort level of users	Laptop (*SPSS*)	Primary and secondary data	Performing correlation analysis

Data Analysis Methods

The research method used is descriptive evaluative research method with a quantitative approach to retrieval and analysis of thermal comfort data. This study employed a descriptive evaluative method with a quantitative approach to objectively examine the relationship between thermal comfort attributes and users' thermal comfort perceptions. The quantitative approach enables systematic measurement and statistical evaluation, providing empirical evidence on how thermal comfort conditions relate to user perceptions across two contrasting street canyon segments—one with dense vegetation and another with sparse vegetation. Data compilation is done by direct observation on Jl. MH Thamrin. Characteristics of thermal comfort attributes which include air temperature, wind speed, air humidity, and LST will be obtained with the

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tools as listed in Table 1. This surface temperature (LST) data can be known through the DJI Thermal Drone flight. Data collection will be carried out in the street canyon area with 2 different street green space characteristics, namely green space with lush vegetation and green space with the opposite situation. The study involved a total of 60 respondents, evenly distributed across the two research areas 30 respondents in the dense vegetation area and 30 respondents in the sparse vegetation area. The sampling was conducted in a balanced manner to ensure comparable representation of user perceptions under both conditions. As this research is designed as a case study, the findings are not intended to be generalized to all urban areas; however, they are considered sufficient to represent the microclimatic characteristics of MH Thamrin Street as one of the main urban corridors in Central Jakarta.The perception data is obtained through the distribution of questionnaires that refer to the modified ASHRAE Questionnaire. The data that has been collected is then directly analyzed using perception analysis based on a Likert scale and Spearman rank correlation analysis. The following is the formula for spearman rank correlation analysis:

$$rho = 1 - \frac{6\sum d^2}{n(n^2-1)}$$

Description:

Rho: Spearman Rank Correlation Coefficient

d2 : Squared rank

n : The amount of data (sample)

C. RESULTS AND DISCUSSION

Thermal Comfort Attributes of Non-Dense Green Space Segment

Thermal comfort attributes in non-dense green space segments are measured using a mini weather station (Figure 1). Mini weather station is placed right at point 0 non bushy green space segment that is not shaded by trees, to get the value of different climatic conditions of the bushy green space segment. Data collection of thermal attributes was carried out for 3 days, starting from Monday, March 13, 2023-Wednesday, March 15, 2023.

Figure 1. Mini Weather Station Tool Set

Air temperature measurements were taken based on time intervals of every 10 minutes. The air temperature on the first day was quite high with a maximum temperature in the morning of 34.45°C, and a minimum temperature in the afternoon of 33.15ºC. This figure shows that the air temperature at the location on the first day has exceeded the threshold of a comfortable temperature category for humans, especially indigenous people (Mom & Wisebrom, 1940). The air temperature on the second day was different from the first day. The weather was not so hot and tended to be cloudy, making the air temperature lower. Based on the measurement results, the total average air temperature on day 2 was 29.77°C. These results also exceeded the threshold. This condition is reinforced by the theory of Lippsmeier (1980) which states that a temperature of 26°C TE - 30°C TE, makes endurance and work ability begin to decline. The air temperature was measured again on day 3. The measurement results showed that the average temperature on that day was 29.89°C. Similar to days 1 and 2, the air temperature on day 3 was also classified into the uncomfortable temperature range. Moreover, according to Lippsmeier (1980), the effective temperature that provides comfort is between 19°C TE - 26°C TE. The high air temperature in the non-dense green space segment is also more or less influenced by the availability of minimal and less dense tree plants. This is reinforced by a research study from Aluyah & Rusdianto (2019) which states that the air temperature in non-canopied areas is higher than in canopied areas. This is because in non-canopied areas, sunlight is insolated, and the intensity of the incoming sun is more maximum. Setiawan (2014) also said that areas with denser vegetation cover can result in a decrease in temperature to be cooler than the surrounding environment with less dense vegetation cover.

Based on the measurement of air humidity (RH) on day 1, it was found that the average total air humidity was 51.94%. This humidity level is still categorized as ideal humidity. The RH (Relative Humidity) standard for comfort is 45%-65%. Dry RH is in the range of <45%, while RH that is too humid exceeds 65%. In contrast to the thermal comfort standards of ASHRAE in Kartika, et al (2020), comfortable relative humidity ranges from 50-80%. The air humidity on the second day was much higher than the humidity on the first day. The result of the average total air humidity on day 2 was 68.61%. This average shows that the air humidity on that day was too humid because it exceeded 65%. This result also shows that the 2nd day air humidity is the most humid among the three days. The results of the 3rd day air humidity measurements were also classified as too humid (>65%) with a total average of 65.94%. According to Ginting, et al (2022), air humidity that is too humid will cause the development of pathogenic organisms and organisms that are allergens.

Based on the results of day 1 wind speed measurements, the average wind speed was 1.34 m/s. According to Prianto & Depecker (2002) wind speed for comfort is at speed limits between 0.1 m/s to 0.5 m/s. If it exceeds this limit, the sensation is said to be uncomfortable. Therefore, the first day's wind speed was classified as uncomfortable for humans. The second day's wind speed was slightly slower than the first day's measurement, with a total average of 1.2 m/s. Similar to the first day's wind speed, the second day's wind speed was also less than ideal for human comfort. The measurement was continued on the 3rd day, on that day the wind condition was not as strong as the first and second days, which was 0.45 m/s. Therefore, when viewed based on the research study by Elbes & Siti (2019), the 3rd day wind speed is classified as comfortable (0.25m/s-0.5m/s). The wind speed of the non-dense green space segment is not so high, it is possible because the wind has been blocked first by the trees in the dense green space segment. This is because the location of the non-dense and dense greenery segments are close to each other, only 20 meters apart. The dense green space segment is located to the north of the non-dense green space segment.

Land surface temperature (LST) is defined as the average surface temperature of a surface depicted in the coverage of a pixel with different surface types (Faridah & Krisbiantoro, 2014 in Guntara, 2016). Surface temperature is different from air temperature. Their actual values can be much different and vary with space and time. Surface temperature affects the sensible heat flux, especially during the day, because the surface temperature is higher than the air temperature (Mannstein, 1987 in Noer, 2022). The surface temperature in this study was obtained through thermal image portraits using a DJI Thermal Drone (Figure 2). Based on the results of thermal images along the pedestrian path in the non-dense green spaces segment that have been processed using color indicators, it was found that the average surface temperature on day 1 was very high at 38.02°C. In contrast to the average surface temperature on days 2 and 3 which are still below 30°C, respectively 29.67°C and 27.88°C. The high surface temperature in the non-dense green space segment is influenced by the type of land cover, some locations are not shaded by trees. This causes direct sunlight to hit the pedestrian path and the heat waves are absorbed by the object. This condition is also reinforced by Siombone's research (2022) which states that areas with high NDVI values tend to have low LST values, and vice versa. This relationship expresses the situation, if the higher the vegetation density of an area, the lower the land surface temperature (Maharani et al., 2021).

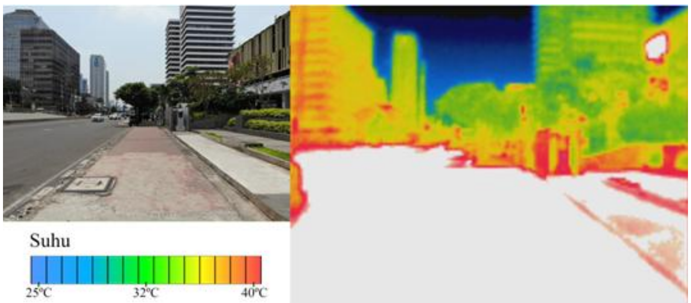

Figure 2. Results of Thermal Image Processing in the Non-Heathery Greenhouse Segment

Table 2. Average climate conditions of non-dense green space segments

No	Day	Time	Air Temperature (°C)	Air Humidity (%)	Wind Speed (m/s)	Surface Temperature (°C)
1		Morning	34,45	49,67	1,15	37,6
2	Day-1	Afternoon	33,63	53	1,02	39,1
3		Evening	33,15	53,17	1,85	37,35
4		Morning	28,4	75,5	1,07	27,9
5	Day-2	Afternoon	29,35	70	1,13	28,95
6		Evening	31,57	60,33	1,4	32,15
7		Morning	29,57	69,83	0,1	26,95
8	Day-3	Afternoon	28,97	70,33	0,34	28,85
9		Evening	31,15	57,67	0,9	27,85

Thermal Comfort Attributes of Dense Greenery Segments

Thermal comfort attributes in dense greenery segments were measured using a thermohygrometer, anemometer data logger, and DJI thermal drone (Figure 3). The measurement mechanism is the same as that carried out in non-dense green space segments. The measurement location point is under the shade of a tree located on the pedestrian path in front of the Sari Pacific Hotel.

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Figure 3. Anemometer Data Logger and Thermohygrometer

The air temperature measurement results of the dense greenery segment on the first day showed that the total average temperature on the first day was 30.64°C (Table 3). This figure is lower than the measurement in the non-dense green space segment. However, the results of the average temperature still show that the temperature conditions in this segment are not in accordance with comfort standards. However, this shows that the climatic conditions in 2 types of green spaces with different densities give different results. In line with research by Tauhid (2008), vegetation functions as climate control for human comfort by absorbing heat from sunlight so as to reduce temperature and microclimate. The air temperature on the second day was not much different from the air temperature on the first day. The air temperature has an average of 30.93°C. The results of air temperature measurements on the second day also show that the condition does not comply with comfort standards. According to SNI 03-6572-2001, the thermal comfort standard for the comfortable warm category is 25.8°C - 27.1°C. It can be said that the availability of tree plants in the dense green space segment may not be able to create climate amelioration effectively. Air temperature measurements in the dense green space segment continued on the 3rd day and resulted in a total average of 29.23°C. It turns out that the air temperature conditions on day 3 were lower than the air temperature on the first and second days. Even so, this figure is still classified as uncomfortable when viewed based on comfort standards.

Air humidity measurements on the first day detected a maximum RH of 54.17% and a minimum RH of 51.33%. Based on the data in the table below (Table 3), it can be calculated that the average air humidity is 52.92%. Health experts recommend an air humidity level (also known as Relative Humidity - RH) in the range of 45% - 65%, as the ideal level. Furthermore, the air humidity standard for Indonesians according to SNI (1993) is 40% - 70%. Therefore, the air humidity in the dense green space segment on the first day is considered ideal according to health and Indonesian National Standards (SNI). The air humidity on the second day was higher than the air humidity on the first day, with an average air humidity of 65.1%. Based on comfort standards according to SNI (1930), this situation can be said to be comfortable. However, according to experts' opinions on health, humidity exceeding 65% is considered unhealthy. This is because air that is too humid can trigger allergies and trigger the proliferation of bacteria and viruses. According to Murniati (2018) in Ratnasari & Imaniar (2021), high humidity can increase symptoms of sick building syndrome because it impacts the growth of bacteria and viruses. Based on the air humidity measurement data on day 3, the average total air humidity is 70.03%. Through this average, it can be concluded that on the 3rd day the air was much more humid than the first and second days. The high humidity in the dense greenery segment has an influence from the presence of denser vegetation. In line with the research of Aluyah & Rusdianto (2019), high tree density also causes high evapotranspiration, so that there is more water vapor in the air which has an impact on increasing air humidity.

The first day wind speed in the dense greenery segment has an average of 1.02 m/s. The average first day wind speed in the dense greenery segment was lower than the non-dense greenery segment. This is in line with the research of Setiawan (2014) which based on his observations, the narrower the plant density the wind speed tends to decrease. This phenomenon is due to denser plants, the wind is not free to blow. However, this situation is also classified as uncomfortable because according to Lippsmeier (1997) wind speeds of 1-1.5 m/s are said to be mild to unpleasant air movement. Based on wind speed measurements on day 2, the average wind speed was 1.51 m/s. This data shows that the wind speed on day 2 was quite strong, so it did not meet the standard of wind speed comfort for humans. According to Bradshaw (1985) wind speeds of >1.02 cause a human response that is more likely to complain due to air movement that blows hair, shakes clothes, and other disturbances. The results of wind speed measurements continued on day 3 showed that the wind speed on that day was much higher than the first and second days with an average of 1.7 m/s. The wind conditions on the 3rd day were indeed quite strong, so it is not surprising that after being measured the numbers obtained were high.

Based on surface temperature measurements in the dense greenery segment, the average surface temperatures on day 1, day 2, and day 3 were 32.55°C, 28.1°C, and 26.55°C, respectively. These figures show that the surface temperature in the dense green space segment is lower than the non-dense green space segment. This situation is certainly influenced by the tree canopy which is able to create climate amelioration around the vegetation. According to Saroh & Krisdianto (2020), tree canopy can affect the microclimate of an area, because the canopy is a collection of several crowns that can affect temperature, humidity, and sunlight intensity that is counteracted by the shade. This is also emphasized by Mala et al (2018) that according to his research, low temperatures are influenced by wide canopy trees. The following is a thermal image of the dense green space segment (Figure 4) along with surface temperature data (Table 3).

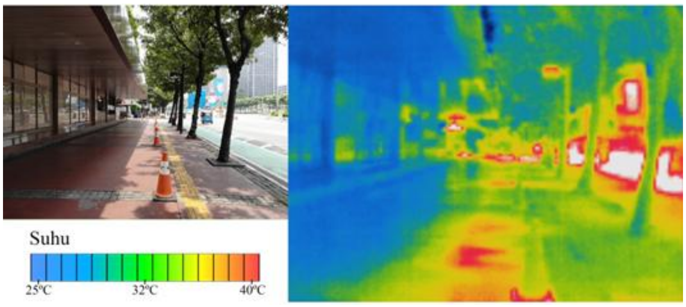

Figure 4. Thermal Image Result of Dense Greenery Segment

Table 3. Average Climate State of the Dense Greenery Segment

No	Day	Time	Air Temperature (°C)	Air Humidity (%)	Wind Speed (m/s)	Surface Temperature (°C)
1		Morning	30,18	51,33	0,92	32,15
2	Day-1	Afternoon	30,72	54,17	0,92	33,9
3		Evening	31,03	53,25	1,22	31,6
4		Morning	29,48	69,92	1,43	27,45
5	Day-2	Afternoon	30,63	64,83	1,39	27,3
6		Evening	32,68	60,58	1,69	29,55
7		Morning	29,52	68,58	1,48	26,45
8	Day-3	Afternoon	29,12	72,33	1,67	26,1
9		Evening	29,04	69,17	1,96	27,1

Visitor Perceptions of Non-Dense Green Space Segment

Based on the table below (Table 4), it can be seen that the respondents of this questionnaire which amounted to 30 people, dominantly assessed that the level of thermal comfort in the non-dense RTH segment in the medium category. This is shown through 13 respondents (43.3%) gave a medium score that is between 14.7 to 19.33. However, the frequency of respondents who gave moderate and low scores was not much different. There were 12 respondents, 40% of the total, who gave a low score of

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less than 14.7. There is only a difference of 1 person on both assessments. Therefore, through these calculations it can be explained that according to user perceptions, the level of thermal comfort in the non-dense green space segment on Jl. MH Thamrin falls into the medium category but tends to be low.

This condition may occur due to the lack of shade and greenery in the non-dense segment, which results in higher surface and air temperatures, increased solar radiation exposure, and intensified glare reflected from nearby high-rise buildings dominated by glass facades. Respondents reported feeling discomfort caused by direct sunlight and heat reflection from surrounding structures during the questionnaire session. Similar findings have been reported in previous studies, where limited vegetation cover and high building density were found to significantly increase air temperature and thermal discomfort in urban street canyons (Mulya & Nedyomukti, 2022, Mulia, 2025; Emmanuel & Krüger, 2012). These studies emphasize the crucial role of vegetation in reducing radiant heat and improving pedestrian thermal comfort in densely built environments.

Table 4. Distribution of Non-Dense Greenery Segment Scores

No	Score	Frequency	%	Category
1	X≥19,33	5	16.66667	High
2	14,7≤X<19,33	13	43.33333	Medium
3	X<14,7	12	40	Low

Visitor Perception of Dense Green Space Segment

Respondents of the questionnaire perception of thermal comfort in Street Canyon, Jl. MH Thamrin which amounted to 30 people, dominant assess the level of thermal comfort in the dense green space segment also falls into the category of moderate (Table 5). This is indicated by 15 respondents ie as much as 50% of the total gave a moderate score that ranged from 15.67 to 19.33 points. Respondents who gave a score in the high category were also quite a lot when compared to the results of the score distribution in the non-dense green spaces segment, namely 36.67%. Through the calculation of the results of this questionnaire it can be seen that according to user perceptions the level of thermal comfort in the segment of dense green spaces on Jl. MH Thamrin into the category of moderate (15.67≤X<19.33).

Most respondents answered six perception items with the response "quite comfortable," indicating that while the presence of vegetation provides noticeable cooling effects, it does not completely mitigate thermal discomfort. Although the tree canopy in the dense green space segment is relatively thick, the high density of surrounding buildings and the intensity of vehicle traffic still contribute to accumulated heat and limited airflow, reducing the overall cooling effectiveness. This phenomenon aligns with findings by Shashua-Bar et al. (2021), who noted that vegetation can lower surface and air temperatures through shading and evapotranspiration, yet its cooling capacity becomes constrained in narrow, high-density urban canyons.

Table 5. Score distribution of dense greenery segments

No	Score	Frequency	%	Category
1	$X \geq 19,33$	11	36.66667	High
2	$15,67 \leq X < 19,33$	15	50	Medium
3	$X < 15,67$	4	13.33333	Low

Correlation Analysis of Thermal Comfort Attributes and Respondents' Perceptions (SPSS)

The basis for decision making to determine whether or not there is a correlation, seen through the significance value. If the significance value is <0.05 then the two variables are correlated, otherwise if the significance value is> 0.05 then there is no correlation. The figure below (Figure 5) shows the results of processing the Spearman rank correlation between air temperature and respondents' perceptions, which obtained a significance value of 0.000. The magnitude of this significance indicates that the air temperature variables and respondents' perceptions are correlated. Furthermore, the strength of the correlation relationship between the two can be seen from the correlation coefficient value, which is -0.853. The correlation coefficient value which is in the range of 0.76-0.99 indicates that there is a very strong correlation relationship for the two variables. Furthermore, the sign (-) listed on the correlation coefficient value shows the direction of the relationship between variables. A negative correlation coefficient indicates that the relationship between the two variables is not unidirectional. This means that an increase in air temperature results in a decrease in the respondent's perception value and a decrease in air temperature causes an increase in the respondent's perception. In line with research from Ramawangsa & Atik (2021) conducted in the threshold area in the microclimate, it was found that an increase in air temperature made the thermal comfort level of room users decrease. This is characterized by the physiological stress level of most respondents who experience moderate heat stress. Sastrawan & Mustika (2018) in their research also showed that during the day the

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perception of users in Lumintang City Park was in a warm condition. This tendency is certainly influenced by climatic factors, and one of them is temperature.

Correlations

			Total Air Temperature	Total Respondents' Perception
Spearman's rho	Total Air Temperature	Correlation Coefficient	1.000	-.853**
		Sig. (2-tailed)	.	.000
		N	36	36
	Total Respondents' Perception	Correlation Coefficient	-.853**	1.000
		Sig. (2-tailed)	.000	.
		N	36	36

**. Correlation is significant at the 0.01 level (2-tailed).

Figure 5. Spearman Rank Correlation of Air Temperature with Respondents' Perception

Based on the significance values listed in the figure below (Figure 6), it can be seen that air humidity and respondents' perceptions are correlated. In addition, the strength of the relationship between air humidity and respondents' perceptions has a very strong correlation, with a correlation coefficient value of 0.911. A positive correlation coefficient indicates that the relationship between the two variables is unidirectional. The meaning of unidirectional is, if the value of variable X increases, it will also be followed by an increase in the value of variable Y. Vice versa, a decrease in the value of variable X also has an impact on decreasing the value of variable Y. This strong positive correlation suggests that higher air humidity tends to enhance users' perception of thermal comfort, as moist air reduces evaporative heat loss and makes the environment feel warmer and more stable. Similar results were reported by Fadli et al. (2023) and Nguyen & Vo (2022), who found that relative humidity is one of the dominant climatic parameters influencing outdoor thermal perception in tropical urban settings. These findings reinforce that humidity should be considered a key determinant when evaluating thermal comfort in dense urban environments.

Correlations

			Total Air Humidity	Total Respondents' Perception
Spearman's rho	Total Air Humidity	Correlation Coefficient	1.000	.911**
		Sig. (2-tailed)	.	.000
		N	36	36
	Total Respondents' Perception	Correlation Coefficient	.911**	1.000
		Sig. (2-tailed)	.000	.
		N	36	36

**. Correlation is significant at the 0.01 level (2-tailed).

Figure 6. Spearman Rank Correlation of Air Humidity with Respondents' Perception

Spearman rank correlation analysis between wind speed and respondents' perception at Street Canyon, Jl. MH Thamrin gave correlated results (<0.05). The relationship between the two has a very strong strength, seen from the correlation coefficient value (0.893) which is in the range of 0.76-0.99 (Figure 7). Furthermore, based on the data, it can also be seen that the relationship between wind speed and respondents' perceptions is unidirectional (positive value). Therefore, the increase in wind speed turned out to have a positive effect on the increase in respondents' perceptions of the level of thermal comfort. This strong positive association indicates that airflow plays a crucial role in enhancing thermal comfort by facilitating heat dissipation and increasing convective cooling around the human body. In dense urban canyons such as Jl. MH Thamrin, limited air circulation often exacerbates heat accumulation. Therefore, even moderate increases in wind speed can significantly improve perceived comfort. Similar findings were reported by Shahidan et al. (2019) and Yunus et al. (2022), who demonstrated that wind speed effectively reduces surface temperature and physiological thermal stress in tropical urban streets.

Correlations

			Total Wind Speed	Total Respondents' Perception
Spearman's rho	Total Wind Speed	Correlation Coefficient	1.000	.893**
		Sig. (2-tailed)	.	.000
		N	36	36
	Total Respondents' Perception	Correlation Coefficient	.893**	1.000
		Sig. (2-tailed)	.000	.
		N	36	36

**. Correlation is significant at the 0.01 level (2-tailed).

Figure 7. Spearman Rank Correlation of Wind Speed with Respondents' Perception

The results of the Spearman rank correlation between surface temperature and respondents' perceptions also indicate a correlation between the two (Figure 8). Similar to the correlation between air temperature and perception, this correlation has a large correlation coefficient value of -0.928. It can be concluded that surface temperature and respondents' perceptions have a very strong correlation strength and the direction of the relationship between the two is not unidirectional. Through these calculations, it is found that the higher the surface temperature, the lower the respondent's perception value and vice versa. This strong negative correlation highlights that elevated surface temperatures intensify radiant heat exposure, thereby increasing thermal stress and reducing pedestrian comfort in dense urban canyons. High surface temperatures often resulting from heat-retaining materials such as asphalt and concrete contribute substantially to the urban heat island effect and limit the cooling influence of surrounding vegetation. Previous studies by Santamouris et al. (2020) and Li et al. (2022) reported that surface materials with high thermal emissivity and low albedo significantly increase mean radiant temperature (MRT), directly reducing outdoor thermal comfort. These findings reinforce that surface temperature acts as a critical driver of outdoor discomfort in high-density tropical urban environments.

Correlations

			Total Surface Temperature	Total Respondents' Perception
Spearman's rho	Total Surface Temperature	Correlation Coefficient	1.000	-.928**
		Sig. (2-tailed)	.	.000
		N	36	36
	Total Respondents' Perception	Correlation Coefficient	-.928**	1.000
		Sig. (2-tailed)	.000	.
		N	36	36

**. Correlation is significant at the 0.01 level (2-tailed).

Figure 8. Spearman Rank Correlation of Surface Temperature with Respondents' Perception

The findings of this study provide valuable insights for urban design and environmental planning, particularly in developing strategies to improve outdoor thermal comfort in dense urban corridors. The strong correlations between vegetation density, microclimatic parameters, and users' thermal comfort perceptions highlight the importance of integrating greenery into street design. In practical terms, tree placement and canopy coverage should be optimized to maximize shading efficiency while allowing sufficient air circulation within the street canyon. Urban planners and landscape architects can utilize these results to guide the selection of tree species with broader canopies and higher evapotranspiration rates for streets similar to Jl. MH Thamrin. Furthermore, implementing green infrastructure strategies—such as permeable pavements, vertical greenery systems, and continuous roadside planting—can significantly mitigate surface heat accumulation and enhance pedestrian comfort. These implications are particularly relevant for high-density tropical cities, where achieving thermal balance between built surfaces and natural elements is essential for sustainable urban livability.

D. CONCLUSIONS

Thermal comfort attributes in Street Canyon, Jl. MH Thamrin when viewed as a whole does not meet the standards of human thermal comfort. The average total air temperature in the non-dense green space segment is 31.12°C. This result is higher than the dense green space area which is 30.27°C. The total average air humidity in the dense green space segment is 62.69%, while in the non-dense green space segment it is 62.16%. The amount of wind speed in the dense greenery segment has a total average of 1.41 m/s. The wind condition is quite high, making it less comfortable for road users. In the non-dense green space segment, the wind speed from day 1 to day 3 averaged 0.99 m/s. Furthermore, the average surface temperature in the non-dense green space segment is around 31.86°C, while in the dense green space segment it is 29.07°C. The results of road users' perceptions in Street Canyon, Jl MH Thamrin at different levels of vegetation density, it was found that the perception of users in the dense green space segment fell into the moderate category ($15.67 \leq X < 19.33$). Meanwhile, the level of thermal comfort in the non-dense green space segment on Jl. MH Thamrin also falls into the medium category but tends to be low. This is because 43.3% of respondents gave a medium score that is between 14.7 to 19.33. However, the frequency of respondents who gave a score of moderate and low in fact not much different, namely 40% gave a score of less than 14.7. All attributes of thermal comfort with the perception of road users turned out to be correlated. Air temperature with user perception has a strong correlation relationship and the direction of the relationship is not unidirectional (correlation coefficient -0.853). Similarly, the surface temperature and user perceptions are strong correlation relationship with the direction of the relationship is not unidirectional (correlation coefficient -0.928). The meaning of the unidirectional relationship is that the increase in variable 1 will affect the decrease in the value of variable 2, and vice versa. In contrast, air humidity and user perception also have a strong correlation relationship, but the direction of the relationship is unidirectional (correlation coefficient 0.911). Wind speed and road user perceptions are strongly correlated and the direction of the relationship is unidirectional (correlation coefficient 0.893). Unidirectional relationship here means, an increase in wind speed levels will cause an increase in respondents' assessment of thermal comfort.

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