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Analysis of Thermal Characteristics of Urban Streets Using Thermal Imaging Camera : Case Study of Commercial Streets in Banjarbaru

Yuswinda Febrita, Rudi Hartono
Department of Architecture, Civil Engineering Faculty, Lambung Mangkurat University, Banjarbaru, South Kalimantan, Indonesia

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ABSTRACT

Continuous urban growth and global warming over the past few decades have led to the urban heat island (UHI) effect, which has become a serious threat to urban residents. Impervious surfaces, low-albedo buildings, and lack of vegetated areas are the main causes of poor urban thermal environments, especially during summer. Several previous studies only focused on the thermal characteristics of each building unit that influence pedestrian thermal comfort. The aim of this research is to analyze the thermal characteristics of various physical elements on urban roads using thermal imaging cameras, and present a conceptual model of improved road shapes and materials for buildings and pavements with respect to the thermal environment in cities to improve the thermal comfort of outdoor pedestrians room. This study examines the road-scale thermal environment of two main commercial roads: A. Yani street km.33-37 and Panglima Batur street, in Banjarbaru, South Kalimantan. This study conducted field measurements both during the day and at night in July 2023 to investigate changes in urban surface temperatures over time. The results show that trees are the most effective mitigation element for reducing surface temperatures. With regard to the type of building use, the highest surface temperature is near asphalt shophouses with minimal trees along the road. Glass building facades and dark-colored or partially metal-covered walls contribute to high surface temperatures. Likewise, the temperature of cast concrete in parking areas and sidewalks on urban streets is also very high during the day. The thermal characteristics of various urban road elements should be considered to reduce surface temperatures and reduce the urban heat island effect.

Keywords: Urban Heat Island, Thermal Characteristics of Urban Road Elements, Thermal Imaging Cameras

I. INTRODUCTION

Continuous urban growth and global warming over the past few decades, as well as the urban heat island effect which refers to the phenomenon where the ambient air temperature in cities is higher than in rural areas, have become a serious threat to urban residents. Impervious surfaces, low-albedo buildings, and lack of vegetated areas are the main causes of poor urban thermal environments, especially during summer in humid tropical climates.

In recent years, summer air temperatures have continued to rise. Moreover, more and more residents are threatened by the effects of urban heat islands (UHI) and tropical night phenomena [1]. The UHI phenomenon negatively impacts human health, increasing the intensity of heat waves, which in turn adversely impacts human health due to increased exposure to extreme thermal conditions [2]. In this context, many researchers have tried to solve the above-mentioned problems using UHI mitigation strategies to reduce urban air temperature directly or indirectly using urban physical elements to achieve shading effects and create a better walking environment [3-5]. In addition, the thermal characteristics of various urban road elements must be considered to reduce surface temperatures and reduce the urban heat island effect [6].

Although many studies on the effects of UHI in dense areas have been conducted, most of the studies conducted use thermal simulation tools and focus mainly on urban form [7-9]. In other words, only a few studies have measured the thermal characteristics of urban road elements using thermal imaging cameras. This study aims to investigate the influence of urban road elements including street trees, pavement materials, parking and shophouse buildings (ruko) on road surface temperatures in the city of Banjarbaru, the capital of South Kalimantan, using thermal imaging cameras. Temperature differences caused by the amount of solar radiation reaching the ground surface were analyzed during the day and at night. Thus, the aim of this research is not only to test better road forms and materials for buildings and pavements with respect to the thermal environment in cities, but also to propose implications for improving the thermal comfort of outdoor pedestrians by analyzing the thermal characteristics of urban street elements.

Urban landscape morphology greatly influences microclimate conditions. Microclimatic conditions show variations in different urban landscapes. To create a better urban street thermal environment for pedestrians, the shading effect of street trees should be optimized, construction materials with high albedo values or high emittance (especially at lower levels of buildings) should be used. These strategies should be considered especially in urban areas where pedestrians are exposed to extreme heat stress [6].

Yamazaki et al. (2009) conducted research on the effects of UHI in Tokyo, Japan, using thermal images. The research results show that the surface temperature of asphalt roads is significantly higher compared to other types of pavement. This study also found that areas with roadside trees and plants in the middle of the road are cooler than areas of sidewalks or building walls. Researchers used air thermal sensors to investigate the mitigating effects of urban rooftop greening. The results showed that the highest temperature of the tile roof was 46.4 °C, while the vegetated roof surface was significantly cooler. In addition, this study discusses the mitigation effects of various types of vegetation. [10].

Additionally, Hwang et al. (2014) in [6] examined urban elements that have the potential to negatively impact the thermal environment using thermal imaging cameras. According to the results, urban surfaces—for example, road pavement, green areas, shading effects, building facades, and signage materials—play an important role in the UHI effect.

In most cases, dark-colored pavement types, such as asphalt, concrete, or granolith pavement surfaces, have been shown to contribute to high temperatures, whereas vegetated pavements are significantly 10 °C cooler than other pavements or nearby buildings, due to the protective trees. direct solar radiation. Construction materials are also discussed. The surface temperature of building facades made of artificial construction materials is generally higher than that of building facades in green areas, because artificial construction materials have lower albedo values, and building facades are exposed to direct solar radiation during the day. Researchers identified several main factors that cause the UHI effect, including paved roads, signage, and building walls. However, these studies address the thermal behavior of only a few construction materials.

Furthermore, Yoon (2009) in [6] examined the thermal environment in a medium-sized city in Korea, with different research times, namely autumn and winter. In accordance with previous research findings on urban surface temperature, the results of the study showed that the surface temperature of asphalt pavement was higher than the surface temperature of vegetated areas or dewalk blocks around artificial fountains during both easons. The study also found a strong relationship between urban surface temperatures and ambient air temperatures. For example, high surface temperatures lead to warmer air temperatures in many cases. Despite these findings, this study has limitations in that it only considers limited urban surfaces found in the immediate study area.

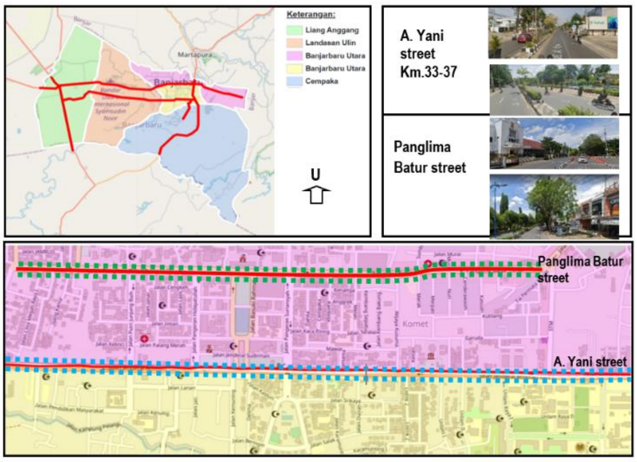
A study by Elhinnawy (2004) conducted on a building at Arizona State University evaluated the thermal behavior of the building envelope. This study found that the surface temperature of the eastern facade varies depending on the albedo value. For example, a 3°C decrease in surface temperature was observed for every 0.05 increase in albedo at 9:00, when the highest temperature value was measured. Therefore, surface albedo values can be effectively applied to urban planning processes as a powerful UHI mitigation strategy. However, despite these findings, this study has limitations because it only focuses on one particular building, which prohibits generalization of temperature changes on building facades constructed from the same materials in different locations [11].

In addition to albedo values, several studies have discussed the thermal properties of various types of building materials (e.g., specific heat capacity, radiative power) to analyze their thermal behavior [12-14]. These studies address the role of specific heat capacity. For example, materials with a high heat capacity, such as concrete ground surfaces, tend to emit more heat energy, especially at night, when compared to materials with a lower heat capacity. As a result, materials with a high heat capacity can create an uncomfortable thermal environment for pedestrians. Material heat release may also be very important for surface temperature [15]. Materials with low heat emittance can have high surface temperatures due to less heat emissivity and less heat loss due to convection.

The assessment of human comfort in outdoor spaces is a multi-physics subject, requiring consideration of the interrelationships between environmental and thermo-physiological parameters. Microclimate conditions should be studied at a small-scale level, taking into account incident solar radiation, weather conditions at the site and the properties of building materials in the surrounding area [16].

II. METHODS AND MATERIAL

As areas close to the equator, urban landscapes in hot-humid tropical areas are often exposed to high intensity solar radiation. The city of Banjarbaru is located at coordinates 03°27' - 03°29' South Latitude and 114°45' - 114°48' East Longitude. Two main commercial roads, A. Yani Street Km.33-37, and Panglima Batur street, located in North Banjarbaru District, Banjarbaru City were chosen as study areas. These roads are close together, so they are considered to experience the same climatic conditions. Various characteristics are found on each street, even though both are commercial streets. More specifically,



different types of building use (e.g., restaurants, coffee shops, cosmetic/clothing shops, residential buildings), street tree density, street width, and building shape are characteristics of each street (Figure 1).

Figure 1. Two urban streets of case study in Banjarbaru.

A. Yani street, the main commercial street in Banjarbaru, has sidewalks along the two-lane road, and is famous for its distinctive features. There are street trees and many shops, such as food stores, restaurants, clothing stores, mini markets, residential houses, office, bank and coffee shops, which give the street a very unique atmosphere. Compared with other streets in the study area, A.Yani street has more retail shops. Its two-lane structure also allows driving at relatively higher speeds than on other roads. Regarding building configurations, different construction materials and building heights provide an interesting variety of building designs. Some stores provide parking areas and sidewalks for pedestrians by setting the buildings back from the street, and consistent building lines were identified for this study area, and the sidewalk width was also constant.

Likewise, Panglima Batur street is almost the same as A, Yani street as a commercial area. Existing shophouses and buildings, most of which are used for residential, office and educational purposes, coexist on Panglima Batur street, forming a distinctive feature of the street. Trees are still visible along roads and near residential and educational buildings. Regarding car traffic, there are two lanes on Panglima Batur street but they are narrower than A.Yani street ensuring lower driving speeds. Additionally, not many cars were observed in the study area due to its residential features.

To analyze the surface temperature of urban elements such as building use type, construction materials, street tree width, and other features under sunny climate conditions, two adjacent commercial streets were selected for this study. Even though the roads are around 3000 m long, the researchers focused on selecting of around 500 m length of each road as the study area.

Climate data from Banjarbaru Meteorology and the K-Weather database are used to determine the timing of measurements in the hottest month of the last 5 years. High resolution infrared thermal imaging camera. Seek ShotPRO Pocket-Sized Thermal Imaging Camera and Fluke VT02 are used to measure urban surface temperatures. The camera receives radiation from the target object, plus radiation from its surroundings that has been reflected onto the object's surface. Surface temperature is calculated by emissions from objects, reflected emissions from surrounding sources, and emissions from the atmosphere. is the most advanced thermal imaging camera for professional buildings. Snapshots and videos can be immediately analyzed with the on-board thermography tool. With the addition of a measurement and temperature box for making reports, it will save time on the spot. Precisely diagnose problems with 16 times the camera resolution. The Seek ShotPRO camera has a field of view (FOV) of 57° and a thermal sensor: 320 x 240 and has a temperature measurement range of -40 °C to 330 °C. Meanwhile, the Fluke VT02 camera has a temperature measurement range: -10 °C to +250 °C (14 °F to 482 °F). has a field of view or field of view: 28° x 28°. The minimum distance to obtain an accurate thermal image is <23cm (9 inches) from the target and the maximum distance is >23cm (9 inches) from the target, and the image is automatically calibrated to that distance.

Analysis of the thermal images produced for the Seek ShotPRO Camera can be used directly on the camera so

it will make things easier. Meanwhile, the Fluke VT02 uses Fluke's special analysis software. Thermal images are taken from the front, because they provide more accurate thermal data and are not obstructed by pedestrians. Field measurements were carried out in July 2023. In addition, measurements were carried out during the day and at night, which were set at 12:00–14:00 and 19:00–20:00 respectively. Thus, the urban surface temperature characteristics during both time periods were obtained by analyzing the average values at each time 13:00: average temperature, average humidity (RH), average wind speed.

Two thermal imaging cameras were used for each road (Figure 2). Images of each building on the street were obtained, including images of sidewalks adjacent to the buildings. To get a more accurate pavement surface temperature at close range. As illustrated in Figure 2, analyzing the surface temperature of five points, including the middle height of the outer wall of the first floor, the bottom of the building facade, the sidewalk adjacent to the building, the sidewalk adjacent to the street, and the asphalt road. This spot was chosen because it is considered to represent the main factors that influence pedestrian thermal comfort. Thus, the thermal characteristics of urban elements at five different points are observed.

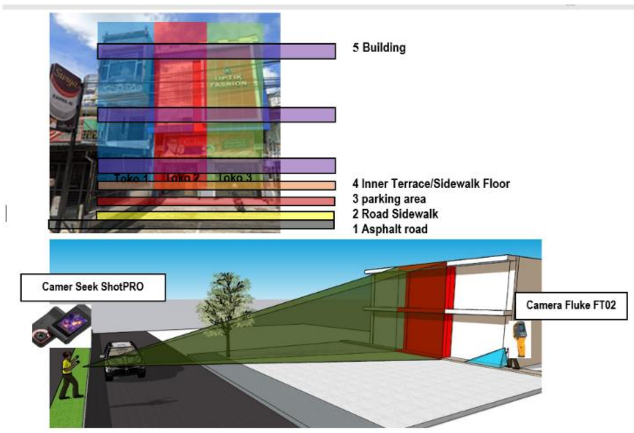


Figure 2. Example of field measurements using two thermal imaging cameras

Sample	Block 1			Block 2			Block 3			Block 4		
	AY 1	AY 2	AY 3	AY 4	AY 5	AY 6	AY 7	AY 8	AY 9	AY 10	AY 11	AY 12
Figure												
Material	glass 80%, white paint plaster brick 20%	glass 80%, white paint plastered brick 10%, shop billboards (metal) 10%	glass 80%,brick plastering white paint 20%	glass 30%, brick plastering cream paint 10%, ACP 60%	70% glass, 10% cream paint plastered brick, 20% ACP	30% glass, 30% cream paint plastered brick, 30% iron folding door, 10% wooden door	glass, 30% cream paint plastered brick, 35% iron folding door, 5% wooden door	glass 20%, plastered brick with cream paint 40%, iron folding door 35%, wooden door 5%	Glass 35%, 30% cream paint plastered brick, 35% iron folding door, 5% wooden door	glass 30%, brick plastering cream paint 10%, ACP 60%	glass 50%, brick plastered with cream paint 50%	glass 50%, brick plastered with cream paint 50%
Material of Inner Terrace/ Sidewalk Floor	ceramic	ceramic	ceramic	ceramic	ceramic	ceramic	ceramic	ceramic	ceramic	ceramic	ceramic	ceramic
Material of parking area	Cast concrete	Cast concrete	Cast concrete	Cast concrete	Cast concrete	Cast concrete	Cast concrete	Cast concrete	Cast concrete	Cast concrete	Cast concrete	Cast concrete
Material of Road Sidewalk	Cast concrete	Cast concrete	Cast concrete	Cast concrete	Cast concrete	Cast concrete	Cast concrete	Cast concrete	Cast concrete	Cast concrete	Cast concrete	Cast concrete
Function	Shop house	Shop house	Shop house	Shop house	Shop house	Shop house	Shop house	Shop house	Shop house	Shop house	Shop house	Shop house

III.RESULTS AND DISCUSSION

Shophouse environmental surface materials A. Yani street km. 33-37. Which consists of two and three storey shophouses. The orientation of 3 shophouse blocks facing north (blocks 1-3) and 1 shophouse block facing south A. Yani street (block 4) as in Figure 3.

Figure 3. Surface materials of shophouse environment A. Yani street km.33-37

Panglima Batur street was observed to have the highest asphalt surface temperature among the two study object streets. The surface material for the highest street element is asphalt, the second is the outer sidewalk made of cast concrete and the third is the parking area which is also made of cast concrete. Shophouse environmental surface materials Panglima Batur street, which consists of a two-story shophouse. Orientation of 3 shophouse blocks facing north and 1 shophouse block facing Panglima Batur street as in Figure 4.

Sample	Block 1			Block 2			Block 3			Block 4
	PB 1	PB 2	PB 3	PB 4	PB 5	PB 6	PB 7	PB 8	PB 9	PB 10
Figure										
Material	glass 30%, yellow paint plastered brick 10%, shop billboards (metal) 60%	20% glass, 40% yellow paint plastered brick, 40% iron folding door	20% glass, 20% yellow paint plastered brick, 20% shop sign (banner), 40% iron folding door	glass 50%, yellow paint plastered brick 20%, shop billboards (metal) 20%	50% glass, 20% yellow paint plastered brick, 20% shop billboards, 10% shop banners	glass 50%, yellow paint plastered brick 20%, shop billboards (metal) 30%	10% glass, 40% cream paint plastered brick, 30% iron folding door, 10% wooden door, 10% shop banner	40% glass, 40% white paint plastered brick, 60% white paint laser cutting iron plate	10% glass, 40% cream paint plastered brick, 30% iron folding door, 10% wooden door	glass 5%, blue paint plastered brick 40%, iron folding door 30%, shop advertising banner 25%
Material of Inner Terrace/ Sidewalk Floor	ceramic	ceramic	ceramic	ceramic	ceramic	ceramic	ceramic	ceramic	ceramic	ceramic
Material of parking area	Cast concrete	Cast concrete	Cast concrete	Cast concrete	Cast concrete	Cast concrete	Cast concrete	Cast concrete	Cast concrete	Cast concrete
Material of Road Sidewalk	Cast concrete	Cast concrete	Cast concrete	Cast concrete	Cast concrete	Cast concrete	Cast concrete	Cast concrete	Cast concrete	Cast concrete
Function	Shop house	Shop house	Shop house	Shop house	Shop house	Shop house	Shop house	Shop house	Shop house	Shop house

Figure 4. Surface materials of shophouse environment Panglima Batur street km.33-37

Figure 5 shows the average surface temperature at five different points on each road during the day and night, measured using a thermal imaging camera. As shown in the picture, the five different points are the middle height of the building wall, inner terrace/sidewalk floor, parking area, sidewalk road, asphalt road.

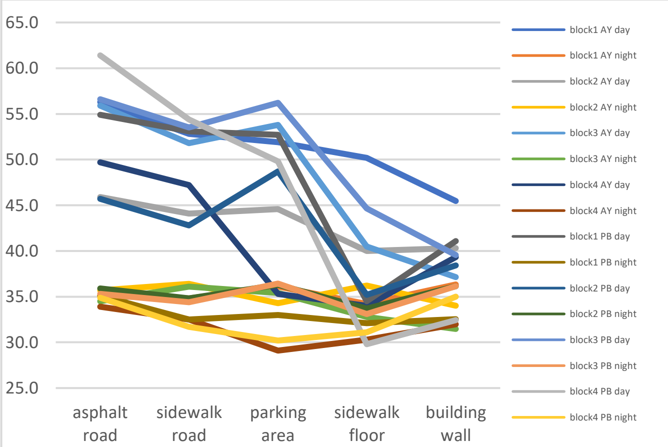


Figure 5. Average surface temperature analysis of case study streets.

The highest surface temperatures mainly occur on roads. In contrast, the lowest temperatures were measured on the building facade. The cause of the low surface temperature of a building facade is due to the facade material. Glass facades are found on every street, and glass is easily affected by cold indoor air. In other words, the air conditioning system cools the indoor air, which ultimately lowers the surface temperature of the glass facade.

When comparing the average daytime temperatures on the two roads, the lowest average road surface temperature occurs in block 2 of Jalan Panglima Batur (45.7 °C), where most of the road is covered by the shadows of trees. Meanwhile, the average road surface temperature is highest in block 4 Jalan Panglima Batur (61 °C), where there are shop houses with few trees and many restaurants which can emit large amounts of anthropogenic heat. The highest average surface temperature was measured in block 1 of Jalan A. Yani (56.3 °C), due to the lack of trees on the street. On Jalan A. Yani, only a small part of the sidewalk is covered in shadow, because the street trees are far away on Jalan A. Yani, especially in the block of shop houses. Generally, the parking area has very few trees due to maximizing the parking area. In contrast to office blocks, many of the sidewalks are covered in shadow, because the distance between adjacent street trees is in accordance with standards. Some shophouse areas experience a shadow effect from street trees in the office area next to them, thus affecting the surface temperature of the shaded street elements which lowers the surface temperature.

In contrast, higher surface temperatures were seen in block 2 of Panglima Batur street, where there were more vehicles and people with supermarkets (35.9 °C) at night. In addition, there are more anthropogenic heat emissions from supermarkets on Jalan Panglima Batur. Interestingly, street trees show a negative impact on nighttime temperatures, as they trap heat generated during the day.

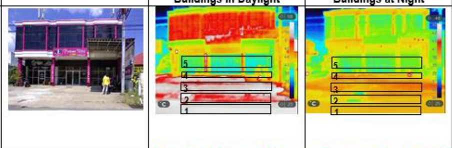
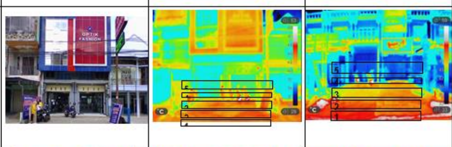
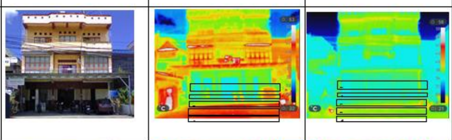
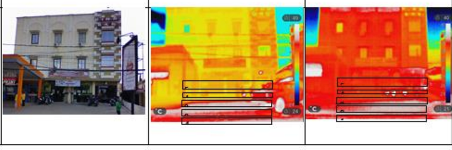
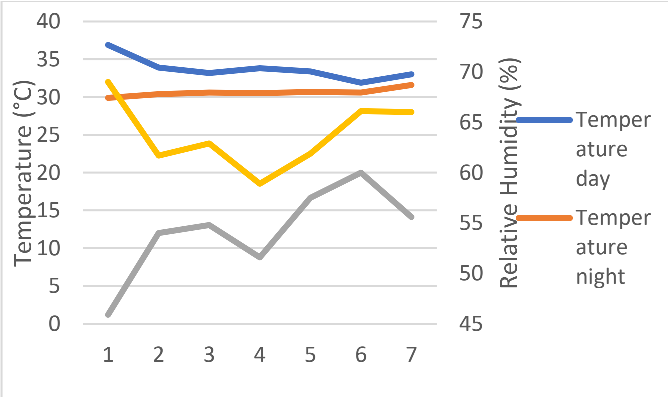
No.	Photo	Thermal Photos of Roads, Outside Sidewalks, Parking Lots, Inside Sidewalks/Terraces, Buildings in Daylight	Thermal Photos of Roads, Outside Sidewalks, Parking Lots, Inside Sidewalks/Terraces, Buildings at Night	Day/Night Temperature
AY 1 AY 2 AY 3				T day 33,7°C, T night 30,6°C
AY3 AY4 AY5				T day 34,5°C, T night 30,7°C
AY 7 AY 8 AY 9				T day 34,8°C, T night 30,7°C
AY 10 AY 11 AY 12				T day 35,7°C, T night 30,1°C

Figure 6. Influence of Environmental Temperature by Surface Temperature of Road Elements on A.Yani street

Environmental temperature on A. Yani street results of field measurements for seven days during the day from 12.00 - 14.00 and at night from 19.00 - 21.00, with clear skies. Figure 7 shows the environmental temperature of shophouses in blocks 1 - 4. When the environmental temperature increases, humidity is low due to high wind speeds during the day. The difference in average environmental temperature during the day and night is 3.1 °C. Likewise, the difference in average humidity that occurs in the environment during the day and night is around 9.6%. The average wind speed during the day is 1.7 m/s and at night 1.5 m/s. Meanwhile, according to Wei and Yang (2014), the thermal comfort value of PET PET (psychologically equivalent temperature) in Singapore with a tropical monsoon climate is around 25-30°C with case studies in parks [17]. The PET Index considers several climate variables, namely; air temperature (Ta), air humidity (RH), wind speed (V) and radiation temperature (Tmrt), as well as physiological variables, namely human condition (activity, clothing and body size). From the measurement results it was found that the temperature conditions in the environment on Jl. A. Yani 33.7 °C during the day and 30.6 °C at night, so the temperature is beyond thermal comfort for pedestrians crossing the road with the existing urban elements.



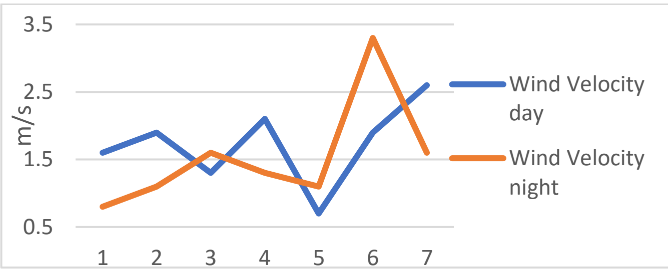


Figure 7. Comparison of Microclimate Conditions (Temperature, Humidity and Wind Speed) on A.Yani street for 7 Days in July 2023

For the coldest shophouse block on A. Yani street is in the second block with an orientation to the north. The facade of the shophouse building in block four consists of 30-70% glass, 10-30% cream paint plastered brick, 20-60% ACP, 70% glass and 30% iron folding doors, wooden doors. 10% percentage of glass area smaller than the shophouses in the first block. The average surface material temperature of the hottest AY3 shophouse in the second block is glass, Floor 2, namely 47 °C and the second hottest shophouse surface material temperature is brick plastered with cream paint, Floor 3, namely 43 °C. Meanwhile, the surface material temperature of the hottest shophouse environment in the second block is asphalt, namely 45.9 °C and the second hottest surface material temperature of the shophouse environment is the outer sidewalk, namely 44.1 °C. The asphalt temperature in this second block is lower than in other blocks along the road, Yani km. 33-37.

On Panglima Batur street, the highest surface temperature was observed in the third block, which is shown in Figure 8. This block has the least shade compared to other blocks of Jalan Panglima Batur. In addition, more than 60% of the building facade is covered with laser-cut iron plates, and 40% glass glass material. The average surface temperature of the road asphalt is 56.6 and the sidewalk in this block is 53.5 °C, and the cast concrete parking lot is 62.8 °C, which is the highest compared to the average temperature of other surfaces and the ceramic terrace floor is 62.4 °C. The lowest temperature on Jalan Panglima Batur was observed in the fourth block (Figure 5.6). The ceramic terrace floor or inner sidewalk in this block is 100% covered in shade, lower than the average for all blocks of 29.8 °C. Glass is applied to only 5% of the building facade, and blue paint plastered brick material is the most dominant for 40% of the overall facade. The average surface temperature of the outer sidewalk is 54.4 °C, 0.9 °C higher than the block with the highest temperature on Panglima Batur street which is caused by minimal shade from trees along the sidewalk.

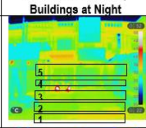
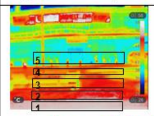
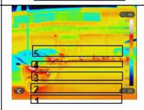
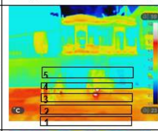
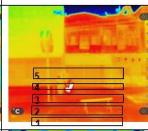
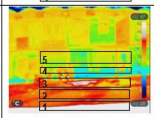
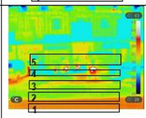
No.	Photo	Thermal Photos of Roads, Outside Sidewalks, Parking Lots, Inside Sidewalks/Terraces, Buildings in Daylight	Thermal Photos of Roads, Outside Sidewalks, Parking Lots, Inside Sidewalks/Terraces, Buildings at Night	Day/Night Temperature
PB 1 PB 2 PB 2				T day 35,6°C, T night 30,3°C
PB4 PB 5 PB 6				T day 35,9°C, T night 30,2°C
PB 7 PB 8 PB 9				T day 35,8°C, T night 30,3°C
PB10				T day 35,6°C, T night 30,1°C

Figure 8. Influence of Environmental Temperature by Surface Temperature of Road Elements on Panglima Batur street

The results of the analysis of differences in environmental temperature from day to night are very interesting. The sample area with the lowest environmental temperature during the day reaches the highest environmental temperature at night. On the other hand, in the sample area with the highest environmental temperature during the day, there is a very large temperature drop after sunset. The reason behind this is that street trees capture and store heat during the day, the effects of which are felt at night.

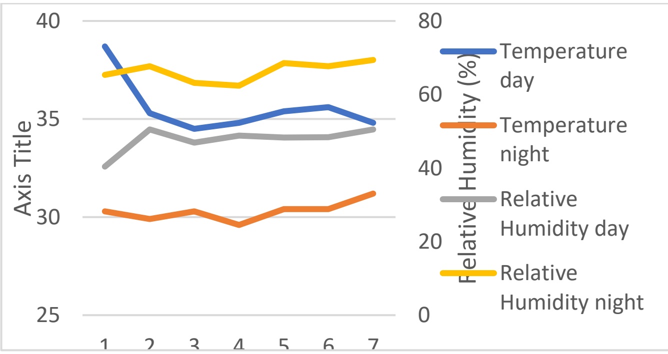


Figure 9. Comparison of Microclimate Conditions (Temperature, Humidity and Wind Speed) on Panglima Batur street for 7 Days in July 2023

Environmental temperature on Panglima Batur street results of field measurements for seven days during the day from 12.00 - 14.00 and at night from 19.00 - 21.00, with clear skies. Figure 9 shows the environmental temperature of shophouses in blocks 1-4. When the environmental temperature increases, humidity is low due to high wind speeds during the day. The difference in average environmental temperature during the day and night is 3.1°C. Likewise, the difference in average humidity that occurs in the environment during the day and night is around 9.6%. The average wind speed during the day is 1.7 m/s and at night 1.5 m/s. Meanwhile, according to Wei and Yang (2014), the thermal comfort value of PET PET (psychologically equivalent temperature) in Singapore with a tropical monsoon climate is around 25-30°C with case studies in parks. From the measurement results it was found that the temperature conditions in the environment on Panglima Batur street is 35.5 °C during the day and 30.3 °C at night, so the temperature beyond thermal comfort for pedestrians crossing the road with the existing urban elements is the same as in A. Yani street.

The highest surface temperatures are mainly observed on highways. In contrast, the lowest temperatures were measured on the building facade. The reason for the lower surface temperature of the building facade is because of the facade material. Glass facades are mainly found on every street, and glass is easily affected by cold indoor air. In other words, the air conditioning system cools the indoor air, which ultimately lowers the surface temperature of the glass facade. In addition, the solar elevation angle mainly reflects the highest surface temperature measured on the roadway. The elevation angle of the sun in Indonesia is 68.1° (http://indonesia.distanceworld.com/sun/2781669) so the area exposed to solar radiation is greater on the road than on the building facade.

In comparing the average daytime temperatures of the two roads, the lowest average road surface temperature was measured on A. Yani street Block 1 (33.7 °C), where most of the road was covered by the shadow of the trees in the median. The asphalt surface temperature of A. Yani Street (56.3 °C), where commercial buildings (shophouses) are adjacent to the Banjarbaru Police Office which has trees on the grass in the front yard and a palm tree configuration along the road. The highest surface temperature was measured in the fourth block of Panglima Batur street (61.4°C), due to the lack of trees on the street in this block, and many food store can emit large amounts of anthropogenic heat. Additionally, road width can contribute to this surface temperature distribution. A. Yani street is 15 m wide, with trees along the median of the road and on either side of the road which cast shadows on the sidewalk during the day on office building blocks, housing complexes, city parks and rarely on commercial blocks (shopehouses). Likewise, Panglima Batur street is 15 m wide, most of the commercial blocks (shophouses) are without trees, so there is no way to block sunlight. On the other hand at night, higher surface temperatures were observed on A. Yani street and Panglima Batur street, where more vehicles and people were observed on A. Yani street (Block 2) 35.7 °C and Panglima Batur street (Block 2) 35.9°C. Apart from that, there are more anthropogenic heat emissions from shophouses that function as supermarkets on Panglima Baturstreet. Interestingly, street trees show a negative impact on nighttime temperatures, as they trap heat generated during the day.

To compare the effect of each material on the thermal environment of each road, factors were observed from the highest and lowest surface temperatures on both roads with the same material, namely cast concrete.

On A.Yani and Panglima Batur streets, street trees have a dominant influence on surface temperature. Since trees can be used to block direct sunlight during the day and create shadows to lower surface temperatures, they should be planted in appropriate places along roads. Regarding building materials, glass was observed to have the third highest surface temperature after shop signs (metal), banners (plexy banners) and videotrons, followed by ACP building materials and fourthly plaster walls. On the other hand, building materials, such as laser cutting iron plates, have the highest surface temperatures. The highest surface temperature of dark colored building materials is caused by the low albedo value or low emissivity value of dark colored building materials. Building materials with low emissivity values emit little thermal radiation, ultimately reducing heat loss through convection.

There is a lack of trees in blocks with commercial functions because maximizing the area in front of the shophouse as a parking lot with cast concrete pavement causes the environmental temperature to be hot compared to areas shaded by trees. Urban greening and building design have great potential to improve the climate of urban areas through the processes of evapotranspiration, surface shading and water evaporation [18 – 19].

There are two main causes of this warming in cities. First, most urban building materials are impermeable, so moisture is not available to dissipate solar heat. Second, dark matter in building configurations and road pavement collects and absorbs more solar energy. Anthropogenic heat, or human-generated heat, slower wind speeds and air pollution in urban areas also contribute to the formation of heat islands.

Urban materials have three thermal characteristics that influence the increase in UHI in urban areas, namely albedo, emissivity and heat capacity. In general, the use of materials with high albedo will reduce the amount of solar radiation absorbed through the construction of urban envelopes and structures and inhibit the cooling of urban surfaces. According to Chudnovsky et al. (2004), light colored objects will reflect more solar heat than dark colored objects. A white roof will reflect most of the sun's heat, while a black roof will absorb most of the heat from the sun [20].

Based on the discussion of factors that influence urban thermal, it can be concluded that in the urban spatial landscape, including urban road elements, what needs to be considered is the composition and configuration of the urban spatial landscape in the form of land cover components. Urban land cover components consist of urban geometric components (buildings and roads) and natural components (trees, parks, grass, soil and water). Judging from the thermal and radiation properties, as well as the thermal properties of each component of urban land cover, it has an influence on urban thermal conditions. From these urban physical characteristics, several design parameters of the urban landscape that influence the urban thermal system can be concluded, namely as follows:

- Percentage of land cover components (landscape elements)
- Regional orientation
- Building mass placement pattern
- Comparison of H/W Values
- Vegetation placement patterns
- Shadowing (buildings and trees): percentage of shadowed area.

For further research to obtain a more complete character of the urban thermal system, this is by including the factors mentioned above. By using a simulation program modeling microclimate conditions and thermal comfort which is widely used by previous researchers, namely ENVI-met. ENVI-met simulates all meteorological parameters including air temperature, relative humidity, wind speed and solar radiation. ENVI-met requires only one data input for each meteorological parameter in the simulation, which creates the most likely weather conditions.

Agree with the statement (Oke, T.R., 1973; Yang, F. et al, 2010; Yang, X. et al, 2015; Sharmin, T. et al, 2017), that the effects of urban morphology, namely, the basic elements of urban structure such as buildings, roads and other features influence the thermal environment in cities that have been analyzed in this research [21 – 24]. The research results also show that the surface temperature of asphalt roads is significantly higher compared to other types of pavement. Where the results show that the highest temperature is 61.4 °C higher than the outer sidewalk and parking area with cast concrete material. This study also found that areas with roadside trees and plants in the middle of the road are cooler than sidewalk areas or building walls in accordance with research by Yamazaki et al. (2009) [10].

This research also shows that urban elements that have the potential to have a negative impact on the thermal environment using a thermal imaging camera such as road pavement (asphalt, concrete sidewalks and concrete parking areas), building facades (glass, ACP, metal, dark paint plastered walls) and signage materials. /advertising (metal, flex banners, Videotron Signboards) which play an important role in heating in urban environments is in accordance with the opinion of Hwang et al. (2014) in Lee at al. (2018 [6].

Good road shapes and materials for buildings and pavement in relation to the thermal environment in the city to increase the thermal comfort of outdoor pedestrians are using parking pavement materials from grass paving blocks. Outside sidewalk with granite material in accordance with Irmak. et al (2017) that grass, travertine, and granite cubes are optimal surface materials, because they exhibit heat stress levels close to the comfort range (18.1 - 23.0 ºC) [25]. Users apply the appropriate type of glass, color and thickness as well as an effective shading system that responds to solar radiation in shophouse buildings which ensures visual and thermal comfort for users and its impact on the internal and external environment of the building. Application of 20-80% glass percentage, 20-80% white paint plastered brick on the shophouse facade Figure 8.

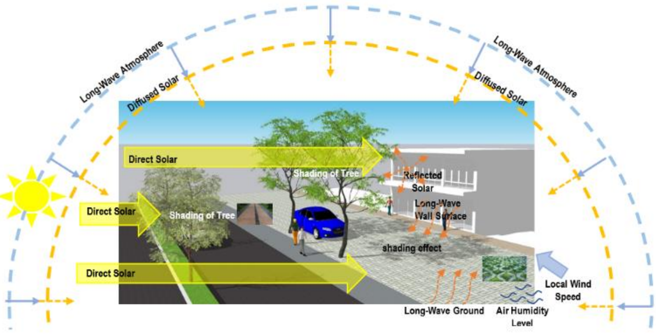


Figure 8 Conceptual Model of Shafe and Material Street, Building, Pavement in Relation to the Urban Thermal Environment

IV. CONCLUSION

This study analyzes the thermal characteristics of two different commercial roads using thermal imaging cameras. The findings show that the shading effects of street trees and building canopies play an important role in lowering surface temperatures during the day. Other factors (e.g. albedo and emission values of building materials, type of building use) also influence road surface temperature. High albedo and emittance contribute to lowering the surface temperature of the material. Regarding the type of building use, this research identified that the surface temperature is relatively high near shophouse buildings with the dominant use of metal and glass coated walls on the second floor. These findings suggest that large amounts of low-albedo material lead to higher surface temperatures nearby. Regarding the type of building use, this research identified that surface temperatures are relatively high near restaurant and supermarket buildings. These findings suggest that large amounts of anthropogenic heat emissions cause higher surface temperatures near restaurants and supermarkets.

Therefore, it is necessary to consider the influence of various factors on the thermal characteristics of urban road elements. More specifically, based on the findings of this research, to create a better urban street thermal environment for pedestrians, the shading effect of street trees should be optimized, construction materials with high albedo values or high emittance (especially at lower levels of buildings) should be used, and there must be a vegetated area rather than a covered parking lot dominated by cast concrete/paving. These strategies should be considered especially in urban areas where pedestrians are exposed to extreme heat stress.

A comparative case study with two different urban streets was implemented in this research. Due to the limited sample of shophouse buildings that are willing to be case objects and urban road elements that influence the urban thermal environment found in the field of study here, research using simulations with computer programs is needed to obtain more reliable information about the effects of urban elements on the thermal characteristics of the urban environment. which takes into account the height and width ratio between buildings (H/W) as well as the orientation and configuration of the site design. The results of the current study suggest a conceptual model for improving the thermal environment of urban roads in summer, and these findings can be used in the initial stages of further studies.

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