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Original research article

A Study of Regional Thermal Environment Quality Based on the Physical Mass Arrangement Characteristics of River Bank Settlements in Jodipan Colorful Village

Alya Nafisa Fidelista*, Agung Murti Nugroho, Lisa Dwi Wulandari

Department of Architecture, Universitas Brawijaya, Malang 65145, **Indonesia**

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ABSTRACT

Jodipan Colorful Village, originally a slum, has transformed into a popular tourist destination. This study investigates how the physical arrangement of the settlement mass and its thermal environment affect the comfort of activities in the road corridor, a critical public space utilized by both visitors and residents for tourism, commerce, and interaction. The research aims to analyze the relationship between the spatial configuration of the buildings and the thermal conditions of the area, particularly in this densely populated riverside village. Utilizing visual techniques, the study formulates criteria for the spatial arrangement of settlements, focusing on the balance of solids and voids in the layout. Thermal environment measurements are conducted to assess air temperature and humidity along the road corridor. The findings indicate that the spatial arrangement significantly impacts the thermal environment. Factors such as building density, corridor width, and proximity to the river influence temperature and humidity levels, with closer proximity to the river correlating with higher humidity and lower temperatures. These results provide insights into optimizing public space design in high-density urban environments, particularly in similar riverside settlements.

1. Introduction

The transformation of urban slums into vibrant tourist destinations has become an increasingly important phenomenon in urban studies, particularly in developing countries. Public spaces play a crucial role in fostering social interactions and economic activities, especially in environments with high tourist footfall [1]. However, the design and thermal quality of these spaces are often overlooked, resulting in discomfort for both residents and visitors. Understanding how physical space arrangements and environmental factors influence urban thermal comfort is essential for improving both livability and visitor experiences in high-density.

According to data from the Central Statistics Agency, the population in Indonesia until mid-2022 reached 275.773 thousand people. Malang City contributes to the high population in Indonesia as a city with a fairly high population of up to 7.826 people/km² with a population of 844.933 people until 2021. In light of the rapid global urbanization, providing a better quality of life in cities is becoming an increasingly critical issue for urban planning [2]. Urbanization primarily impacts climate variations by altering the natural surroundings, including adjustments to surface albedo and roughness, as well as modifications to the thermal and hydrological characteristics of the ground surface [3].

Based on the profile of the slum area of Malang City, the slum area is 29 (twenty-nine) locations spread out, one of which is the river border area of the Brantas watershed, Jodipan sub-district. Jodipan Colorful Village is a dense settlement located in Sub-districts 06, 07, and 09, District 02, Jodipan Village, Blimbing District, Malang City, which has changed from a slum area to a tourist village. The physical condition of the environment, infrastructure, and community in Jodipan Colorful Village is still not optimal as a tourist village because the changes are too forced. The phenomenon of changes and development of this village causes the importance of reviewing thermal environmental conditions, especially in outdoor spaces, in order to support the comfort of tourist activities carried out in public spaces or in this road corridor, considering that this village grows naturally without good planning with contoured land topographic conditions. There needs to be an evaluation of the physical environment conditions in Jodipan Colorful Village with a high enough density to provide sufficient comfort, especially for tourist

*Corresponding author: Department of Architecture, Universitas Brawijaya, Malang 65145, **Indonesia**
E-mail address: nafisdelista@student.ub.ac.id (Alya Nafisa Fidelista)
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activities in public spaces, which are new activities since turning into a tourist village [4]. The thermal comfort of open spaces plays a crucial role in enhancing the social interactions and community life of residents. It is essential to prioritize the thermal comfort of urban open spaces to foster social and economic activities [5].

Jodipan Colorful Village has an organic building mass arrangement that is arranged irregularly according to the topographic conditions of the contoured land with the orientation of the building with its back to the river facing the North-South and East-West directions without considering the environmental characteristics and climatic conditions that exist in Indonesia. Contoured land topography results in adaptation to aspects of regional arrangement in terms of building mass layout, building orientation, building distance, circulation path, building height, and open space. Lee et al. [6] mentioned that the ratio of total height to floor area, building distance, building height, and open space will affect the urban thermal environment.

Jodipan Colorful Village is located in a humid tropical climate where the air temperature is relatively high, up to 35,°C and the air humidity is very high, up to 80%. As a form of adaptation to humid tropical climatic conditions, the design of buildings and the built environment must have good thermal environmental quality. The elements forming the region's microclimate will affect the quality of the thermal environment. Heat, humidity, airflow, and sun radiation are the components that make up the microclimate [7]. The microclimate is climatic conditions in a particular area with different characteristics than the surrounding area [8]. Thermal comfort refers to the psychological state that reflects contentment with the thermal conditions of the surroundings [9]. It plays a crucial role in the happiness and overall well-being of individuals. It is of the utmost significance to prioritize climatic comfort when designing urban spaces [10]. As the climate continues to warm, ensuring thermal comfort becomes even more essential for future housing developments [11].

A suitable thermal environment requires careful consideration of specific factors when building a home space. There is variation in the level of quality between housing located on riverbanks and those not. Settlements outside riverbanks tend to have better quality than riverbank settlements [12]. The growing concentration of communities on river banks aims to produce an environment unfit for human habitation based on settlement health requirements [13]. The livability of an area is determined by the quality of the built and natural environment, while the quality of life is assessed based on the users' experiences and judgments of the facilities available. Another aspect that can affect the habitability of an area or dwelling is thermal comfort [4], [9], [10] and energy decline [14]. Aspects that make up the residential environment, such as building layout and configuration, including dimensions and distances between buildings, will affect the microclimate because the design of a good residential environment will affect the microclimate [15]. Residential areas built without good planning tend to cause discomfort for residents of these settlements [16].

The thermal environment on the banks of the river has different conditions in terms of temperature and air humidity. The average humidity will decrease if the floor surface of the building is higher than the ground; the humidity will also be higher if the location of the house is closer to the water or river field [17]. Studies have shown that in the built environment, four main factors have a cooling effect on the thermal environment: vegetation, urban geometry, reflective surfaces, and water bodies [18], [19]. This study traced and analyzed the factors that affect the thermal environmental conditions of Jodipan Colorful Village in terms of solid elements (mass pattern, building height, distance between buildings, building orientation) and voids (corridor width and corridor scope). The aim is to evaluate the quality of the thermal environment of the area, which is influenced by the physical characteristics of the mass layout of riverside settlements in Warma-Warni Jodipan Village, especially on road corridors as public spaces for tourists.

2. Method

This research applies qualitative and quantitative methods. The stages of research are divided into two: first, qualitative methods with visual techniques to evaluate the condition of the mass layout of settlements in Jodipan Colorful Village. Second, quantitative techniques using the WBGT Logger Heat Index tool to measure air temperature and humidity to evaluate thermal environmental conditions. The research location is in Jodipan Colorful Village. The object of study is a road corridor divided into 2 zones with 4 measuring points in each zone (**Figure 1**). The qualitative method in this study was carried out with visual techniques that contained data on the elements forming riverside settlements. Visual data will then be observed on solid elements (mass patterns, building height, building orientation, distance between buildings) and voids (corridor width and scope). Visual methods can identify key spatial qualities that influence microclimates and user comfort [1].

The measurement data carried out on the Jodipan Colorful Village Corridor is air temperature and humidity using the Heat Index WBGT Meter Data Logger tool. Measurements were taken for three consecutive days to obtain the same daily climatic conditions in the data collection time range every hour from 06.00 to 18.00. The choice of time range is based on the influence of time on river conditions and the surrounding environment (**Figure 2**). In addition, the difference between day and night is also a research topic and has an impact on the coastal hydrothermal environment [20], [21], [22]. The selection of measuring days is Monday (January 23, 2023), Tuesday (January 24, 2023), and Wednesday (January 25, 2023) with clear weather conditions.

Although only three days of data collection were used, it is common in environmental studies to rely on short-term measurements to capture a snapshot of conditions in specific environments. Nikolopoulou and Steemers [23] emphasize that even short-term measurements can provide valuable insights into thermal comfort, particularly when aiming to assess conditions under stable weather patterns. Additionally, studies often employ similar timeframes to analyze the effects of microclimatic factors without the need for extensive seasonal data [24]. Therefore, the three-day window chosen offers a reliable representation of the thermal environment under typical daily conditions.

Figure 1. Zone and measuring points at the research site

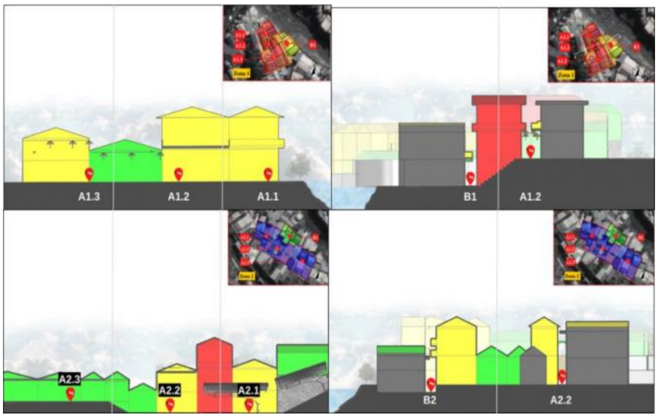

Figure 2. Section of zones 1 and 2 along with the placement of the heat index WBGT meter data logger measuring instrument

This research focuses on the influence of building mass management on the thermal environment in Jodipan colorful village. The thermal environmental conditions were measured, namely air temperature and humidity. The mass layout of riverside settlements with predetermined parameters was studied with the criteria of riverside settlements and their effects on the thermal environment. The criteria for mass planning of riverside settlements are based on the criteria that include solid and void elements, namely mass patterns, building heights, distances between buildings, building orientation, enclosures, and road corridor widths [25], [26], [27], [28].

In this study, quantitative descriptive analysis was used to calculate temperature (Ta) and air humidity (RH) in riverside settlements of Jodipan Colorful Village. Temperature and humidity data are presented using graphs to get a brief picture, which is then carried out an evaluative analysis of air temperature and humidity against thermal environmental comfort standards, namely the neutral temperature (Tn) of Malang City, which is between 22.4-27.4 °C [29] and air humidity 40–60% according to Ministry of Health standard No. 261 / MENKES / SK / II / 1998.

3. Result and Discussion

The research findings are based on visual analysis of architectural aspects (solid and void elements) and measurement analysis of environmental aspects of climate (air temperature and humidity). Based on the results of field measurements in the thermal environment of the area that have been carried out, 5 architectural aspects affect the condition of the thermal environment of the area, namely mass patterns, building height, distance between buildings, building orientation, scope, and width of road corridors (Table 1). These architectural aspects can affect the temperature and humidity of the air in the region.

Table 1. Components and indicators of mass arrangement criteria and regional thermal environment criteria

Components	Indicators	References
Physical Mass Arrangement Characteristic		
Building Mass Pattern	Upper water areas generally have cluster, organic, and irregular patterns.	[25], [30], [31], [32], [33]
Building Height	The ratio of total height to floor area, building distance, building height, as well as open space will affect the urban thermal environment.	[30], [31]
Distance Between Buildings	Settlements on the water generally have close characteristics in terms of the distance between tight buildings and the density of high buildings; besides that, there are also irregular slums, dirty, and others	[30], [33]
Building Orientation	The orientation of the original building is generally facing the water. Further developments in building orientation tend to face toward the ground and consider more functional aspects and accessibility	[25], [31], [32], [33]
Enclosure	The enclosure in the form of a building appears as an outer space wall	[28]
Corridor Widht	Road network (road corridor) / linear closed system, namely as a unifying structure for building configurations and containers for community life activities Void elements (outer space) are also formed due to the presence of solid elements (in the form of building mass)	[28], [30]
Regional Thermal Environment Criteria		
Air Temperature	In each region, the differences in air temperature are caused by natural factors such as the elevation of a place, wind direction, clouds, and the field of solar dating to the length of sunlight.	[30], [32], [33], [34]
Humidity	Air humidity on the banks of the river has characteristics that are quite different from other areas; this is due to river conditions that are enough to affect the air humidity in the surrounding environment.	[24], [30], [31], [33], [34]

3.1. About Jodipan Colorful Village

Malang City is located between 112.06°–112.07° East Longitude and 7.06°–8.02° South Latitude. Malang City Boundary is Malang Regency, which is located north of Gosari Baru District and Karang Puloso District, east of Bagis District and Dongbang District, and south of Taguig District and Paki District. South Sagi District, west of Wajir District and Jalan Raya District. area. Malang is surrounded by mountains, with Mount Arjuno in the north, Mount Semeru and Mount Bromo in the east, and Mount Kawi in the west. There is one meteorological observation station in the Malang area, namely the Malang Climatology Secondary Station located in Ngijo village in Karangploso.

Jodipan Colorful Village is a tourist village that was originally a slum located on the banks of the Brantas River. This village is included in the Sub-districts 06, 07, and 09 areas, District 02, Jodipan Village, Malang City, which has sloping contoured topographic conditions. This village is located in RW02 Jodipan Village, Blimbing District, Malang City, and has an area of 1.29 ha. Here are roads and rivers that are directly adjacent to Jodipan Village based on the cardinal directions. This village is also located at an altitude of 400-440 meters above sea level (mdpl).

3.2. Visual Analysis of Solid and Void Elements in Jodipan Colorful Village

Jodipan Colorful Village has an organic and diverse combination of mass patterns, with the elements forming the dominant mass pattern: topography, followed by density and distance between buildings, and finally building orientation. It is shown in (Figure 3) the visual analysis of solid and void elements in Jodipan Colorful Village. The mass order of this village is divided into upper and lower parts. The upper village is near Jalan Raya Gatot Subroto and Ir. H. Juanda, while the lower village is on the banks of the Brantas River. Organic patterns such as Jodipan Colorful Village can be classified as solid masses. This organic form of the village is caused by the distribution and development of riverside settlements in the Jodipan District, caused by the increasing population who chose to move into the Djodipan District because of the attractiveness of the strategic location near the central trading location of Malang city.

The results of the visual analysis of building heights in both zones have varying building heights ranging from 1-story, 2-story, and 3-story buildings. Buildings with a height of 1 floor have a percentage of 60%, with the most distribution in zone 2 points A2.1-A2.3. Buildings with a height of 2 floors have a percentage of 10%, and 3-story buildings have a percentage of 30%, with an even distribution in zones 1 and 2. There are several types of buildings based on their building size, including building types less than 30 m^2; 30-45 m^2; 46-60 m^2, and more than 60 m^2.

The results of the visual analysis of the distance between buildings in both zones have varying distances ranging from a distance of 1 m, 2.5 m, 3 m, and a maximum of 3.5 m. Zone 1 has variations in the distance between buildings with a width of 1 m and 2.5 m. Zone 2 has variations in the distance between buildings with widths of 1 m, 3 m, and 3.5 m. The results of the visual analysis of building orientation in both zones have 4 types of building orientation, namely facing southwest and northeast in Zone 1, and facing north and south in Zone 2, as shown below.

The results of visual analysis of road corridor coverage in both zones have 3 types, namely open, partially closed, and fully closed, with the type of coverage in the form of the roof overhang made of wave asbestos, tiles, balconies, and road pergolas with distribution. The results of the visual analysis of the width of the road corridor in both zones have 2 types of corridor widths, namely 1 m and 3 m wide. Zone 1 has a corridor width of 1 m, while zone 2 has a corridor width of 1 m and 3 m.

3.3. Thermal Environmental Conditions Measurement of Corridor in Jodipan Colorful Village

Based on air temperature measurements in zones 1 and 2, there are similarities, namely that the lowest temperature is at the B1 and B2 measuring points, while the highest temperature is at the A1 and A2 measuring points. In order of air temperature from highest to lowest is A1.3, A1.2, A1.1, and B1 for zone 1, and A2.1, A2.2, A2.3, and B2 for zone 2. Daily air humidity for 3 days in zones 1 and 2, the lowest humidity is at the measuring points A1 and A2, while the highest humidity is at the measuring points B1 and B2, with the order of highest to lowest air humidity, namely B1, A1.1, A1.2, and A1.3 for zone 1, and B2, A2.2, A2.1, and A2.3 for zone 2 (Figure 4).

The measuring points B1 and B2 have similar solid and void condition characteristics, namely being at a low elevation, directly adjacent to the river, building density and corridor width that is quite tight and narrow, the scope is fully closed to be classified as dark, and the height of the building is 2-3 floors, with different orientations, namely, B1 tends to face southwest and B2 faces south.

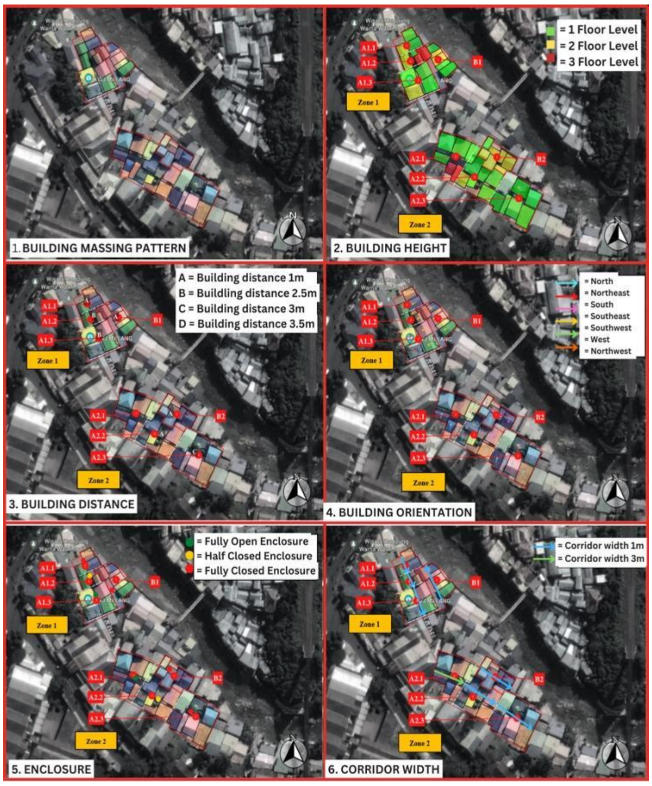

Figure 3. Visual analysis of solid and void elements in Jodipan colorful village

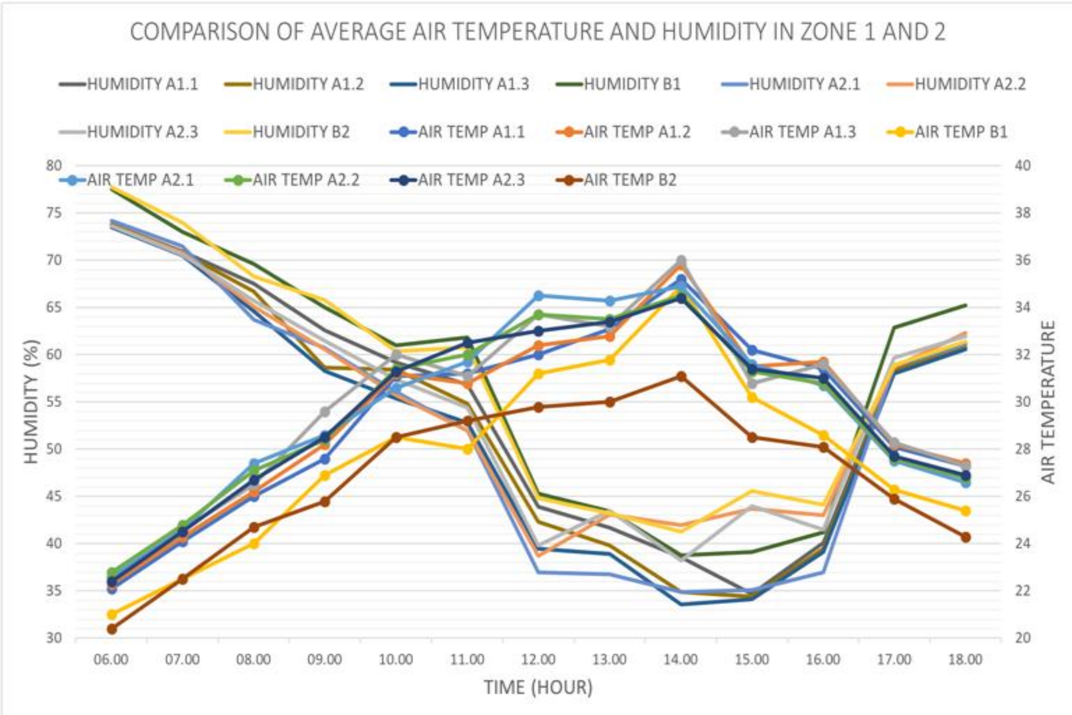

Figure 4. Thermal environmental conditions of air temperature and humidity in Jodipan colorful village

As for points A1 and A2, they have various characteristics at each point, with a tendency for building density and corridor width to be wider and larger than points B1 and B2, building heights and scopes that vary from closed, partially open, and fully open. The results of measurements and calculations of thermal environmental conditions, air temperature, and humidity are then linked and further analyzed to the elements forming the mass layout of riverside settlements, namely solid and void elements.

3.4. *Analysis of the Effect of Riverside Settlement Mass Arrangement on Air Temperature*

The wide mass pattern makes the surface area exposed to direct sun larger so that the air temperature becomes high. The highest temperature is at points A1.3 and A2.1, caused by maximum exposure to sunlight due to lack of shade from the scope of the corridor and the shadow of surrounding buildings and positions far from the river with a distance between buildings and a corridor width that is wide enough to 3 m. The environmental characteristics of solid elements and voids at points A1.3 and A2.1 affect the high air temperature at those points. The main influence of urban geometry on the thermal environment is to change the radiation and convection heat exchange in urban open space [35].

Table 2 show the results of air temperature conditions and environmental characteristics of solid void elements in both zones are in accordance with the theory stated by [34] that land fields on the edge of water will feel up to twice as hot as water fields of the same area; this is caused by the loss of heat energy in the water field due to evaporation so that the air temperature becomes higher. The measurement results show that zones B1 and B2 have the lowest air temperature with physical massing characteristics such as 2-3 floor levels and closed enclosures (Figure 5). This condition is due to Buildings and vegetation blocking and scattering the solar radiation,

Table 2. Analysis of highest and lowest air temperature

Zone	Analysis of Regional Thermal Environmental	Analysis of Physical Mass Arrangement Characteristics
Highest Air Temperature (°C)		
1	A1.3 (36 °C) 	1. BH: 1 floor level 2. DBB: 2.5 m 3. BO: southwest and northeast 4. E: open with no shading 5. CW: 1m 6. Far from the river and high area
2	A2.1 (34.9 °C) 	1. BH: 1 dan 3 floor level 2. DBB: 3.5m 3. BO: north and south 4. E: opens with a slight shading tone in the form of a sunshade net 5. CW : 3m 6. Far from the river and high area
Lowest Air Temperature (°C)		
1	B1 (21 °C) 	1. BH: 2-3 floor level 2. DBB: 1 m 3. BO: Southwest 4. E: fully enclosed in the form of a balcony 5. CW: 1m 6. Next to the river and low area
2	B2 (20.4 °C) 	1. BH: 2 floor level 2. DBB: 1m 3. BO: south 4. E: completely covered in the form of a roof drip 5. CW: 1m 6. Next to the river and low area

BH (BH), DBB (Distance Between Building), BO (Building Orientation), E (Enclosure), CW (Corridor Width)

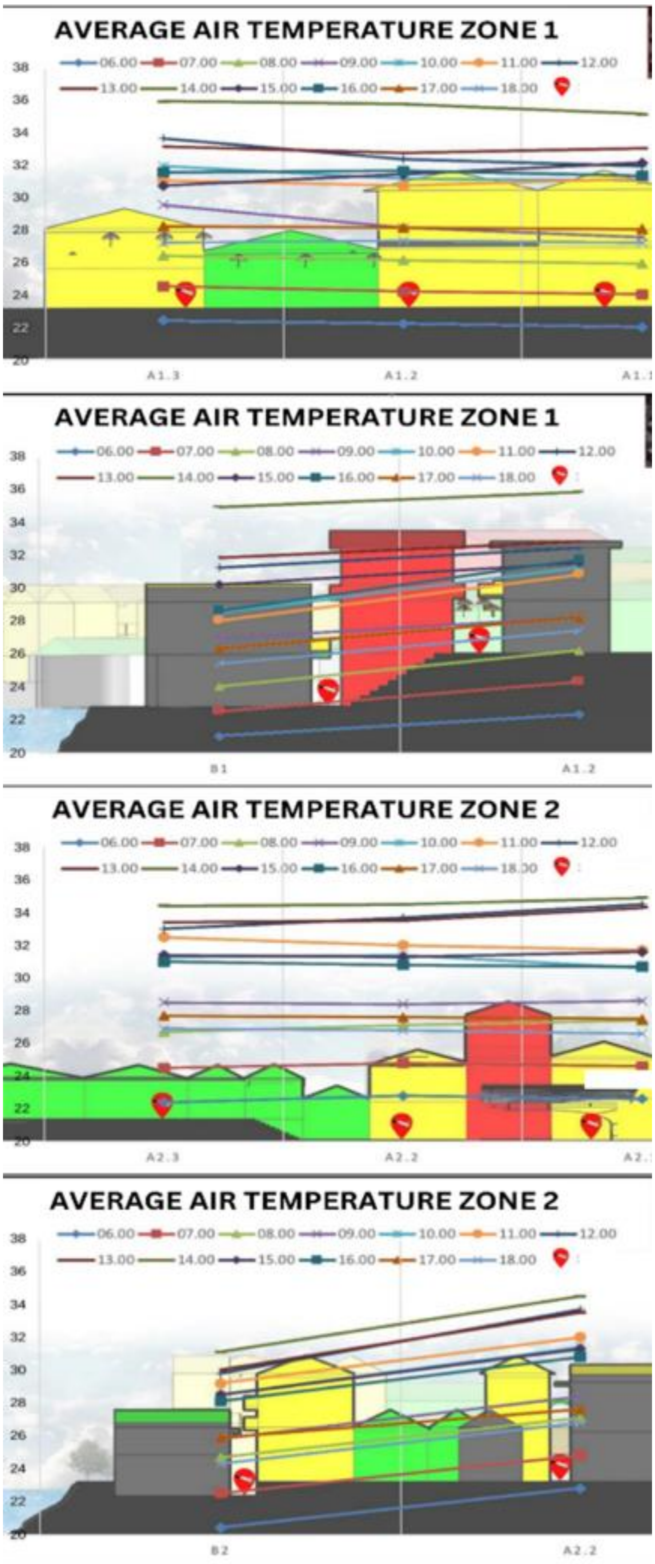

Figure 5. Average air temperature visualisation graph in Jodipan colorful village

which enhances thermal heterogeneity because of the heterogeneous shaded and sunlit patterns [36], [37] and the riverside area has denser buildings [37], The measurement results are also following the theory of belonging [6] which states that the ratio of total height to floor area, building distance, building height, and open space will affect the urban thermal environment. Specifically, these factors interact to influence how heat is retained or dissipated within a built environment. For instance, closely spaced buildings with significant height ratios relative to floor area tend to trap more heat, affecting both temperature and humidity levels. In contrast, greater building distances and open spaces can facilitate better air circulation and reduce heat accumulation, creating a cooler microclimate. These findings in Jodipan Colorful Village demonstrate how built environment configurations directly influence thermal conditions, reinforcing the need for strategic urban planning that carefully considers mass layout and spatial arrangements to support thermal comfort in dense settlements.

3.5. Analysis of the Effect of Riverside Settlement Mass Arrangement on Humidity

Building density and solid building mass pattern result in less direct exposure to the sun considering the narrow distance between buildings blocks the sun's heat directly to the surface so that the air temperature becomes low, but the density of the building and the width of the narrow corridor have the potential to retain heat longer in the area so that air humidity becomes high.

Humidity outside the comfortable and healthy humidity range is at points B1 and B2 in the morning at 06.00-11.00 and in the afternoon at 17.00-18.00 (Table 3) when compared to a comfortable and healthy humidity range of 40%- 60% caused by lack of exposure to sunlight does not even get sunlight at all due to the shade from the scope of the corridor that covers and shadows the surrounding buildings (Figure 6).

Not only that, this area's position is close to the river with a distance between buildings and a narrow corridor width of only 1 m. Water bodies have physical characteristics such as large latent heat of evaporation, large specific heat capacity, and small reflectivity, resulting in differences in surface temperature and air temperature from the land and regulation of the surrounding thermal environment [38]. The environmental characteristics of solid elements and voids at points B1 and B2 affect the high humidity of the air at those points.

Different from other points in zone 2, point B2 has a fairly high humidity. In addition to its solid and void conditions, low elevation and location adjacent to the river are also the cause of high humidity at this point, even though there is still quite a distance of several meters from the river. unlike point B1, which is right on the Brantas River, only 1 m from the river. The value of air humidity will depend on the amount of water vapor content at certain temperatures and pressures [39].

The position of solid elements/voids against the river can also affect the thermal environment, the higher the floor surface of the building from the ground, the average humidity is reduced, the closer the location of the house to the water / river field, the higher the humidity.

3.6. Analysis of the Effect of Physical Mass Arrangement Characteristics on Regional Thermal Environment Quality

Every building changes the climate of its surroundings. The city's geometry and section, the height and size of the buildings, the direction of the buildings, the streets, and the exterior surface, are all factors of the city's climate change [40]. Therefore, the physical arrangement of buildings in residential contexts, which are the most important and broadest physical space of urban architecture, plays a significant role in reducing or increasing these phenomena [41]. Jodipan Colorful Village has an organic and diverse combination of mass patterns with the dominant mass pattern forming elements being topography, followed by density and distance between buildings, and finally the orientation of the building. The mass order of this village is divided into upper and lower parts. The upper village is near Jalan Raya Gatot Subroto and Ir. H. Juanda, while the lower village is on the banks of the Brantas River.

Organic patterns such as Jodipan Colorful Village can be classified as a dense mass. Physical aspects such as building mass patterns, building heights, distances between buildings, building orientation, enclosures, and corridor widths are interrelated in forming a regional thermal environment. The main factors that influence urban ventilation performance include the street width between buildings, distances between individual buildings, and heights of buildings [42], [43], [44], [45], [46]. Through reasonable building layout planning, a ventilation corridor can be formed, which is conducive to the circulation of natural wind within an urban area [47], [48].

Table 3. Analysis of highest and lowest humidity

Zone	Analysis of Regional Thermal Environmental	Analysis of Physical Mass Arrangement Characteristics
Highest Humidity (RH%)		
1	B1 (77.5%) 	1. BH: 2-3 floors 2. DBB: 1 m 3. BO: southwest 4. E: fully enclosed in the form of a balcony 5. CW: 1 m 6. The location of the measuring point is right next to the Brantas River and at a low elevation
2	B2 (77.7%) 	1. BH: 2 floors 2. DBB: 1 m 3. BO: south 4. E: fully enclosed in the form of a roof overhang 5. CW: 1 m 6. Measuring point close to Brantas River at low elevation
Lowest Humidity (RH%)		
1	A1.3 (33.6%) 	1. BH: 1 floor 2. DBB: 2.5 m 3. BO: southwest and northeast 4.E: open without shade 5. CW: 1 m 6. Measuring point far from Brantas River at high elevation
2	A2.1 (37%) 	1. BH: 1 and 3 floors 2. DBB: 3.5 m 3. BO: north and south 4. E: open with a slight shade tone 5. CW: 3 m 6. Measuring point far from Brantas River at high elevation

BH (Building Height), DBB (Distance Between Building), BO (Building Orientation), E (Enclosure), CW (Corridor Width)

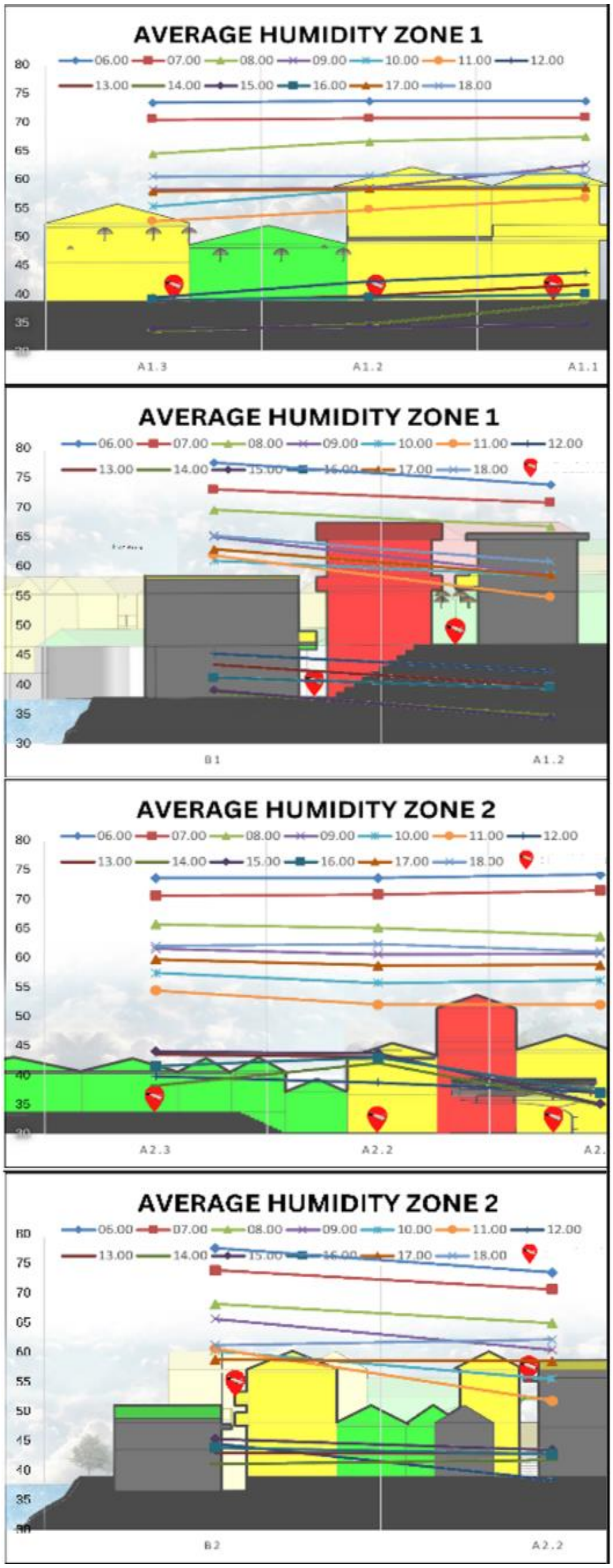

Figure 6. Average humidity visualisation graph in Jodipan colorful village

3.7. *Comparison Between Visual Results and Field Measurements*

The results of thermal environment measurements of air temperature and humidity, which are associated with the condition of solid elements and voids, and the results of visual analysis on mass patterns, building heights, distances between buildings, building orientation, and the width of the corridors, It is shown that the higher air temperature is at points A1.3 and A2.1 and the lowest air temperature is at points B1 and B2, with air humidity inversely proportional. The building spacing forms a wind corridor in the waterfront area. The wider the wind corridor, the better the cooling effect of the river, particularly when it is parallel to the wind direction [48]. It Is shown that the highest at points B1 and B2 and the lowest air humidity at A1.3 and A2.1 are caused by corridors that are fully exposed to sunlight due to lack of shade from the shadowing of surrounding buildings and the scope of corridors without the slightest shade or vice versa, namely corridors that are not exposed to sunlight at all due to shade from shadowing surrounding buildings and corridor scopes that close the corridor completely. The waterfront building area with a slab building and tower or low plot ratio and a building layout with more spacious ventilation corridors in the middle are more conducive to river cooling [49]. A lower building density is helpful to dissipate street-level excess energy, while higher building density improves roof level heat dissipation [50]. This is in accordance with the theory of belonging [6] which states that the ratio of total height to floor area, building distance, building height, and open space will affect the urban thermal environment. The position of the measuring point on the river which also affects the temperature and humidity of the air, the closer to the river, the higher the air humidity and vice versa. This is in accordance with the theory explaining that the average humidity will decrease if the floor surface of the building is higher than the ground, the humidity will also be higher if the location of the house is closer to the water/river field [17].

The results of the analysis of the measurement of two climate variables and with architectural variables of solid and void elements, it was found that the most influential element in the thermal environment of the road corridor in this village was the void element in the form of corridor coverage because it affected the shadowing in the corridor, This is followed by solid elements in the form of mass patterns, distances between buildings, building heights, and orientations that also affect thermal environmental conditions. The position of the corridor towards the river is also a factor forming the terral environment.

4. Conclusion

The research has revealed significant insights into the impact of mass layout and corridor configurations on the thermal environment of Jodipan Colorful Village, a dense riverside settlement. The village's organic, unplanned development results in two primary mass patterns: dense and wide. Dense mass patterns, characterized by narrow corridors and extensive shading from architectural elements like roof overhangs, balconies, and canopies, reduce direct sun exposure but tend to trap heat, leading to lower air temperatures but higher humidity levels. On the other hand, wide mass patterns, with greater distances between buildings and minimal shading, expose larger areas to direct sunlight, raising air temperatures but reducing humidity.

The position of the road corridor relative to the river also plays a crucial role in shaping the thermal environment. Buildings situated closer to the river experience higher humidity, while those at elevated positions have lower humidity levels. Measurement results indicate that thermal conditions in the village exceed the comfortable limits during peak daytime hours (12:00-14:00) but remain most comfortable in the early morning (06:00-09:00). Furthermore, areas with wide mass patterns, such as points A1.3 and A2.1, experience higher temperatures due to greater sun exposure, while points B1 and B2, which are shaded and near the river, exhibit higher humidity levels beyond the comfortable range, especially in the morning and evening.

These findings highlight the importance of considering mass patterns, building orientations, and corridor designs in urban planning, particularly for riverside settlements. The research underscores the need for more detailed studies that explore these dynamics across different seasons and weather patterns, given the limited three-day data collection. It also suggests that future research should expand measuring points to capture more diverse environmental conditions across settlements.

For policymakers and urban planners, this study offers valuable insights into improving thermal comfort in dense urban villages. Architectural recommendations aimed at optimizing the mass arrangement, corridor width, and shading strategies could significantly enhance outdoor thermal comfort, particularly in tourist areas like Jodipan. Informed by these results, the Malang City government should prioritize the development of urban designs that mitigate extreme thermal conditions and enhance the livability of riverside settlements, fostering sustainable urban development.

Author Declaration

Authors' contributions and responsibilities

The authors made substantial contributions to the conception and design of the study. The authors took responsibility for data analysis, interpretation and discussion of results. The authors read and approved the final manuscript.

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Competing interests

The authors declare no competing interest.

Additional information

No additional information from the authors.

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