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Bioclimatic Design Strategies for a Public Plaza in Pekanbaru, Indonesia

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ABSTRACT

The development of commercial areas in major cities such as Pekanbaru continues to grow rapidly in line with increasing economic activity and the rising demand for multifunctional public spaces. However, most commercial buildings in Indonesia remain focused on visual image-making and modern aesthetics, with limited consideration for energy efficiency and thermal comfort. This design study examines the application of bioclimatic architectural principles to a three-story commercial plaza whose primary functions include a culinary center, coworking space, and retail area. The aim of this design is to create a climate-responsive and energy-efficient building that ensures optimal thermal comfort for its users. The design method employs a bioclimatic approach through analysis of building orientation, spatial layout, facade treatment, and the integration of passive elements such as vegetated balconies, secondary skin, and overhangs. The design results indicate that the façade strategy using a secondary skin effectively reduces direct heat exposure from the west, while the addition of vegetation on balconies and the roof provides natural shading and enhances the building's visual quality. Furthermore, the spatial orientation based on sun path and wind flow improves the efficiency of natural lighting and ventilation. Overall, this design demonstrates that the integration of passive architectural elements can create sustainable commercial buildings that are adaptive to tropical climatic conditions.

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1. INTRODUCTION

The rapid growth of commercial developments in Indonesian cities has increased the demand for multifunctional buildings that combine retail, dining, and public activities. In cities such as Pekanbaru, commercial plazas have become important urban destinations that accommodate various social and economic activities. As these buildings are designed for intensive daily use, providing a comfortable indoor environment has become one of the main challenges. However, many commercial buildings in Indonesia continue to prioritize contemporary appearance and commercial appeal while giving limited attention to climate-responsive design. As a result, thermal comfort is often achieved through extensive use of air-conditioning systems, leading to high operational energy consumption.

The analysis of land surface temperature and the *Urban Heat Island* (UHI) phenomenon in Pekanbaru indicates a significant increase in the 25–28°C temperature class, which covers approximately 61.34% of the city's total area. The dominance of this temperature range suggests a considerable rise in land surface temperatures, reflecting the expansion of urbanized areas and changes in land cover. This finding indicates that the *Urban Heat Island* effect has become increasingly pronounced in Pekanbaru, with potential implications for outdoor thermal comfort, environmental quality, and the cooling energy demand of buildings [1].

Previous studies have shown that buildings are among the largest consumers of energy because of their dependence on mechanical cooling systems. According to [2], [3], [4], the excessive use of air conditioners contributes significantly to building energy consumption. Many modern buildings fail to provide adequate thermal comfort through passive design strategies, making mechanical cooling the primary solution [3]. This issue is particularly important in humid tropical cities such as Pekanbaru, where high temperatures and humidity create continuous cooling demands throughout the year.

One approach that addresses this challenge is bioclimatic architecture. Rather than relying mainly on mechanical systems, bioclimatic design responds to local climatic conditions by optimizing natural environmental resources [5], [6], [7]. Passive strategies such as appropriate building orientation, natural ventilation, solar shading, daylight utilization, vegetation, and climate-responsive materials can improve thermal comfort while reducing cooling demand. Buildings should be designed according to local climatic conditions to create comfortable environments [8], [9]. Similarly, [10] argued that architecture in tropical regions should utilize natural environmental potentials to reduce energy consumption while maintaining occupant comfort.

Although bioclimatic architecture has been widely discussed in residential [5], [11], [12], market [13], office [6], [7], [8], and educational buildings [14], [15], [16] its application in the design of contemporary commercial plazas has received less attention, particularly in the context of humid tropical cities such as Pekanbaru. Commercial plazas generally require large enclosed spaces, accommodate various public activities, and operate for long hours, resulting in considerable cooling demands. These characteristics make them an appropriate building type for exploring passive environmental design strategies. Integrating bioclimatic principles into contemporary commercial architecture therefore offers an opportunity to improve environmental performance without compromising functionality or architectural expression.

This study explores how bioclimatic architectural principles can inform the design of a contemporary commercial plaza in Pekanbaru. Rather than focusing only on the final architectural form, the study examines how local climatic conditions influence key design decisions, including building orientation, spatial organization, facade treatment, landscape planning, material selection, and natural ventilation. These strategies are integrated into the design to improve thermal comfort, reduce dependence on mechanical cooling, and create a commercial building that responds more effectively to the humid tropical climate. The proposed design is expected to provide a practical reference for integrating bioclimatic principles into future commercial developments in similar climatic contexts.

2. METHOD

This study adopts a design-based research approach to explore the application of bioclimatic architectural principles in the design of a contemporary commercial plaza in Pekanbaru. Rather than evaluating an existing building, the study investigates how climate-responsive design strategies can be integrated into the design process to improve thermal comfort and reduce dependence on mechanical cooling systems. The design process combines site analysis, climate analysis, literature review, and architectural design development to produce a proposal that responds to the environmental characteristics of a humid tropical climate.

Both primary and secondary data were used in this study. Primary data were collected through site observations to identify the physical characteristics of the location, including site orientation, surrounding buildings, existing vegetation, access, and environmental conditions. Secondary data consisted of climate information, relevant literature on bioclimatic architecture, planning regulations, and previous studies related to sustainable commercial buildings. These data provided the basis for developing appropriate design strategies for the selected site.

The design process began with an analysis of the site's climatic conditions, including solar orientation, prevailing wind direction, temperature, rainfall, and surrounding environmental conditions. These analyses were used to identify both the opportunities and constraints that influence the building design. The findings were then interpreted using bioclimatic architectural principles proposed by Yeang (1994) and Olgyay (1963), focusing on passive strategies to improve environmental performance.

Based on the analysis, several design strategies were developed, including building orientation, spatial organization, facade treatment, natural ventilation, daylight optimization, landscape design, and material selection. These strategies were integrated throughout the design process to reduce heat gain, improve natural air movement, and maximize daylight while maintaining user comfort. The proposed design was developed using ArchiCAD 28 for architectural modeling and technical drawings, while D5 Render was used to produce three-dimensional visualizations of the final design. The resulting design was then evaluated qualitatively by examining how each design strategy responded to the site's climatic conditions and reflected the principles of bioclimatic architecture.

3. RESULTS AND DISCUSSION

The design process began with an analysis of the site and local climatic conditions to identify environmental opportunities and constraints that influence architectural decisions. The findings from the site analysis were then translated into a series of bioclimatic design strategies that respond to the humid tropical climate of Pekanbaru. Rather than applying passive elements as individual features, the proposed design integrates building orientation, spatial organization, facade treatment, vegetation, and material selection into a comprehensive climate-responsive design. This section discusses how each strategy contributes to improving thermal comfort while reducing dependence on mechanical cooling.

3.1. Site Analysis

The proposed site is located on Arifin Ahmad Street, one of the main commercial corridors in Pekanbaru. The location offers good accessibility and strong commercial potential but also presents several environmental challenges that influence the building design. These include high solar exposure, traffic noise, and the need to maintain thermal comfort in a hot and humid climate.

(a) Site Location

(b) Wind Analysis

(c) Sun Path Analysis

(d) Noise Analysis

Figure 1. Site Analysis (Source: author, 2026)

The climate analysis indicates that Pekanbaru experiences high temperatures, high humidity, and significant annual rainfall throughout the year. The strongest solar radiation occurs on the eastern and western façades, while the prevailing winds generally come from the southeast and east. These climatic conditions highlight the importance of reducing solar heat gain while maximizing natural ventilation. Consequently, the design prioritizes passive environmental strategies such as appropriate building orientation, facade shading, and vegetation to improve the building's environmental performance.

Site observations also revealed that traffic noise is concentrated along Arifin Ahmad Street. To reduce this impact, the building mass is positioned according to the required setback, while vegetation is introduced along the site boundary to function as both a thermal and acoustic buffer. In addition, the surrounding commercial buildings create opportunities for the proposed plaza to establish a stronger architectural identity while remaining responsive to the local urban context.

3.2. Application of Bioclimatic Design Strategies

3.2.1. Building Orientation and Spatial Organization

The orientation of the building was determined based on the site's solar exposure and prevailing wind direction. The main openings are positioned to receive natural daylight while minimizing direct heat gain from the east and west. The building is oriented to avoid facing east and west in order to minimize direct solar exposure. At the same time, the building layout encourages cross-ventilation by allowing air movement through the main activity spaces.

In tropical climates, building orientation plays a crucial role in controlling solar heat gain. Positioning a building to minimize direct solar exposure on the eastern facade, and particularly on the western façade, can reduce heat absorption and help maintain lower indoor temperatures. Furthermore, aligning the building with the prevailing wind direction enhances natural ventilation, improving air circulation and contributing to greater indoor thermal comfort [17].

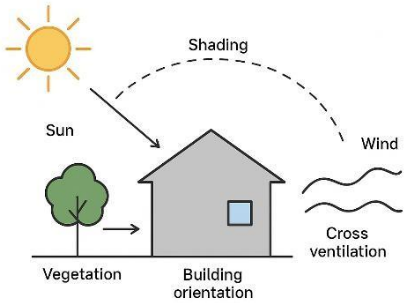

Figure 2. Building orientation (Source: author, 2026)

3.2.2. Spatial Organization

The spatial organization also reflects the functional requirements of the plaza. Public functions such as retail and culinary spaces are located on the ground floor to improve accessibility, while coworking spaces are placed on the upper floors where daylight and views are more effectively utilized. This arrangement not only supports user activities but also contributes to better environmental performance by reducing the need for artificial lighting during daytime.

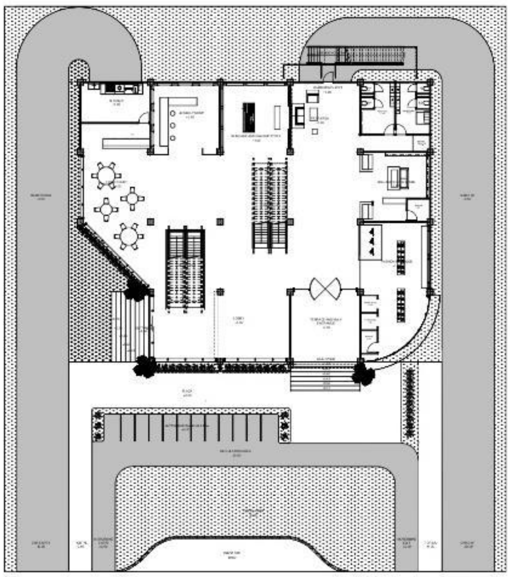

Figure 3. Spatial Organization (Source: author, 2026)

3.2.2. Facade Design and Solar Shading

Controlling solar radiation is one of the main challenges in designing buildings for humid tropical climates. For this reason, the façade incorporates several passive shading elements, including secondary skin panels and overhangs. This is also stated by [18], the application of secondary skins, canopies, and other shading devices is an effective passive strategy for reducing solar heat gain in tropical climates. Since solar radiation is the primary source of heat accumulation in buildings, these shading elements act as protective layers that intercept and reduce direct sunlight before it reaches the building envelope. As a result, heat transfer into the interior is minimized, lowering cooling loads and improving indoor thermal comfort. This approach represents a fundamental principle of passive design for buildings located in hot-humid climates.

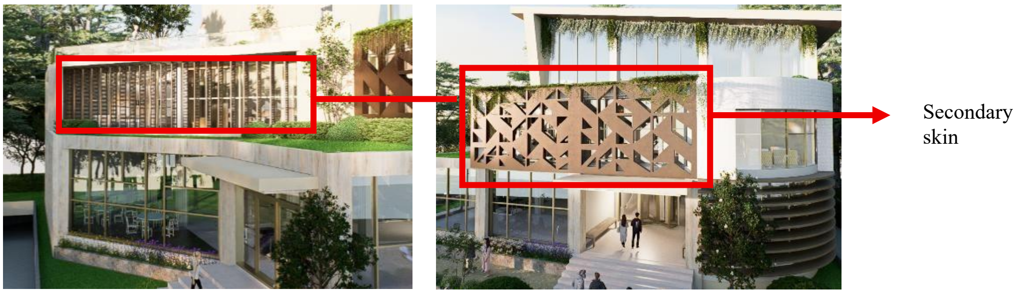

Figure 4. Secondary Skin (Source: author, 2026)

The secondary skin functions as more than an architectural feature. It filters direct solar radiation before it reaches the building envelope, thereby reducing heat gain while still allowing daylight and natural ventilation. Different secondary skin patterns are introduced to strengthen the contemporary architectural expression without compromising environmental performance.

Horizontal overhangs are also provided above major openings and circulation areas. These elements reduce direct sunlight and protect users from heavy rainfall while creating shaded semi-outdoor spaces that improve pedestrian comfort. Together, the secondary skin and overhangs contribute to lowering cooling demand through passive solar control.


Figure 5. Overhang (Source: author, 2026)

3.2.3 Vegetation and Landscape Design

Vegetation plays an important role in improving the microclimate surrounding the building. Trees, shrubs, and climbing plants are distributed throughout the site to reduce surface temperatures and provide natural shading for outdoor spaces. According to [19], vegetation serves as a natural shading element that can reduce surface temperatures, improve the microclimate, enhance thermal comfort by moderating humidity conditions, and mitigate the urban heat island effect. In tropical public spaces, areas shaded by vegetation have been shown to exhibit lower temperatures than exposed open spaces without tree canopy or other forms of natural shade.

Green balconies are introduced as transitional spaces between the interior and exterior environments. Besides enhancing the visual appearance of the building, vegetation on the balconies helps lower façade temperatures through shading and evapotranspiration. These passive cooling effects create a more comfortable environment while maintaining adequate airflow and daylight.

Figure 6. Green Balcony (Source: author, 2026)

The landscape design also contributes to user comfort by creating shaded pedestrian areas and outdoor gathering spaces. Instead of functioning solely as decorative elements, the landscape becomes an integral component of the building's environmental strategy.

Figure 7. Landscape design (Source: author, 2026)

3.2.4. Building Materials and Natural Ventilation

Material selection was guided by both environmental performance and architectural character. Low-E glazing is used to reduce solar heat gain while maintaining daylight penetration. Natural stone is applied in outdoor areas because of its durability and compatibility with the tropical climate, while wood is incorporated into interior finishes to create a warmer and more comfortable atmosphere.

Natural ventilation is enhanced through the placement of large openings on multiple sides of the building. This arrangement supports cross-ventilation and allows fresh air to circulate through the interior spaces, reducing dependence on mechanical cooling. Together with the shading devices and vegetation, these strategies demonstrate how passive environmental design can improve thermal comfort in commercial buildings.

Figure 8. Building materials and natural ventilation (Source: author, 2026)

3.3 Discussion

The proposed design demonstrates that bioclimatic principles can be integrated into contemporary commercial architecture without limiting architectural expression. Instead of treating passive design elements as additional features, the proposed plaza incorporates climate-responsive strategies from the earliest stages of the design process. Building orientation, façade shading, vegetation, natural ventilation, and material selection work together to improve environmental performance while supporting the functional requirements of a commercial plaza.

Table 1. Application of Bioclimatic Design Strategies (Source: author, 2026)

Bioclimatic Design Strategies	Design Application
Building Orientation	• The building is oriented to avoid facing east and west in order to minimize direct solar exposure.
Spatial Organization	• The spatial organization reflects the functional requirements of the plaza performance by reducing the need for artificial lighting during daytime
Facade Design and Solar Shading	• The secondary skin functions as more than an architectural feature. It filters direct solar radiation before it reaches the building envelope, thereby reducing heat gain while still allowing daylight. • Horizontal overhangs reduce direct sunlight and protect users from heavy rainfall while creating shaded semi-outdoor spaces that improve pedestrian comfort.
Vegetation and Landscape Design	• Vegetation on the balconies helps lower façade temperatures through shading and evapotranspiration. • The landscape design also contributes to user comfort by creating shaded pedestrian areas and outdoor gathering spaces.
Building Materials	• Low-E glazing is used to reduce solar heat gain while maintaining daylight penetration. Natural stone is applied in outdoor areas because of its durability and compatibility with the tropical climate, while wood is incorporated into interior finishes to create a warmer and more comfortable atmosphere.
Natural Ventilation	• Natural ventilation is enhanced through the placement of large openings on multiple sides of the building. This arrangement supports cross-ventilation and allows fresh air to circulate through the interior spaces, reducing dependence on mechanical cooling.

The findings also support previous studies that emphasize the importance of passive environmental strategies in tropical climates. As suggested by [9] and [10], responding to local climatic conditions through orientation, shading, and natural ventilation can improve thermal comfort while reducing dependence on mechanical cooling. In this study, these principles are translated into practical architectural strategies suitable for commercial developments in Pekanbaru.

Although the study does not include quantitative energy simulations or thermal performance measurements, it demonstrates a systematic approach to integrating bioclimatic principles into architectural design. Future studies may combine this design approach with building performance simulations to evaluate the effectiveness of each strategy in reducing energy consumption and improving thermal comfort.

4. CONCLUSION

This study explored the application of bioclimatic architectural principles in the design of a contemporary commercial plaza in Pekanbaru. The design process demonstrates that climate-responsive strategies can be integrated into architectural decisions from the early planning stage. Building orientation, spatial organization, facade shading, natural ventilation, vegetation, and material selection were developed as complementary passive strategies to improve thermal comfort while reducing dependence on mechanical cooling.

The findings suggest that bioclimatic principles can support both environmental performance and contemporary architectural expression. Rather than treating sustainability as an additional design feature, the proposed approach integrates climate considerations into the overall design concept. This integration allows the building to respond more effectively to the humid tropical climate while maintaining its functional and aesthetic qualities as a commercial plaza.

Although this study is based on a design proposal and does not include quantitative performance evaluation, it provides a practical framework for applying bioclimatic principles to commercial buildings in tropical cities. Future research may incorporate building performance simulations or post-design evaluations to measure the effectiveness of the proposed strategies in improving thermal comfort and reducing energy consumption.

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