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Application of bioclimatic parameter as sustainability approach on multi-story building design in tropical area

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Abstract

The main objective in construction of a physical facility is to provide a place for humans (bio) in order to achieve their goals. Building as built environment with a particular physical form at a particular location is affected by climate. If the building design process ignores the climate considerations, the influence of climate can lead to interference human activities. Bioclimatic design is a concept of sustainable approach that consider of climate and human relations in reviewing the feasibility of a design. At this time, a growing number of designers, especially young architects that interested in using bioclimatic concept as sustainable approach in their design process. However, the application of this concept in the design process has not shown significant results in building operation. This paper elaborates the bioclimatic concept, in order to obtain a good understanding of bioclimatic design that can be used as a reference, especially for novice designers, in the application of sustainability concepts in the design of multi-story buildings in the tropical area. This paper also suggests a design method that utilizes a sustainable approach which is expected to help novice designers in applying the bioclimatic design concept.

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1. Introduction

In the humid tropical areas such as Jakarta, the humidity is very high that reaches maximum humidity 96% which is average 86% [2]. This leads to an indoor temperature is relatively higher than the outdoor temperature. As a result, without artificial thermal control, the room conditions can negatively affect to the health and productivity. Therefore, in order to control the indoor thermal comfort, almost all buildings...
in Jakarta require artificial cooling system. This condition causes high energy consumption for air conditioning during building operation.

The efforts to reduce the energy load on the building operation are necessary; on the other hand, the requirement of thermal comfort needs to be full filled, and one of the efforts in order to meet the requirement is to apply the bioclimatic concept in the building’s design. Bioclimatic approach is a perspective on viewing the relationship between climate and humans, which is associated with human comfort in a built environment and in the surrounding natural environment [9].

This research objective is to give a good understanding for young designer on building design by using climatic approach, and to provide design criteria in order to achieve better solution in implementing sustainable design concept. The final design solution is not a result of subjective trial and error process, but as a systematic decision making process.

The strategy to respond the climate by adjusting the design masses, building form and material selection of the building envelope; it is one way of implementing bioclimatic concept. Bioclimatic approach is the strategy adopted in building design in order to get comfortable conditions for occupants to perform their activities by using minimum energy sources. A variety of options in elaborating the bioclimatic concept require knowledge of its components, which, until now, has not been mapped in detail. Efforts are needed to summarize the knowledge about bioclimatic components so it can be used as a reference criterion in the design process.

2. Bioclimatic Design Justification and Its Process in Sustainable Approach

According to Olgyay [9], there are three interrelated considerations that can shape the balance between climate and the built environment during the design process, including climate consideration, biological need evaluation (according to the level of human comfort), technological solution and architectural application. Ken Yeang [14] introduced two justifications of bioclimatic design concepts, namely (1) the achievement of maximum comfort level for the user in building operation, and (2) minimum energy consumption and cost in building operation. In implementing this approach, it requires a specific strategy because both approaches can be contradictory to each other in its implementation. Figure 2 below shows the relationship between human, the climate and the environment in the perspective of bioclimatic.

![Fig. 1. Relationship in bioclimatic design perspective (Larasati, 2000)](image)

Case studies show that buildings which respond to climate conditions have high-performance of energy efficiency. One example is the effort of designers to change the building orientation, shape and envelope according to sun radiation in designing office building of Ministry of Public Works that results in the OTTV (Overall Thermal Transfer Value) of the building only 28w/m2 in its operation. This OTTV
is far below the standard of Green Building Council Indonesia (GBCI), Indonesia National Standard and Jakarta (province) Governor Decree which is 45 W/m². Additionally, the acquisition of Energy Consumption Index (ECI) for the building is 145-155Kwh/m²/year which is also far below the standard GBCI which is 250Kwh/m²/year. On the other hand, through consideration to the climate in building design, the energy saving in the building is around 100Kwh/m²/year; also, water usage can save up to 83% during the rainy season and 61% during the dry season.

Therefore, climate as one of the peculiarities of a building site should receive major attention in the building design process. Criteria for building design in the country with a humid tropical climate will vary with the design criteria in a country with a subtropical climate. The abundance of sunlight and heat conditions in the humid tropics areas are appropriately serious attention in setting the design criteria.

It is necessary to map the bioclimatic components in the design process. If the bioclimatic components have been mapped in assisting the design process, it also required an understanding of how to implement these components in applying sustainable design principles in Indonesia as a tropical-humid area, how many components can be applied to buildings in humid tropical climates, and how are the necessary conditions so that these components can function optimally. It required an effort to collect and develop knowledge about the application of bioclimatic components in the building in accordance with the conditions of tropical-humid climate in Indonesia.

Furthermore, the procedures are necessary to accommodate the development of understanding, knowledge and technology related to bioclimatic to be applied as a passive system of sustainable design criteria in the regulations, standards or rating systems that is applicable in Indonesia. For that, this research will answer some questions as follows: what are the components bioclimatic on sustainable design? What are the criteria that can be applied bioclimatic design associated with the humid tropical climate conditions in Indonesia? And, how the procedures in the development of criteria bioclimatic design that can be used in Indonesia? With answers to these questions, it is expected to obtain bioclimatic design criteria in the application of sustainable design in Indonesia that could be responsible for and can be utilized by the designers.

3. Mapping of Bioclimatic Components in Sustainable Design Process

William [13] stated that the design process is a robust process, since the design process will not only meet requirement but also at the same time providing value. If the value to be conveyed is sustainability, the design process should provide a comprehensive solution that takes into account energy, building form, construction processes, materials and its sources throughout the life cycle of buildings. The principle of sustainable in bioclimatic concept supposed to use a comprehensive approach, it is to avoid the practical solution that only meet immediate needs or only complete a part of the solution need.

Handler [6] directs the concept of the build process in the context of sustainable development, where the process is seen as a system that consists of sub-systems. In this approach, the characteristic of the build process requires the entire system includes a feedback control system, which is carried throughout project life cycle. The process gives attention to usage of resources in the design process, procurement, construction, operation, up to its maintenance. The design process is in a significant position in the project life cycle, since most of the design problems will appear during construction and operation/maintenance (Figure 2).

Furthermore, McLennan [10] states that sustainable design is a design philosophy which seeks to maximize the quality of the built environment, and minimize or eliminate negative impacts on the natural environment. McLennan also indicates a misunderstanding of what is called the sustainable building (architecture), since most of misinterpreting sustainability is only as an ornament (features) and not as an approach to design process. The clear understanding is important because Guy and Farmer [5] indicate a
tendency to classify sustainable design in just one specific category and less accommodating to other approach. The category should be comprehensive which considerate 3 elements, namely:

- Minimizing impact on the environment (Eco Friendly)
- Attention to human comfort and health (Human Friendly)
- Consider to energy efficiency and energy conservation (energy Friendly)

The considerations mentioned above are also mentioned by several experts in the architectural design since several decades before. According to the conclusion of the various views on bioclimatic design, therefore, these considerations are the parameter in bioclimatic design, which will be described in more detail in the subsequent description.

### 3.1. Eco friendly

Abidin [1] suggested several strategies for eco-friendly criteria, including:

- Site selection and building utilization. Selection of sites related to spatial planning, as well as utilization. In the utilization of sustainable design, it can also be done by expanding the size to a green area or watershed, and build as needed to avoid unused space as small as possible.
- Material selection. The use of material need to consider the limitations of its availability in nature and the impact on the environment. Materials are difficult to obtain from nature has in place for restricted use. And materials that proved to bring harm to the occupants should not be used anymore.
- Use water sparingly. Efficient use of water can be done by reducing the amount of water needs as much as possible, and doing the process of recycling waste water to be reused. Use water sparingly is done well throughout the building life cycle.
- Reduction of pollution (impacts) on the environment. Maximum reduction of pollution (impacts) on the environment can be done throughout project life cycle. Construction methods directed not to disturb the balance of the ecosystem and reduce air pollution (dust, CO2) and noise pollution (noise during construction). During construction and operation, there should be a reduction in the amount of trash or wastes are produced.

### 3.2. Human friendly

The first thing to consider associated with the human as the user in a building is human comfort. According Hegger [7] concerning the human comfort, there are three aspects related:

- Physical Condition
- Intermediaries Conditions
Physiological Conditions

This means that comfort is not just a matter of physical conditions, such as thermal condition, but is also affected by the intermediaries, such room conditions and also physiological conditions, such as gender and age. So comfort is a combination of all three. Hegger [7] is in line with Bougdah [4] argued about human comfort that comfort is a state of mind derived from the physical environment, the human ability to control, and other physiological conditions. The results of the two categories in the researches are important to know space design that meets the needs of human comfort.

About the visual condition, Bauer [3] stated that there are three factors influencing the quality of sunlight in space, namely:

- Dimension of the space
- The presence of shading device
- The options of lighting technology installed on building facade

Furthermore, Bauer [3] specified room qualification that meets visual comfort requirement which has the following criteria:

- Lighting condition inside the building is the same brightness as outside
- The sun lighting is distributed evenly in the room
- Day lighting can be modified by using sun shading
- Avoid glare in the room
- Optimum usage of daylight

As for the condition of audio, Bauer [3] stated that the condition of it is influenced by the sources of noise, associated with the origin of the sound source (internal and external) and the specification of the sound source (power, frequency, etc.). The exterior material specifications (façade) and the interior (floor, walls, ceiling, furniture) must be planned in accordance with the conditions of the sound source at each location.

The indoor air condition related to pollutants is important to support the activities of occupants. Pollutants enter into room through the equipment, sanitary tools and finishing materials of the building; the amount of pollutants also depend on the amount and the type of energy used in buildings and others. Reducing the amount of energy used is proportional to the amount of pollutants in a room.

3.3. Energy friendly

Hegger [7] presented that each air conditioning activity requires energy. But, there are several ways to optimize the energy use. Agreeing with Hegger, Sarte [11] stated that optimization of energy used strategies for green building namely:

- Reducing energy demand through design
- Using energy efficiently
- Choosing a sustainable energy source
- Reducing emissions of CO₂

Additionally, Sarte also described that the reduction energy need of the building can be reached by:

- Development of site analysis
- Clearly defined the requirements and the objectives of a project
- Matching the energy that available at the site.

Because the characteristic of each site is unique; hence, designers need to find and adopt the most suitable strategy for energy used applications. Designs that consider the building location can produce buildings with following characteristics:

- In harmony with its surroundings.
- Answering the demands of the environment
Delivering more value and comfort for the occupants.

Therefore, consideration of the location which has a particular climate is an absolute design considerations; it must be considered, in order to meet bioclimatic justification; the justification is the optimum use of energy in order to get the maximum comfort. Based on the explanations above, the following diagram describes the various components that are considered in building design with bioclimatic approach (Fig 3).

![Diagram of components considered in the design process with bioclimatic approach](image)

Fig. 3. Components considered in the design process with bioclimatic approach (Larasati, 2000)

4. Implementation of Bioclimatic Design in Tropical Area

Designing of human, eco and energy friendly buildings can be conducted in two ways, namely passive and active designs. In bioclimatic approach, it tends to apply the passive design. The energy saving is through the use of day lighting and wind passively, without conversion of solar and wind to electrical energy. The passive design relies more on architect’s ability to design buildings that are able to anticipate climate problems.

The passive design in humid tropical regions, such as Indonesia, is generally to seek how to prevent building heating that caused by solar radiation, without sacrificing the needs of natural lighting. The sunlight that consists of light and heat will only be used its light component, while the heat component will be eliminated. In addition to the sun lighting utilization, the use of wind in accordance with building ventilation is also explored to obtain the optimal thermal comfort. According to Sharma [12], the passive system in bioclimatic design is used through the following basic strategies:

- Understanding of climate and climate zones
- Identification of the comfort zone
- Identify the sources of heat
- Optimization of micro-climatic conditions
- Defining the characteristics required for the configuration of building and the building envelope

Furthermore, Sharma [12] that is in line with Ken Yeang [14] mentioned that an important component in bioclimatic design is passive cooling for indoor air condition. The strategies that can be done to get the optimal passive cooling system are as follows:

- Proper placement of windows and natural lighting design
- Selection of the proper material for the glass windows and the skylights
- Proper shading on the glass when the heat is not desirable
- The use of light-coloured material for the building envelope and roof
- Correct building placement and orientation
- Good landscape planning

As for the natural ventilation, Sharma [12] stated that the natural ventilation is good cooling technique and has been used throughout the world, which provide cooling by using air to carry heat out of the building (convective cooling) and from the human body (physiological cooling). The effectiveness of the technique of natural ventilation is determined by outdoor conditions, microclimate and characteristics of the building (building orientation, number and size of windows). In order to get maximum natural ventilation, it would require the following efforts:
- Installation of windows can be operated
- Use landscape elements to direct the wind
- Proper windows placement with window size for cross ventilation
- Reduction of internal barriers (e.g. walls) to keep the wind can flow
- The use of wing walls when natural cross ventilation is not possible to apply
- Use stack ventilation to get a chimney effect

Sarte [11] added that, in principle, the use of passive systems can improve the energy performance of buildings. Passive system can be done through building design and orientation of the building that are:
- Landscaping arrangement to create the desired microclimate
- Selection of the proper building envelope
- Design of natural ventilation
- Selection of building materials
- Use of low-remittance glass
- Installation of radiation barrier
- Use of bright or reflective colors

With regard to lighting, Bauer [3] stated that natural lighting is highly dependent on the location and to optimize the results can be done through optimization of geometry and optimization component. In line with Sharma and Bauer, Ken Yeang [14] stated the principles of design bioclimatic as follows:
- Building mass arrangement
- Building orientation
- Cladding design and exterior wall
- Landscape vertical
- Usage of natural lighting and natural ventilation
- And low building operation and maintenance

Based on the explanation above, in designing multi-story building in the tropics area, it needs to conduct several analyses that include:
- Mass composition (zoning and core placement arrangement) that will affect the performance of thermal and visual comfort
- Building orientation, which will affect performance in anticipation of high solar radiation
- Cladding and exterior wall design, which will affect the performance of thermal, solar buffer and cross ventilation.
- Utilization of natural ventilation, which will affect the performance of thermal comfort and building stiffness
- Horizontal and vertical landscaping design, which is used to obtain the ecological and aesthetic benefits, lowering the temperature of the micro climate, improving air quality through photosynthesis, and increase the biodiversity of ecosystems.

Various design considerations described previously are applied differently in each stage of the design process. The following figure shows the implementation process of bioclimatic concept in the design
stages for multi-story building in tropical area (Fig 4).

Fig. 4. Criteria and output of design stages in implantation of bioclimatic concept for multi-storey building in the tropical area [8]

5. Conclusion

The following conclusions can be drawn from previous discussion:

- Bioclimatic approach needs to be implemented in the design process, since this approach leads to sustainable design, which the justification are energy saving and the reduction of energy consumption that is not renewable.

- With the elaboration of bioclimatic design concept, the designer can implement a better design approach. That is through a good understanding of bioclimatic definition, understanding the basic considerations bioclimatic design, map design alternatives based on the possibility of its implementation in bioclimatic design concepts, as well as ongoing assessment procedures based on
It is concluded that passive design strategies in bioclimatic approach include site design, setting the landscape elements (plants, water, etc.), building orientation, building mass, building form, building envelope, sun shading design, window/ façade design and design of openings for ventilation, which the strategies consider to keep operation and maintenance cost low.

The method developed bioclimatic design consists of 3 (three) main stages namely: 1) the stages selecting alternatives based on needs, 2) justify the use of energy, 3) justify the user comfort. Formulation of criteria developed is still open; thus, it can be further elaborated by the designers in its implementation, so that the resulting solution suit to the needs. However, the method developed is a preliminary study which needs further development in detail and, if possible, with the computing system.

References