Integration of Cultural and Ecological Aspects in the Selection of Sustainable Materials for Traditional Balinese Architecture

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ABSTRACT

Traditional Balinese architecture has a deep cultural value that is reflected in the use of locally-based materials that are in harmony with the philosophy of *Tri Hita Karana* and the principles of *Asta Kosala Kosali*. However, in the era of modernization, there has been a shift in the use of materials from local to industrial materials that are more accessible but have a higher environmental impact. This article examines the integration of cultural and ecological aspects in selecting sustainable materials for traditional Balinese architecture using a multi-criteria approach. The research method used is multi-criteria decision analysis (MCDA) and life cycle assessment (LCA) to compare sustainability parameters such as carbon footprint, material resilience, and local community involvement in the material production process. The study results show that the use of local materials such as bamboo, coconut wood, and natural stone has a higher sustainability value than industrial materials. This study offers policy-based solutions to improve the use of environmentally friendly materials while maintaining Balinese cultural values. This study is expected to be the basis for designing sustainable architecture policies that consider ecological and cultural aspects in a balanced manner.

Keywords: Balinese, Architecture, material, sustainability, Life Cycle Assessment (LCA).

INTRODUCTION

Balinese traditional architecture is a cultural heritage with deep philosophical value and reflects the harmony between humans, nature, and God, as explained in the concept of Tri Hita Karana. In practice, this architecture uses locally available natural materials such as bamboo, coconut wood, and natural stone that have a low environmental impact [1], [2]. However, with the increase in development and modernization, the use of traditional materials has begun to be displaced by synthetic materials such as concrete and steel which hurt the environment [3]. This creates a dilemma between maintaining local wisdom and adopting modern technology.

So far, research on sustainable architecture has focused more on ecological aspects without considering the cultural values inherent in a traditional architectural system. The selection of materials in conventional architecture considers not only the factors of efficiency and sustainability but also the spiritual values and customs of the local community [4]. Therefore, this study seeks to develop a material selection model that integrates ecological sustainability and the preservation of cultural values.

This study seeks to answer several key questions, namely: How can cultural and ecological criteria be identified in the selection of materials for traditional Balinese architecture? How can a sustainable material selection model that integrates cultural and ecological aspects be developed? How does the material selection model validate architectural practices in Bali?

This study aims to develop a sustainable material selection model for traditional Balinese architecture by considering cultural and ecological aspects. Its purpose is to provide guidance for architects and designers in choosing materials that are not only environmentally friendly but also appreciate local cultural values.

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This research has several key benefits. From an academic perspective, this research contributes to the theory of sustainable architecture that integrates cultural and ecological aspects. From a practical point of view, this study provides a material selection model for architects and interior designers. In social and cultural elements, this research contributes to increasing awareness of the importance of cultural preservation in architecture. In addition, from an ecological perspective, this research aims to reduce negative impacts on the environment by using more sustainable materials.

This research offers a new approach to integrating cultural and ecological aspects in the selection of materials, which have been studied separately in architecture. By combining these two aspects, this research is expected to provide a more holistic and applicable solution for architectural practices in Bali and other regions with strong cultural heritage.

Sustainability Theory

Sustainability theory in architecture focuses on the concept of development that can meet the needs of the present without sacrificing the ability of future generations to meet their own needs. One of the key approaches to sustainability is the concept of Cradle to Cradle, introduced by [5]. This approach emphasizes that the materials used in construction should be sustainable, renewable, and have a long life cycle. In other words, any material used must have the ability to be recycled or reused without producing toxic waste that negatively impacts the environment.

In addition, the Life Cycle Assessment (LCA) is used to assess the environmental impact of a material from the production stage to the end of its useful life [6]. LCA considers the entire life cycle of materials, including raw material extraction, production, distribution, use, and final disposal. Through this approach, architects and planners can choose materials that have a low carbon footprint and reduce negative impacts on the environment [3]. A study conducted by [7] shows that applying LCA in material selection can reduce energy consumption in the life cycle of buildings by up to 30%. Therefore, the sustainability approach in architecture focuses on energy efficiency and considers the selection of environmentally friendly and recyclable materials.

Traditional Balinese Architecture Concept

Traditional Balinese architecture has strong cultural roots and is based on Asta Kosala Kosali, a spatial rule that regulates building orientation and materials based on cosmic balance [1]. This concept aims to create harmony between humans, nature, and spirituality by selecting materials that are by local cultural and environmental values. The materials used in traditional Balinese architecture, such as bamboo, coconut wood, and natural stone, reflect the local aesthetic and have a low ecological impact because they are readily biodegradable and leave no toxic waste.

In addition to Asta Kosala Kosali, the concept of Tri Hita Karana is also the main principle in selecting materials and designing Balinese architecture. Tri Hita Karana is a philosophy that emphasizes the balance between the relationship between human beings and God (*Parahyangan*), human relations with fellow human beings (*Pawongan*), and human relations with nature (*Palemahan*) [8]. This principle emphasizes that every architectural element, including the materials used, must consider spirituality, social balance, and ecological sustainability. A study conducted by [9] shows that applying Tri Hita Karana in Balinese architecture can improve environmental sustainability and extend the life of traditional buildings without reducing their aesthetic value.

Previous Research

Various studies have been conducted related to sustainable and traditional Balinese architecture, but there is still a gap in integrating these two aspects. [3] discusses sustainable architecture with a focus on energy efficiency and environmentally friendly materials, but this study does not mention the cultural element in the selection of materials. On the other hand, [4] researched traditional Balinese materials and found that materials such as bamboo and coconut wood have high durability and are easy to renew. However, this study does not address ecological sustainability from the perspective of life cycle analysis (LCA) and the environmental impact caused by the material.

The research offers a unique contribution by combining two main approaches: ecological sustainability and the preservation of cultural values in traditional Balinese architecture. The

material selection model developed in this study refers to the principles of Cradle to Cradle, Life Cycle Assessment (LCA), and Balinese cultural concepts such as Asta Kosala Kosali and Tri Hita Karana.

RESEARCH METHODS

Methods

This study uses a mixed methods approach, which combines quantitative and qualitative methods to gain a more comprehensive understanding of the selection of sustainable materials in traditional Balinese architecture. The techniques used in this study include field observation, in-depth interviews, quantitative surveys, Multi-Criteria Decision Analysis (MCDA) analysis, and Life Cycle Assessment (LCA). This approach was chosen to integrate cultural and ecological aspects in the study of materials used in Balinese architecture.

Field observations were conducted in various traditional villages in Bali, to identify the use of conventional materials and construction practices that are still applied in traditional buildings. This observation also aims to understand how material selection is influenced by cultural, social, and environmental factors [1]. In addition, in-depth interviews with architects, cultural figures, and construction practitioners were conducted to understand their perspectives on the sustainable use of materials and the preservation of traditional Balinese architecture. This interview was conducted with a purposive sampling approach, so the selected respondents were highly relevant to this study [10].

A quantitative survey was conducted on architectural and construction practitioners who have experience in traditional and sustainable architecture projects in Bali. This survey uses questionnaires designed based on sustainability factors established in previous literature, such as energy efficiency, carbon footprint, material durability, and cultural value [7]. The data collected through this survey was analyzed using descriptive statistical methods and regression analysis to identify patterns and relationships between the variables studied.

In addition, this study also applies Life Cycle Assessment (LCA) to assess the environmental impact of various materials used in Balinese architecture. LCA is carried out concerning [6] standard, which includes material life cycle analysis from raw material extraction, production, distribution, and use to final disposal. The purpose of LCA is to identify materials with the lowest environmental impact as well as provide recommendations for the use of more sustainable materials in traditional architectural design [3].

This study aims to produce a material selection model that considers cultural and ecological aspects holistically by combining observation, interview, quantitative survey, MCDA, and LCA methods. The results of this approach are expected to significantly contribute to the development of sustainable architecture policies and increase awareness of the importance of preserving cultural values in the selection of materials.

Data Analysis

The data analysis used is qualitative and quantitative, in addition to using Multi-Criteria Decision Analysis (MCDA) as an evaluation tool in determining the most suitable materials for traditional Balinese architecture based on sustainability parameters. MCDA is used to compare various materials based on carbon footprint, durability, local availability, and suitability with traditional cultural and aesthetic values [11]. In this analysis, the Analytical Hierarchy Process (AHP) method is used to assess the weight of each criterion contributing to the material's sustainability.

RESULT AND DISCUSSION

Identify Cultural and Ecological Criteria

This study identifies various criteria that determine the selection of sustainable materials in traditional Balinese architecture based on cultural and ecological aspects. From the cultural aspect, the choice of materials is greatly influenced by Asta Kosala Kosali, which is the rule of spatial planning and materials in traditional Balinese architecture that considers the balance of cosmic and local aesthetic values [1], [12]. In addition, Tri Hita Karana emphasizes harmony between humans,

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God, and nature, which is also the main guideline in selecting materials [8], [13]. From an ecological perspective, the criteria used in the selection of materials include resource sustainability, carbon footprint, durability of materials, and their ability to be recycled [7], [14]. Materials such as bamboo, coconut wood, and natural stone have ecological advantages because they are renewable and have a lower environmental impact than synthetic materials such as concrete and steel [3], [15]. Therefore, combining cultural and ecological aspects is a key factor in determining the ideal material for traditional Balinese architecture.

Sustainable Material Selection Model

Based on the research results, a sustainable material selection model was developed that integrates the Multi-Criteria Decision Analysis (MCDA) and Life Cycle Assessment (LCA) approaches. This model is designed to provide a systematic method of evaluating and selecting materials based on the weight of cultural and ecological criteria. MCDA compares materials based on traditional, aesthetic, and functional values. At the same time, LCA assesses the environmental impact of the entire material life cycle, including the stages of raw material extraction, production, distribution, use, and final disposal [6], [16]. The model also considers the involvement of local communities in the material production process to support the principles of social and economic sustainability. With this model, architects and planners can more easily determine materials that not only meet ecological standards but also preserve traditional cultural values.

Model Validation through Field Tests and FGDs

To ensure the accuracy and relevance of the model developed, field tests and Focus Group Discussions (FGD) were conducted involving architects, academics, construction practitioners, and cultural figures in Bali. Field tests were conducted in several traditional villages in Bali, where models were tested against construction projects using local materials. The results of field tests show that this model can be used effectively in the material selection process, taking into account ecological sustainability and cultural preservation [9], [17]-[19]. Meanwhile, in the FGD session, participants provided feedback regarding the weight of the criteria used in the MCDA and provided input to improve the model's practicality in field implementation. The FGD results show strong support from the architectural community and academia for this model, with recommendations to be implemented in sustainable development regulations and policies in Bali.

Thus, this study's results show that the selection of materials in traditional Balinese architecture must consider the balance between cultural values and ecological impact. The developed model provides a more systematic and science-based solution to help with sustainable material planning while maintaining local cultural heritage.

CONCLUSION

The results of this study show that the selection of materials in traditional Balinese architecture must balance cultural and ecological aspects. Multi-Criteria Decision Analysis (MCDA) and Life Cycle Assessment (LCA)- based approaches have proven to be practical tools in evaluating the sustainability of materials used in traditional construction. The model developed allows for a more objective evaluation by considering the carbon footprint, material durability, affordability, and the cultural value contained in each material used. The analysis results show that local materials such as bamboo, coconut wood, and natural stone have ecological and cultural advantages compared to industrial materials such as concrete and steel. Local materials have a more environmentally friendly life cycle, are easier to renew, and are more in line with the philosophy of Tri Hita Karana and the principles of Asta Kosala Kosali, which are the basis for traditional Balinese architectural planning. In addition, community involvement in the production and use of local materials also contributes to social and economic sustainability. Field tests and Focus Group Discussions (FGD) conducted with architectural practitioners, academics, and cultural figures show that the material selection model developed is highly relevant and can be applied in sustainable construction practices. By considering ecological and cultural aspects simultaneously, this model is expected to be a reference for architects and planners in more sustainability-oriented decision-making.

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