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Development of an Architectural Design Performance Evaluation Matrix for Meeting Ecological Architecture Criteria: A Case Study of Apartment Design Precedents

Sultan Yazid[1], *Budi Faisal*[2], *Dewi Larasati*[2]

[1]Department of Architecture, Faculty of Technology and Design, Universitas Pembangunan Jaya, Indonesia.
[2]Department of Architecture, School of Architecture, Planning and Policy Development, Institut Teknologi Bandung, Indonesia
*Correspondence: E-mail: sultan.yazid@upj.ac.id

ABSTRACT

The growth of the population has resulted in an increasing demand for housing from year to year, particularly in urban areas of Indonesia. Large-scale apartment construction has been carried out to meet this demand. However, the rapid growth of apartment development has also led to land-use conversion, which negatively affects environmental quality by contributing to biodiversity loss. This phenomenon calls for architectural design approaches that can mitigate the environmental impact of apartment development. One such approach is ecological architecture. The ecological architecture approach aims to minimize the adverse environmental impacts of architectural products by integrating them with natural elements, consisting of both biotic and abiotic components. Based on this background, this paper seeks to elaborate the ecological architecture approach in architectural design by developing an evaluation matrix to assess architectural products. This matrix is then applied to analyze selected apartment design precedents to identify the extent to which they fulfill ecological architecture criteria. The main theoretical foundations of the matrix are drawn from the ecological architecture concepts of Sim Van der Ryn and Ken Yeang, further elaborated with supporting literature. The primary criteria employed include improving human health, enhancing biodiversity, and ensuring water quality. The proposed evaluation matrix was applied to assess five apartment design precedents. The results demonstrate that ecological architecture in apartment design can be realized through three main strategies: utilizing healthy strategies, enhancing habitat diversity, and guiding water flow. Each precedent exhibits unique characteristics in fulfilling the criteria within the matrix. In general, all selected precedents were able to meet part of the established criteria. The findings of this study indicate that apartments designed according to ecological architecture principles have the potential to improve environmental quality.

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1. INTRODUCTION

Urban environmental quality tends to gradually degrade, as evidenced by declining water quality (Zulkarnain, 2014), air quality (Ghaeeni, 2021), and biodiversity (Widiyanto, 2019). This phenomenon occurs due to building developments that pay insufficient attention to the environment. For instance, land-use conversion from natural conditions to built environments reduces the number of habitats, which is followed by a decline in water quality. Furthermore, air quality in urban areas continues to deteriorate due to pollution. For example, the city of Jakarta recorded an Air Quality Index (AQI) of 145, with PM2.5 levels of 53.4 µg/m³, indicating unhealthy air quality (IQAir, 2022).

The decline in environmental quality adversely affects human health in urban areas (Peters, 2017). This condition is exacerbated by the habit of urban residents spending nearly 90% of their time indoors (Ghaeeni, 2021). Poor urban environmental quality and deteriorating human health occur due to insufficient consideration of environmental (natural) factors during the formation of the built environment. This lack of consideration initiates negative impacts that compromise the sustainability of buildings or urban areas (Van der Ryn & Cowan, 2007).

Buildings are the highest contributors in terms of CO2 emissions (Larasati, 2021). Carbon emissions are a major factor in environmental degradation. Among buildings, residential structures, including apartments, are the highest emitters. Urban apartment development continues to rise year by year. For instance, in Indonesia, public apartment (rusun) construction increased by 7,075 units in 2021, representing a 759% increase compared to the previous year (Karnadi, 2022).

In response to this trend and the associated environmental issues, the presence of ecological architecture in apartment design can be considered significant. Ecological architecture encompasses all design efforts aimed at minimizing environmental damage by integrating architectural designs with natural elements (Van der Ryn & Cowan, 2007). Specifically, according to Ken Yeang in a seminar on ecological architecture, ecological architecture is a design process that considers nature, humans, and the built environment in creating environmentally friendly infrastructure (AA School of Architecture, 2015).

2. LITERATURE REVIEW

2.1. A Study of Sim Van Der Ryn's Ecological Architecture Approach

Ryn defines ecological architecture as any form of architectural product that minimizes adverse environmental impacts by integrating the architectural product with nature (Van der Ryn & Cowan, 2007). Ryn summarizes ecological architecture into five principles, which assist architects in identifying factors relevant to ecological values and provide foundational knowledge of natural systems as a means to manage the environment to be intervened (Ziaee, Moztarzadeh, & Movahec, 2020). The five principles of ecological architecture are as follows:

1. Solutions grow from place

Each site to be designed possesses unique characteristics. These characteristics can be observed through sunlight movement, wind direction, and site contours, which can guide design decisions. Involving the natural potentials of the site in the design process initiates architectural products that address thermal comfort. Thermal comfort is the condition in which the thermal environment is within a threshold that is comfortable for humans (Ozyavuz, 2018).

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2. Design with nature

Technologies inspired by forms or systems found in nature embody Ryn's principle of design with nature. Strategies to implement this principle in achieving ecological architecture are manifested in the argument that fossils represent failure, whereas the universe as it exists today serves as a successful model for learning (Xhexhi, 2020).

3. Making Nature Visible

Humans are part of the universe. The human fragment of the universe is reflected in the need for balance between humans and nature. Creating a balance between humans and nature through their connection is the embodiment of Making Nature Visible (Van der Ryn & Cowan, 2007). This strategy naturally enhances human health quality (Ghaeeni, 2021). The validity of this phenomenon has been confirmed by various studies. For instance, exposure to natural views in hospital rooms has been shown to increase patients' recovery rates (RS Ulrich, 1984).

4. Everyone is designer

A sustainable built environment is one designed with consideration of the communities that will inhabit it. According to Ryn, these communities play a crucial role in providing spatial solutions to the problems they experience in creating a sustainable built environment, embodying the principle that everyone is a designer (Van der Ryn & Cowan, 2007). This understanding encourages designers to plan in ways that initiate community involvement in the environment (Van der Ryn & Cowan, 2007).

5. Ecological Accounting

Ecological Accounting is the effort to calculate the impacts of implementing ecological architecture, providing an evaluation of design decisions that have been made (Van der Ryn & Cowan, 2007). This evaluation is supported by modern digital technologies, which help architects assess their designs prior to construction.

2.2. A Study of Ken Yeang's Ecological Architecture Approach

Similar to Ryn, Yeang understands ecological architecture as an effort to reduce the negative impacts of buildings on the environment by integrating physical and systemic aspects of nature with the built environment. (Yeang, 2010). There are six key points that guide buildings in minimizing their environmental impacts (Yeang, 2010). These six points are as follows:

1. Balanced Ecosystem

A balanced ecosystem strategy aims to maintain equilibrium between biotic and abiotic components within the ecosystem (Yeang, 2010). Biotic components are living elements such as animals and plants, whereas abiotic components refer to non-living elements, in this context, buildings.

2. Energy Eficiency

The key to energy efficiency is reducing a building's reliance on non-renewable energy sources (Yeang, 2010). This strategy is achieved by optimizing the building's response to climate in order to maintain thermal comfort. Buildings respond to climate using passive design strategies or a combination of passive and mechanical systems.

3. Minimize Resource Depletion

Resource depletion can be minimized by using building materials that are reusable, recyclable, and returnable to natural systems (Yeang, 2010).

4. Preserve Existing Ecosystem

Site analysis is an essential process in determining strategies to preserve existing ecosystems (Yeang, 2010). The analysis guides the implementation of this strategy through

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various approaches, such as creating continuous connections with the existing natural conditions and considering human needs in relation to the site's natural capacity.

5. Compact Space

The aim of the compact space strategy is to create minimal intervention in the environment. This contributes to reducing urban heat island effects and mitigating microclimatic issues at the design site (Yeang, 2010).

6. Water Management

Water management seeks to develop a system that regulates water inflow and outflow from the building (Yeang, 2010). This can be implemented through various methods, generally including water collection, purification, and distribution systems, enabling controlled water flow and reuse.

2.3. Elaboration of Ecological Architecture Principles

The principles of ecological architecture from Ryn and Yeang are evaluated based on their direct relationship to the three issues addressed (Table 1). This evaluation is presented in the table below. The table assesses whether each principle is closely related—accompanied by keywords—or not related, meaning it does not have a direct connection.

Table 1. Elaboration of Ecological Architecture Approaches

Ecological Architecture Strategy		Human Health	Biodiversity	Water Quality
Solutions grow from place	Ryn	Yes (Keyword: thermal comfort)	Yes (Keyword: preserving natural conditions)	Yes (Keyword: considering water components)
Design with nature	Ryn	Yes (Keyword: integrating nature through biomimicry)	No	No
Making Nature Visible	Ryn	Yes (Keyword: human-nature connection)	Yes (Keyword: providing habitats)	Yes (Keyword: human-nature connection)
Everyone is designer	Ryn	No	Yes (Keyword: providing habitats)	No
Ecological Accounting	Ryn	Yes (Keyword: design evaluation)	No	Yes (Keyword: calculating water flow)
Balanced Ecosystem	Yeang	Yes (Keyword: human-nature connection)	Yes (Keyword: preserving natural conditions)	Yes (Keyword: considering water components)
Energy Eficiency	Yeang	No	No	No
Minimize Resource Depletion	Yeang	No	No	No
Preserve Existing Ecosystem	Yeang	No	Yes (Keyword: preserving natural conditions)	Yes (Keyword: considering water components)
Compact Space	Yeang	No	No	No
Water Management	Yeang	No	No	Yes (Keyword: considering water components)

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Based on the table above (Table 1), the ecological architecture approach in apartment design is formulated by the author into three strategies. These three strategies consist of enhancing biodiversity (A), guiding water flow (B), and utilizing healthy strategy (C). Each strategy is further divided into sub-strategies (Table 2). For ease of discussion, the code X is used for the main strategies, and X(n) is used for the sub-strategy codes.

Table 2. Criteria for Ecological Architecture Approaches

Principle		**Sub-Principle**	
Principle	Definition	Sub-principle	Definition
Enhancing Bio Diversity (A)	Strategy to increase the diversity of existing habitats. This promotes a balanced ecosystem among plant communities, biotic communities, and the physical environment.	Green and Site Ecology Areas (A1)	Analyze site ecology consisting of natural biotic and abiotic components to be preserved and enriched
			Minimize interventions to existing natural conditions, such as open green spaces. If intervention is necessary, the design must provide compensation for constructed green spaces.
		Landscaping and Building Vegetation (A2)	Introduce various types of local plants in both landscaping and buildings, vertically and horizontally.
			Implement green infrastructure in landscaping or buildings that is integrated.
Guiding Water Flow (B)	Strategy to manage water within the site. Generally, this management consists of three steps: collection, purification, and distribution of water. These steps aim to improve water quality.	Rainwater Runoff Management (B1)	Provide rainwater storage to reduce runoff from the site
			Reuse rainwater for irrigation.
		Alternative Water Sources and Water Recycling (B2)	Reuse rainwater for irrigation.
Utilizing Healthy Strategy (C)	Strategy designed to improve human health quality. Generally, the determinants of human quality consist of two factors: first, thermal comfort, achieved by responding to local climate in the design; second, interaction between humans and nature.	Thermal Comfort (C1)	Provide spaces with average annual conditions that meet thermal comfort, particularly regarding temperature and air introduction indoors.
		Lighting and Visual Quality (C2)	Meet the lighting needs of spaces according to standards based on human use.
			Provide openings that face nature for functional spaces.
		Facilities Supporting	Provide green open spaces and other functions that encourage physical activity of apartment users.

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Principle		Sub-Principle	
Principle	Definition	Sub-principle	Definition
		Physical Activity (C3)	Support interaction and active engagement among residents.
		Material Emissions (C4)	Eliminate smoking facilities in public areas of the building.
			Use materials and coatings according to health standards.

3. METHODS

This study is based on a literature review, with primary sources drawn from the works of Sim Van der Ryn and Ken Yeang. These sources discuss the concepts and implementation of ecological architecture. The collected literature was further elaborated with an emphasis on three key issues: human health, biodiversity, and water quality. The findings from this review were supported by additional relevant literature, resulting in an evaluation matrix for assessing the fulfillment of ecological architecture criteria.

The matrix serves as a tool to identify the extent to which five selected apartment design precedents meet the ecological architecture criteria. The precedents were chosen based on several criteria, such as vertical residential function and visual evidence of ecological architecture implementation. Evaluation of the precedents using the matrix was conducted through a review of textual and visual data obtained from data sources. Each precedent was assessed as either **yes** or **no** for each criterion in the matrix. Subsequently, a comparative analysis was conducted to compare the results, leading to findings and conclusions regarding how each precedent fulfills specific criteria in the matrix.

4. RESULTS AND DISCUSSION

4.1. Apartment Precedents

An apartment is a building with shared ownership constructed on common land. This shared ownership consists of residential units arranged either vertically or horizontally (Pemerintah Republik Indonesia, 2021). Five apartment typologies were analyzed in relation to their intensity in implementing ecological architecture approaches. These apartments are presented in the table below, which provides both data and images. Each precedent features a similar arrangement of images (Table 3). The arrangement consists of three images that will be discussed further. For ease of discussion, codes are assigned to the precedents as P(n) and to the images within each precedent as P(n)G1, P(n)G2, and P(n)G3.

Table 3. Apartment Precedents

No	Data		Overview
P1	Project Name	Xixi Wetland Estate	 P1G1  P1G2  P1G3
	Architect	David C.	
	Location	China	
	Climate character	Subtropical	
	Typology	Residential	

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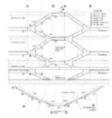
No	Data		Overview
P2	Project Name	79&PARK	 P2G1  P2G2  P2G3
	Architect	BIG	
	Location	Sweden	
	Climate character	Temperate	
	Typology	Residential	
P3	Project Name	M6B2 Tower of Biodiversity	 P3G1  P3G2  P3G3
	Architect	Edouard Francois	
	Location	France	
	Climate character	Temperate	
	Typology	Residential	
P4	Project Name	The Alpha	 P4G1  P4G2  P4G3
	Architect	Tony Owen Partners	
	Location	Australia	
	Climate character	Subtropical	
	Typology	Mixed-use	
P5	Project Name	Gardenhouse	 P5G1  P5G2  P5G3
	Architect	MAD Architects	
	Location	California	
	Climate character	Mediterranean	
	Typology	Residential	

Soruce: Adapted from P1 (Castro, 2015); P2 (Hernández, 2018); P3 (Francois, 2016); P4 (Tony Owen and Partners, 2015); and P5 (Pintos, 2020).

4.2. Precedent Analysis Based on the Matrix

The five precedents described above were analyzed based on textual and visual data provided by the sources. The analysis was conducted by assessing the alignment of the findings with ecological principles. If a criterion was met, it was marked as yes, accompanied by a reference to the image code. If the criterion was difficult to identify, it was marked as no (Table 4).

Table 4. Assessment of Precedent Performance in Fulfilling the Ecological Architecture Matrix

Principle	Sub-Principle	P1	P2	P3	P4	P5
A	A1	Yes, P1G2, wetland preserved	No	Yes, P3G1, ecological compensation by providing habitat diversity	No	No
	A2	Yes, P1G1, building vegetation present	Yes, P2G2, green roof covering entire rooftop.	Yes, P3G3, three vertical planting systems	No	Yes, P5G1, massive green wall technology
B	B1	Yes, P1G2, wetland as	No	No	No	No

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Principle	Sub-Principle	P1	P2	P3	P4	P5
		rainwater storage				
	B2	Yes, P1G2, wetland as alternative water filter	No	No	No	No
C	C1	No	No	No	Yes, P4G1, double-skin technology to reduce heat	No
	C2	Yes, P1G3, windows in all functional spaces	Yes, P2G3, building orientation responds to sun path	No	Yes, P4G3, double-skin framing emphasizes openings	No
	C3	No	Yes, P2G1, mass configuration encourages occupant engagement	No	No	Yes, P5G3, interactive communal space
	C4	No	No	No	No	Yes, P5G2, green wall at frontage

Based on the table above, a comparative analysis was conducted across each principle to derive conclusions. These conclusions are summarized in the table below (Table 5).

Table 5. Summary of Analysis Results

Principle	Sub-Principle	Conclusion
A	A1	Preserve or optimize existing natural conditions and provide compensation for any damaged natural elements. If the existing condition is not natural, efforts are made to convert it into a more natural state.
	A2	Plant local species intensively on both the site and building. The planted vegetation is physically integrated and interconnected.
B	B1	Provide rainwater storage using cut-and-fill techniques, forming an artificial wetland.
	B2	Water is naturally filtered either through landscaping or building technologies. Filtered water is reused for irrigation.
C	C1	Use double-skin technology that is organic, brightly colored, and operable as needed. The double skin reduces radiation while remaining permeable to wind.
	C2	Wide openings face nature, with massing supporting light distribution into the spaces. The building mass is streamlined, avoiding double-loaded corridor configurations.
	C3	Building mass is designed to be welcoming for users. Additionally, communal spaces are integrated with easy and varied accessibility
	C4	Implement green walls as buffers at the building frontage

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5. CONCLUSIONS

The ecological architecture approach has broad applications because nature offers numerous solutions. Therefore, by first defining the specific problems to be addressed in the design, the application of ecological architecture can be more focused and directed. By emphasizing the identified issues, the literature on ecological architecture can be elaborated into three main strategies. These three strategies are then structured into a matrix to evaluate apartment design precedents. This allows the assessment of the significance of each precedent in implementing ecological architecture aspects in their design, specifically in enhancing human health, promoting biodiversity, and responding effectively to water management.

Each precedent possesses unique characteristics and emphasizes different ecological aspects relative to the critical issues it addresses. This paper can serve as a reference for designers facing similar challenges and seeking solutions through an ecological architecture approach.

REFERENCES

AA School of Architecture. (2015, October 9). *Ken Yeang - Ecoarchitecture: Projects, Theory, Ideas, Subsystems [Video]*. From Youtube: https://www.youtube.com/watch?v=-qr7sCqCwQ4

Castro, F. (2015). *Xixi Wetland Estate / David Chipperfield*. From Archdaily: https://www.archdaily.com/777243/xixi-wetland-estate-david-chipperfield-architects-plus?ad_source=search&ad_medium=projects_tab

Francois, E. (2016). *M6B2 Tower of Biodiversity / Edouard Francois*. From Archdaily: https://www.archdaily.com/799902/m6b2-tower-of-biodiversity-edouard-francois?ad_source=search&ad_medium=projects_tab

Ghaeeni, M. (2021). Enhancing elderly health and wellbeing through the true revival of sun and wind architecture. *J. Art Arch. Stud 10.1*, 6-13.

Hernández, D. (2018). *79&PARK / BIG*. From Archdaily: https://www.archdaily.com/905534/79-and-park-big

IQAir. (2022, April 15). *Kualitas udara di Jakarta*. From IQAir: https://www.iqair.com/id/indonesia/jakarta

Karnadi, A. (2022, February 1). *Rumah Susun di Indonesia Bertambah 7.075 Unit pada 2021*. From Dataindonesia.id: https://dataindonesia.id/sektor-riil/detail/rumah-susun-di-indonesia-bertambah-7075-unit-pada-2021

Larasati, D. (2021). *Introduction to Green Building [Power Point Slide].* Bandung: SAPPK ITB.

Ozyavuz, M. B. (2018). Analysis of Bioclimatic Comfort of Tekirdag (Turkey) Province with Geographical Information Systems. *Journal of Environmental Protection and Ecology 19.1*, 407-416.

Pemerintah Republik Indonesia. (2021). *PERATURAN PEMERINTAH REPUBLIK INDONESIA NOMOR 13 TAHUN 2O2I TENTANG PENYELENGGARAAN RUMAH SUSUN.* Indonesia: Presiden Republik Indonesia.

Peters, T. (2017). Super-Architecture: Building Better Health. *Architectural Design March*, 24-31.

Pintos, P. (2020). *Gardenhouse / MAD Architects*. From Archdaily: https://www.archdaily.com/946522/gardenhouse-mad-architects

RS Ulrich, e. a. (1984). View Through a Window May Influence Recovery from. *Science 224, 420*.

DOI: https://doi.org/10.17509/jare.v7i2.90700
p- ISSN 2798-2246 e- ISSN 2798-2165

Tony Owen and Partners. (2015). *The Alpha / Tony Owen Partners*. From Archdaily: https://www.archdaily.com/639376/the-alpha-tony-owen-partners?ad_source=search&ad_medium=projects_tab

Van der Ryn, S., & Cowan, S. (2007). Ecological Design. In S. V. Ryn, & S. Cowan, *Ecological Design.* Washington, D.C.: Island Press.

Widiyanto, A. &. (2019, June 13). *Bumi Krisis Keanekaragaman Hayati*. From Mongabay Situs Berita Lingkungan: https://www.mongabay.co.id/2019/06/13/bumi-krisis-keanekaragaman-hayati/

Xhexhi, K. (2020). Metaphor in Eco Architecture. *International Journal of Software & Hardware Research in EngineerinG*.

Yeang, K. a. (2010). *Dictionary of ecodesign: an illustrated reference.* London & New York: Routledge.

Ziaee, A., Moztarzadeh, H., & Movahec, K. (2020). The Role of Parametric System in the Analysis of Sim Van Der Ryn's Ecological Architecture Principles in Iranian Plateau. *Armanshahr Architecture & Urban Development 13.30*, 167-182.

Zulkarnain, I. (2014, November 12). *LIPI: Kualitas Air Kota Besar Indonesia Memburuk*. From Lembaga Ilmu Pengetahuan Indonesia: http://lipi.go.id/berita/single/LIPI-Kualitas-Air-Kota-Besar-Indonesia-Memburuk/9280

DOI: https://doi.org/10.17509/jare.v7i2.90700
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