

Analysis of Contemporary Tall Building Design in Humid Tropics Using Yeang's Principles

Christopher Aaron Sutantio¹, Rully Damayanti²

¹ Master Student, Architecture Program, Petra Christian University, Surabaya, Indonesia

² Architecture Program, Petra Christian University, Surabaya, Indonesia

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Corresponding Author:

Christopher Aaron Sutantio

Master Student, Architecture Program,
Petra Christian University
Jl. Siwalankerto 121-131, Surabaya,
Indonesia

Email: aaronsutantio@gmail.com

Abstract

Rapid urbanization in humid tropical climates has led to an increase in the construction of contemporary tall buildings due to population growth and land shortages, leading to an increasing number of tall building constructions in urban areas. However, these buildings face several challenges, such as climate, environmental impact, and excessive energy consumption. Integrating Yeang's principles into tall buildings can overcome these challenges. This research explores the application of Yeang's principles to contemporary tall buildings in humid tropical climates, specifically considering sun path and wind rose projections. There are eight iconic contemporary tall buildings that were selected in humid tropical climates based on their public significance as case studies to analyze their building design and compare their implementation with Yeang's principles. Despite some buildings adhering to Yeang's principles, there are several factors that influence the building's design, leading to certain modifications. These adjustments impact the building's form and structures. By looking at how design implementation compares to Yeang's principles, this study shows the challenges and opportunities of creating sustainable and adaptable tall buildings in humid tropical environments.

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INTRODUCTION

Over the years, the urban area in a humid tropical climate has grown rapidly, which gives opportunities for constructing tall buildings as an efficient solution for land use. There are several countries that reside in humid tropical climates and are mainly from Southeast Asia, such as Indonesia, Malaysia, Singapore, Thailand, the Philippines, Brunei, Vietnam, Cambodia, Laos, Myanmar, and Timor-Leste. As of July 1, 2024, the UN's latest population estimates indicate that 695,149,428 people reside in Southeast Asia (*South-Eastern Asia Population*, n.d.). The population in this region is equivalent to 8.52% of the total world population (*South-Eastern Asia Population*, n.d.). The construction of vertical buildings and the demographic conditions in Southeast Asia hold intriguing implications. It turns out that around 52.2% of Southeast Asia's population lives in urban areas, with the total population of urban areas reaching 362,656,317 people as of July 1, 2024 (*South-Eastern Asia Population*, n.d.). This shows that the population in Southeast Asia has been increasing lately, and it is not surprising. As urban areas become increasingly dense, the construction of vertical buildings has become an effective solution to accommodate the need for living space, offices, and other public facilities.

The construction of tall buildings is a consideration because, apart from addressing the increase of population in the humid tropical climates, it can also be used to optimize the use of limited land in urban areas. This statistic illustrates the percentage of total land in Southeast Asian countries that has been used for urban areas (Das & Paul, 2021; Figure 1). The country in Southeast Asia that has the highest percentage of urban land is Singapore, which has a percentage of 79.77% (Das & Paul, 2021; Figure 2). This shows that the growth of urbanization in Singapore has been very rapid, so that 79.77% of the total land has been developed as an urban area. In addition, because land in Singapore is smaller than other Southeast Asian countries and only has one city, the percentage is higher than others. The country in Southeast Asia with the lowest percentage of urban land is Laos, which has 0.44% (Das & Paul, 2021;

Figure 2). This indicates that the development of urbanization in Laos is still lacking due to the fact that the land has many mountains and a lack of flat land, so there is more focus on the development of rural areas rather than urban areas.

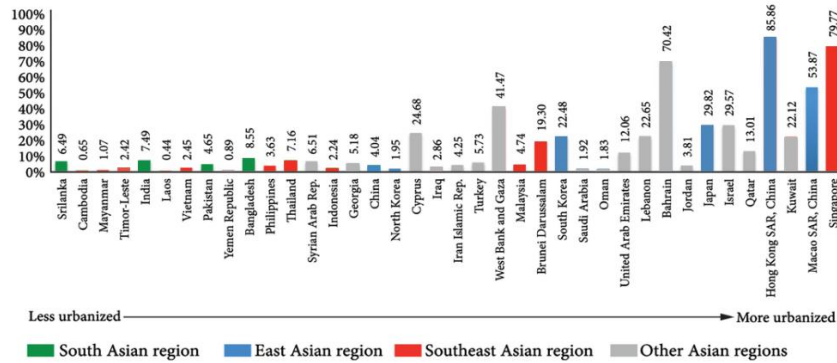


Figure 1. The Urban Land Percentage in All Asia Countries and Territories by 2019 (Source: The World Bank, 2020; Das & Paul, 2021)

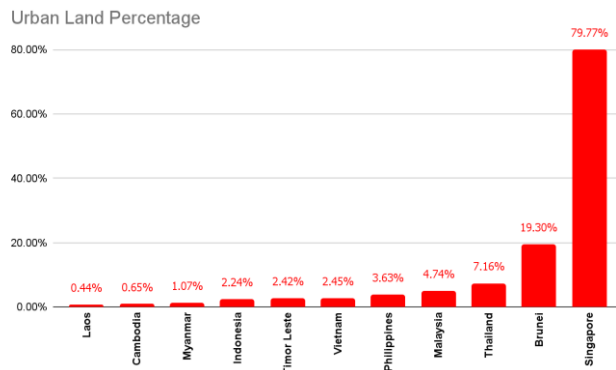


Figure 2. The Urban Land Percentage in Southeast Asia Countries and Territories by 2019 (Source: The World Bank, 2020; Das & Paul, 2021)

The tall buildings in each region are starting to increase rapidly due to the urban areas becoming increasingly dense over the years. According to statistics, the first 17 years of the twenty-first century have seen the construction of more than three times as many skyscrapers as the entire twentieth century, and this trend is likely to continue in the upcoming years (Oldfield, 2019; Figure 3).

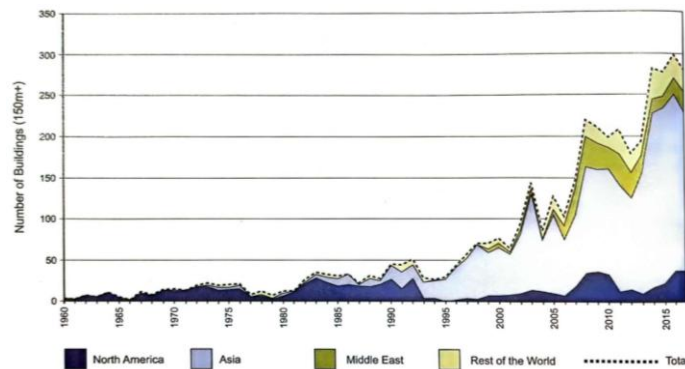


Figure 3. The Annual Tall Building Construction By Region for Heights of 150 m+ from 1960-2017 (Source: Oldfield, 2019)

Several countries in Southeast Asia will have more tall buildings than the others in the year 2024 (Countries by Number of 150m+ Buildings, n.d.; Table 1). For instance, Malaysia boasts a total of 304 tall buildings that are taller than 150 meters. Indonesia ranks second in Southeast Asia with a total of 136 tall buildings that are taller than 150 meters. Thailand has a total number of 131 tall buildings that are above 150 meters. The Philippines has a total of 128 that are above 150 meters. Singapore boasts a total of 98 buildings that are over 150 meters in height. In Vietnam, there are a total of 42 buildings above 150 meters. While Cambodia has a total of 6 buildings that are above 150 meters (Countries by Number of 150m+ Buildings, n.d.; Table 1).

Table 1. The Number of Tall Building in Southeast Asia for heights of 150 m+ in 2024

Rank	Country	Population	Area	Density	Numbers of Buildings			Tallest City
					150 m+	200 m+	300 m+	
4	Malaysia	30,073,353	328,550 M km ² 126,853 M mi ²	92 people per km ² 237 people per mi ²	304	70	6	Kuala Lumpur
9	Indonesia	237,556,363	1,910,931 M km ² 737,811 M mi ²	124 people per km ² 322 people per mi ²	136	50	2	Jakarta
10	Thailand	67,070,000	510,890 M km ² 197,255 M mi ²	131 people per km ² 340 people per mi ²	131	29	3	Bangkok
11	Philippines	94,013,200	300,000 M km ² 115,830 M mi ²	313 people per km ² 812 people per mi ²	128	41	0	Makati
13	Singapore	5,076,700	723 M km ² 279 M mi ²	7,022 people per km ² 18,186 people per mi ²	98	34	0	Singapore
22	Vietnam	93,421,835	310,070 M km ² 119,718 M mi ²	301 people per km ² 780 people per mi ²	42	8	2	Ho Chi Minh City
38	Cambodia	13,395,682	181,035 M km ² 69,898 M mi ²	74 people per km ² 192 people per mi ²	6	4	0	Phnom Penh

Source: *Countries by Number of 150m+ Buildings*, n.d.

However, tall buildings in the humid tropics have faced several challenges related to the climate and surrounding environment. Lots of tall building design often neglects the uses of green spaces and their impacts on the surrounding environment, resulting in using more energy and resources. Constructing tall buildings requires a lot of considerations, especially with their surroundings. There are several architects who have contributed significantly to environmentally responsive architecture, including Heinz Frick with his ecological architecture, Ken Yeang with his bioclimatic approach, and Geoffrey Bawa through tropical modernism (Frick & Suskiyatno, n.d.; Purwanti & Nazir, 2022; Putri & Winarto, 2025; Ramachandran & Subramanian, 2024; Robson, 2002; Yasser, 2025; Yeang, 1994). While Frick and Bawa emphasize harmony between buildings, nature, and human activities in tropical contexts, their approaches are generally more applicable to low- to mid-rise buildings and broader environmental integration. In contrast, Ken Yeang's bioclimatic approach is specifically developed to address the complexities of tall buildings in humid tropical climates, critically examining their high energy demand, material intensity, and ecological impact. Therefore, Ken Yeang's approach is selected over the others because it offers a more explicit, scalable, and climate-responsive framework for evaluating and designing tall buildings with reduced environmental impact. According to Ken Yeang, a tall building can never be a truly green building, and certainly not in totality (Richards, 2007). Besides that, he also mentions that the skyscraper, or tall building, is one of the most unecological building types because lots of tall buildings use a third more (and maybe even more) energy and material resources to build, operate, and eventually demolish (Richards, 2007). From the statement of Ken Yeang, it would seem that a tall building uses much more energy due to daily operation and initial construction than non-tall buildings due to factors moderated by heights (Oldfield, 2019). The tall buildings are now being questioned on whether these buildings could be energy efficient and use fewer resources or not while being sustainable for longer periods of time.

In humid tropical climates, characterized by high temperatures, persistent humidity, and intense solar exposure throughout the year, tall buildings encounter significant environmental and energy challenges. These challenges make the integration of vegetation and bioclimatic design principles particularly important, as such strategies allow buildings to respond effectively to climatic stresses by reducing the use of energy for efficiency, reducing the heat effects that come to the building, and enhancing the air quality of the building. By enabling buildings to adapt more closely to their surrounding climate and environment, bioclimatic design becomes a crucial approach for promoting sustainability and improving the quality of dense urban areas in tropical regions. Moreover, integrating vegetation into the tall buildings could also impact human health as well as their well-being.

The objectives of this research are to dissect the design of iconic contemporary tall buildings in countries with humid tropical climates to identify adaptations of Ken Yeang's principles specifically to considered sun path (core, orientation, shading, balconies, windows) and wind rose projections (transitional spaces, balconies, and landscape). The benefits of this research for architects are expected to be able to provide more specific guidance in applying Ken Yeang's principles to tall buildings in humid tropical climates. For users, it is hoped that this research can provide recommendations for tall building designs that are more comfortable and energy efficient in humid tropical climates, thereby improving the quality of life of their residents. For readers, this research makes a new contribution to the field of contemporary tropical architecture by examining in depth the application of Ken Yeang's principles to tall buildings.

LITERATURE REVIEW

Sustainable architecture is becoming a very popular thing in the modern era, when urban density is getting higher, green open spaces are decreasing, and the use of renewable energy is far from a fire (Syam et al., 2023). According to James Stevens Curl and Susan Wilson (Authors of the Oxford Architectural Dictionary), Sustainable Architecture is architecture that does not waste energy, does not require expensive maintenance, and is not a building that has poor insulation or too much glass (Syam et al., 2023). Moreover, sustainable design in architecture is guided by a set of fundamental principles, ensuring considerations for the environment, user well-being, and energy efficiency (Yasser, 2025). In humid tropical climates, where high temperatures, intense solar radiation, and elevated humidity dominate throughout the year, the application of sustainable architecture principles becomes increasingly complex, particularly in tall buildings. In this context, bioclimatic architecture emerges as a relevant and effective approach within sustainable architecture, as it prioritizes climate-responsive strategies such as optimal building orientation, natural ventilation, solar shading, and façade design adapted to tropical conditions (Yasser, 2025). To further elaborate on how sustainable architecture principles can be effectively implemented in tall buildings under humid tropical conditions, it is necessary to examine bioclimatic architecture as a climate-responsive design approach.

Bioclimatic architecture is an approach that studies and observes the relationship between life and the surrounding environment, including the climate in that area (Christianto & Damayanti, 2021; Yeang, 1994). The bioclimatic approach is a way of designing buildings that could respond to the climate and the surrounding environment while also designing low-energy and passive buildings that focus on occupant comforts (Christianto & Damayanti, 2021; Yeang, 1994). Apart from that, bioclimatic architecture aims to create buildings that become environmentally friendly and save energy by utilizing and managing natural resources effectively (Almusaed, 2011; Khairunnisa et al., n.d.). In designing vertical buildings that apply the bioclimatic concept, Ken Yeang has several bioclimatic design principles for vertical buildings in humid tropical regions, such as core positions, building orientation, window openings, placing balconies, transitional spaces, external walls, connection with planting and landscape, and also solar shading. Core positions are important due to their significantly influencing both the overall structural system and thermal performance of a building. Yeang also classified core positions into three types, which are central core, single-sided core, and double core (which is highly recommended because it could be provided as a buffer zone) (Abubakar et al., 2025; Christianto & Damayanti, 2021; Kurnia & Purwantiasning, 2022; Putri & Winarto, 2025; Yeang, 1994; Figure 4). Building orientation in tall buildings is essential for reducing heat gain and saving energy, with openings recommended to face north and south and minimal surface areas exposed to the east and west (Abubakar et al., 2025; Christianto & Damayanti, 2021; Kurnia & Purwantiasning, 2022; Putri & Winarto, 2025; Yeang, 1994; Figure 4). Window openings are preferred to face the north and south because they aren't exposed to direct sunlight and could still get a great view, additionally curtain walls could also be used for aesthetic reasons (Abubakar et al., 2025; Christianto & Damayanti, 2021; Kurnia & Purwantiasning, 2022; Putri & Winarto, 2025; Yeang, 1994; Figure 4). Placing balconies on tall buildings, especially on the west and east sides, can help reduce solar heat gain because they could also be used as external shading devices while also serving as planting areas that provide additional natural shade (Figure 4). Transitional spaces in tall buildings, such as atriums, voids, skycourts, and balconies that are placed in the center and edge of the building, could act as buffer areas between the indoor and outdoor, enabling cross-ventilation within the building, especially when complemented by vegetation (Abubakar et al., 2025; Christianto & Damayanti, 2021; Kurnia & Purwantiasning, 2022; Putri & Winarto, 2025; Yeang, 1994; Figure 4). External walls are the secondary skin facade and should also have some moveable parts to enable good cross-ventilation, provide solar shading, and control wind-driven rain (Abubakar et al., 2025; Christianto & Damayanti, 2021; Kurnia & Purwantiasning, 2022; Putri & Winarto, 2025; Yeang, 1994; Figure 4). Plants and landscaping should be strategically integrated because they could provide cooling effects and environmental benefits, including absorbing carbon dioxide and releasing oxygen. Solar shading is needed to reduce solar heat gain, especially on the west and east sides that are exposed to direct sunlight (Abubakar et al., 2025; Christianto & Damayanti, 2021; Kurnia & Purwantiasning, 2022; Putri & Winarto, 2025; Yeang, 1994; Figure 4).

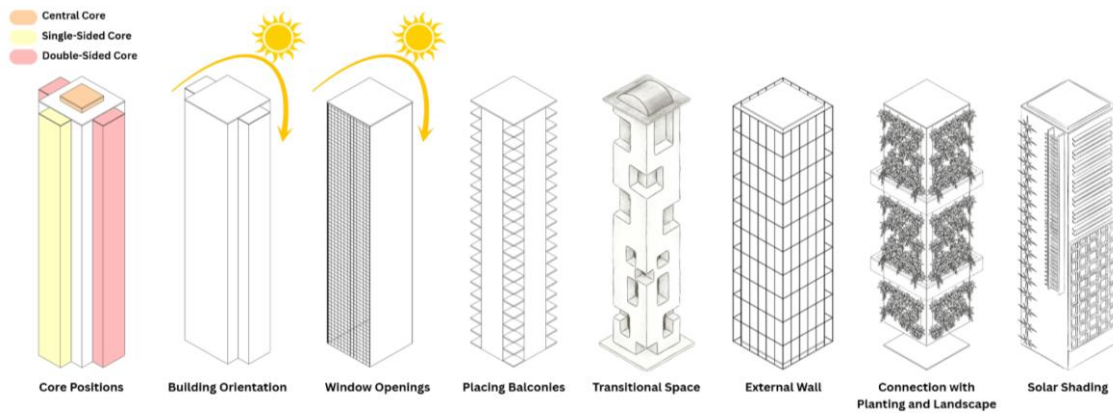


Figure 4. Yeang's Design Principles

(Source: Abubakar et al., 2025; Christianto & Damayanti, 2021; Kurnia & Purwantiasning, 2022; Putri & Winarto, 2025; Yeang, 1994)

METHODS

This research uses a qualitative method in the form of an analysis of Ken Yeang's bioclimatic design principles on 8 case studies of contemporary tall buildings in humid tropical areas, namely, Singapore, Bangkok, Ho Chin Minh, and Kuala Lumpur. We conduct this research in four stages. The first is identifying the criteria for tall buildings in bioclimatic principles by conducting a literature study regarding Ken Yeang's bioclimatic design principles, such as core position, building orientation, window openings, balcony placement, transitional space, external walls, and relationship with landscape, as well as passive shading tools. The second stage involves developing criteria and identifying tall buildings as case studies that adhere to Yeang's principles. As shown in Table 2, this is achieved by conducting literature reviews on case studies that are part of regional icons based on their Public Significance. The third stage involves analyzing the building design of the case study using Yeang's principles, which is achieved by matrixing Yeang's principle criteria with the case study. The final stage is to compare the implementation of bioclimatic design in the case study with Yeang's principles.

Table 2. 8 Tall Buildings in Humid Tropical Climates Regions that are Iconic Based on Public Significance

Case Study	Building's Height	Year of Completion	Public Significance
1. Green Heart Marina One (Singapore)	Office Tower (200 meters) and Residential Tower (139 meters) (<i>Marina One Complex, Singapore - Ingenhoven Architects Architectura Viva, n.d.</i>)	2017 (<i>Green Heart Marina One Singapore / Ingenhoven Architects, n.d.</i>)	The most innovative sustainable and high density building complex (<i>Marina One Biennial, n.d.</i>)
2. Skyville @ Anson (Singapore)	148 meters (<i>SkyVille @ Dawson, n.d.</i>)	2015 (<i>SkyVille @ Dawson, n.d.</i>)	Awarded Platinum Green Mark Rating as Singapore highest and the first public housing (<i>The Skyscraper Museum: GARDEN CITY MEGA CITY: WOHA Rethinks Cities for the Age of Global Warming, n.d.</i>)

3. Petronas Twin Tower (Kuala Lumpur)



452 meters
(*Petronas Towers Complex*, n.d.)

1998
(*Petronas Towers Complex*, n.d.)

Annually 1.5 million people (Total visitors 7.8 millions until 2024) (*Petronas Towers*, n.d.; *PETRONAS Twin Towers*, n.d.)

4. Telekom Tower (Kuala Lumpur)



310 meters
(*Menara TM*, n.d.)

2001
(*Menara TM*, n.d.)

The first supertall 'twisted' skyscrapers in the world (Mohan et al., n.d.; *Telekom Tower*, n.d.)

5. King Power Mahanakhon (Bangkok)



320 meters
(*MahaNakhon*, n.d.)

2016
(*MahaNakhon*, n.d.)

Approximately 1.5 million visitors per year (*King Power Mahanakhon, Bangkok — Stores & Hours*, n.d.)

6. The Met (Bangkok)



231 meters
(*The Met*, n.d.)

2009
(*The Met*, n.d.)

Most tropical high-rise housing in developing countries and self sufficiency index for energy is 0% (received The International Aga Khan Award 2013) (Oswald & Riewe, n.d.; *The Met - WOHA*, n.d.)

7. Landmark 81 (Ho Chi Minh)



470 meters
(*Vincom Landmark 81*, n.d.)

2018
(*Vincom Landmark 81*, n.d.)

Largest “Green Building” in Vietnam (*Landmark 81*, n.d.; “Landmark 81 – The Tallest Building in Southeast Asia,” 2019, p. 8)

8. Bitexco Financial Tower (Ho Chi Minh)



264 meters (<i>Bitexco Financial Tower</i> , n.d.)	2010 (<i>Bitexco Financial Tower</i> , n.d.)	One of the world's top 25 iconic skyscrapers by CNN in 2013 (<i>The Bitexco Financial Tower Office Tower</i> , n.d.)
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RESULTS AND DISCUSSION

The analysis is conducted by selecting eight iconic contemporary tall buildings in humid tropical climates that were chosen based on their public significance as shown from Table 2, and will going to be analyzed in using Yeang's principles. Of all the selected case studies, there are two tall buildings from Singapore, which are **S1** (Green Heart Marina One) and **S2** (Skyvill@Anson) on Table 3. Another two buildings are selected from Thailand, which are **T1** (King Power Makanakhon) and **T2** (The Met Office), which are present on Table 3. From Malaysia there are also 2 buildings, which are **M1** (Petronas Twin Tower) and **M2** (Menara Telekom), which are present in Table 3. While the last 2 buildings are from Vietnam, which are **V1** (Landmark 81) and **V2** (Bitexco Financial Tower), which are shown in Table 3. The selected buildings are categorized into one tables to establish a systematic framework for further analysis based on Yeang's principles.]






Core Positions

Table 3 demonstrates that the two buildings from Singapore have different core positions from one another. The **S1** (Green Heart Marina One) combines a double-sided and single-sided core, and the **S2** (Skyville @ Anson) has a central core in all three towers. There are also two buildings from Malaysia that have the same core positions, which are using a central core, whereas **M1** (Petronas Twin Tower) uses a central core in two towers, while **M2** (Menara Telekom) uses a central core. The two buildings from Thailand have similar core positions in which they are using a central core, but the differences are that **T1** (King Power Mahanakhon) uses a central core, while **T2** (The Met Office) uses a central core in all three towers. From Vietnam, both buildings, which are **V1** (Landmark 81) and **V2** (Bitexco Financial Tower), also use a central core. The only one who follows Yeang's design principles is **S1**, which emphasizes the use of double-sided cores. While the other 7 buildings are not adhering to Yeang's principles, which suggest the placement of a double-sided core. Nevertheless, even though the core placement does not fully comply with Yeang's design principles, it can still function as a buffer zone that limits direct heat gain to the building while supporting the flow of natural ventilation (Abubakar et al., 2025; Christianto & Damayanti, 2021; Putri & Winarto, 2025; Yeang, 1994).

Building Orientation

Table 3 shows that the orientation of buildings from Singapore, such as **S1** (Green Heart Marina One) is dominantly northwest to southeast, while **S2** (Skyville @ Anson) has a more dominant building orientation facing southwest to northeast. Both buildings from Malaysia, **M1** (Petronas Twin Tower) and **M2** (Telekom Tower), have a dominant building orientation facing northwest to southeast. In terms of building orientation from Thailand, **T1** (King Power Mahanakhon) is dominantly oriented southwest to northwest, while **T2** (The Met Office) is dominantly oriented northwest to southeast. Both of the buildings from Vietnam, such as **V1** (Landmark 81) and **V2** (Bitexco Financial Tower), are dominantly facing southwest to northwest. Although all buildings do not have a dominant orientation in the north-south direction, there are several factors that can influence their orientation. These factors include different land sizes, which can influence the shape and orientation of the buildings, as well as following the direction of the wind and sun to maximize natural ventilation and reduce direct solar heat. Apart from that, building orientation also affects window openings and the placement of balconies in the building (Abubakar et al., 2025; Christianto & Damayanti, 2021; Putri & Winarto, 2025; Yeang, 1994).

Table 3. Case Study Analysis of Tall Buildings in Humid Tropical Regions using Yeang's Principles Core Positions and Building Orientation

Case Study	Core Positions	Building Orientation
<p>[S1] Green Heart Marina One (Singapore)</p> 		
<p>[S2] Skyville@Anson (Singapore)</p> 		
<p>[M1] Petronas Twin Tower (Malaysia)</p> 		
<p>[M2] Menara Telekom (Malaysia)</p> 		
<p>[T1] King Power Mahanakhon (Thailand)</p> 		

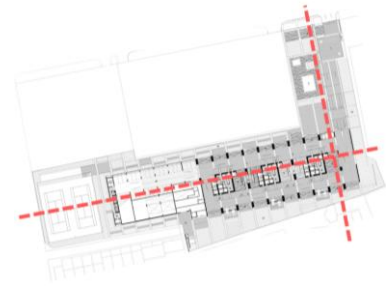
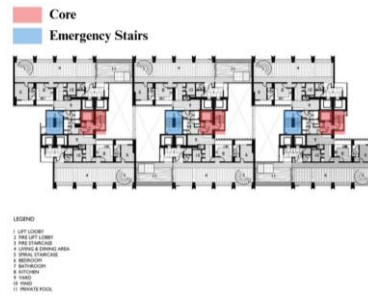
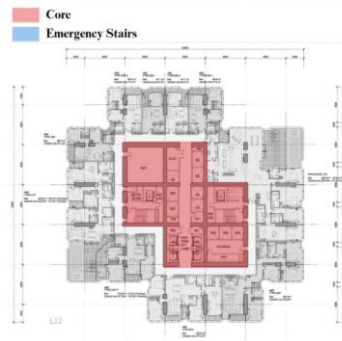
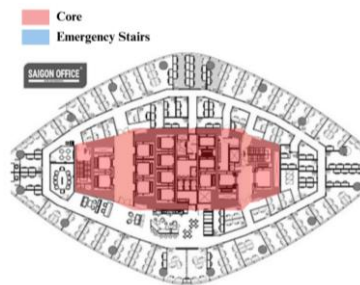

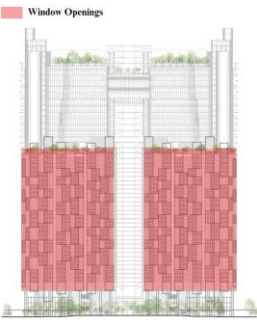
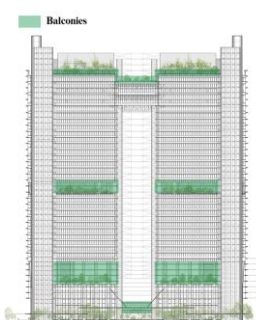


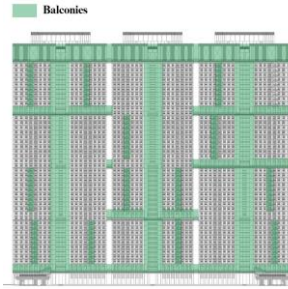

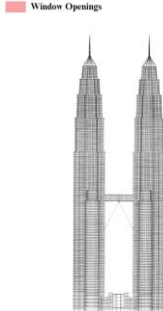
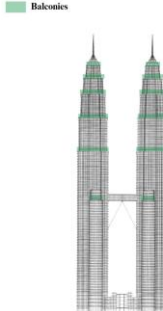

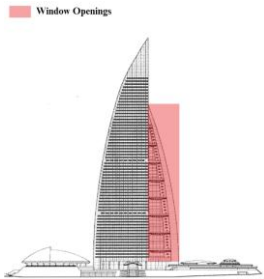


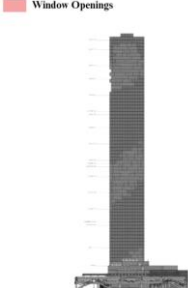
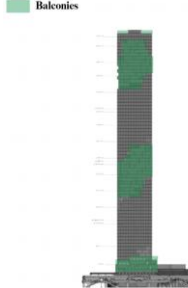
[T2] The Met (Thailand)**[V1] Landmark 81 (Vietnam)****[V2] Bitexco Financial Tower (Vietnam)**

Image source: Ashui.com, 2010; *Compass Office | Bitexco Financial Tower, 2 Hai Trieu Street, Ben Nghe Ward, District 1.*, n.d.; *Green Heart | Marina One Singapore / Ingenhoven Architects*, n.d.; “MahaNakhon - Data, Photos & Plans,” n.d.; *Pelli Clarke Pelli Architects · Petronas Tower*, n.d.; *SkyVille / WOHA*, n.d.; *The Met / WOHA*, n.d.; *Vincom Landmark 81: Case Study*, n.d.; Khai, 2018; Yang et al., 2015

Window Openings and Placing Balconies

In Table 4, **S2** (Skyville @ Anson) has window openings on all sides, and they also use curtain walls on the sides of the building that are not exposed to direct sunlight while also using shading devices such as overhangs. On the other hand, the **S1** (Green Heart Marina One) has some window openings on the residential or apartment area only, the office uses curtain walls while also having shading devices such as overhangs. The buildings from Malaysia, **M2** (Menara Telekom), also feature window openings on their east and west sides while also using a shading device, whereas **M1** (Petronas Twin Tower) doesn't have any window openings and only uses a curtain wall, which has a passive shading device overstek at several floors. The buildings from Thailand, **T2** (The Met), all have windows on nearly every side, allowing natural ventilation to flow through the structure. While **T1** (King Power Mahanakhon) doesn't have any window openings and only uses a curtain wall, some floors have a passive shading device like an overhang. The buildings from Vietnam, such as **V1** (Landmark 81), have some window openings in the apartment and hotel area only, and the rest of the building uses curtain walls, but there aren't many shading devices. However, **V2** (Bitexco Financial Tower) doesn't have any window openings, and all the windows use curtain walls, there aren't any shading devices. S1, S2, M2, T2, and V1 buildings have adhered to Yeang's design principles by incorporating shading devices, especially on their east and west sides to minimize solar radiation, reduce glare, and enhance building aesthetics. Meanwhile, M1, T1, and V2 do not adhere to these principles, relying solely on low-e glass or similar materials to ensure the building remains cool despite direct sunlight exposure. Besides V2, the seven buildings generally have balconies to help reduce incoming solar radiation and allow for natural ventilation, which is consistent with Yeang's design principles (Abubakar et al., 2025; Christiano & Damayanti, 2021; Putri & Winarto, 2025; Yeang, 1994).

Table 4. Case Study Analysis of Tall Buildings in Humid Tropical Regions using Yeang's Principles Window Openings and Placing Balconies

Case Study	Window Openings	Placing Balconies
<p>[S1] Green Heart Marina One (Singapore)</p> 	<p>Window Openings</p> 	<p>Balconies</p> 
<p>[S2] Skyville@Anson (Singapore)</p> 	<p>Window Openings</p> 	<p>Balconies</p> 
<p>[M1] Petronas Twin Tower (Malaysia)</p> 	<p>Window Openings</p> 	<p>Balconies</p> 
<p>[M2] Menara Telekom (Malaysia)</p> 	<p>Window Openings</p> 	<p>Balconies</p> 
<p>[T1] King Power Mahanakhon (Thailand)</p> 	<p>Window Openings</p> 	<p>Balconies</p> 

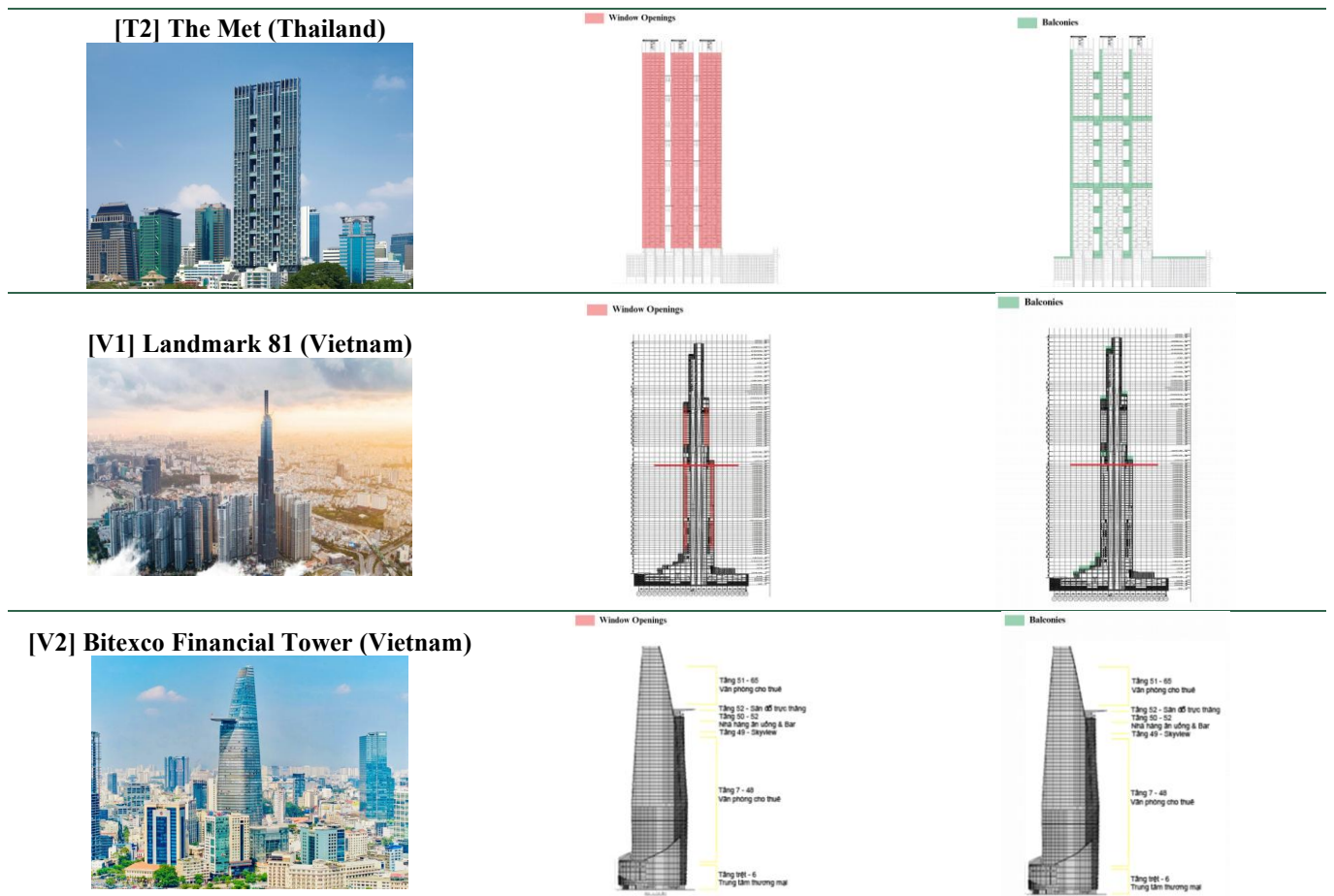


Image source: *Green Heart | Marina One Singapore / Ingenhoven Architects*, n.d.; *HO CHI MINH CITY | Vincom Landmark 81 | 461m | 1513ft |...*, 2011; "Petronas Towers - Data, Photos & Plans," n.d.; *SkyVille / WOHA*, n.d.; *The Design of Mahanakhon Tower, Bangkok, Thailand*, 2018; *The Met / WOHA*, n.d.; *Vincom Landmark 81: Case Study*, n.d.; Khai, 2018; seethespace.vn, n.d.; Yang et al., 2015

Transitional Space and Connection with Planting and Landscape

Table 5 shows that both buildings from Singapore have transitional space in the form of voids that permit cross-ventilation and are **S1** (Green Heart Marina One) and **S2** (Skyville @ Anson). The relationship between the building and the landscape plays a crucial role in ensuring the building receives cool natural ventilation. S1 and S2 buildings also feature openings and vegetation on the ground floor, which allow cool air to circulate through the building due to the presence of voids. However, the balcony for both buildings is given artificial landscaping so that natural air ventilation can enter but does not flow to each floor because it does not have a void as a transition space (Abubakar et al., 2025; Christianto & Damayanti, 2021; Putri & Winarto, 2025; Yeang, 1994).


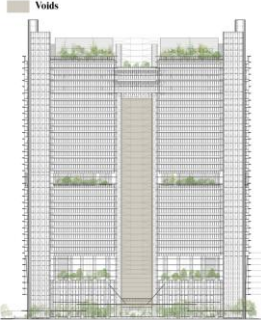


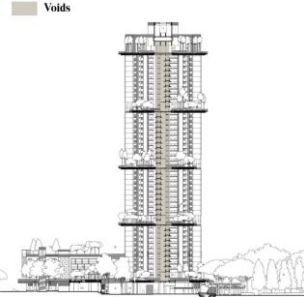


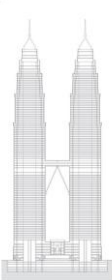


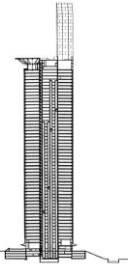

The two buildings from Malaysia (M1 and M2) from Table 5 also do not have any transitional spaces and voids, so they can't create cross-ventilation in the buildings, resulting in using energy from the building's cooling load. On the other hand, M2 still has balconies, which allow it to receive natural ventilation, even though it does not spread throughout the building. Apart from that, the **M2** (Telekom Tower) has balconies filled with green plants so that natural ventilation is cooler than at **M1** (Petronas Twin Tower). The relationship between the building and the landscape plays a crucial role in ensuring the building receives cool natural ventilation. Only M2 buildings that feature openings and vegetation on the ground floor facilitate the flow of cool air through the building, but their effectiveness is limited due to the absence of any voids within the structure (Abubakar et al., 2025; Christianto & Damayanti, 2021; Putri & Winarto, 2025; Yeang, 1994).

As shown in **Table 5**, it reveals that both buildings from Thailand, such as **T2** (The Met), are the only buildings that feature a transitional space that facilitates cross-ventilation within the building, whereas **T1** (King Power Mahanakhon) lacks this feature, resulting in relying on energy from their cooling load for cross-ventilation. The relationship between the building and the landscape plays a crucial role in ensuring the building receives cool natural ventilation. T2 has openings and vegetation on the ground floor, so they receive ventilation for cool air flowing through the building due to the presence of voids, whereas T1 doesn't have openings and vegetation on the ground

floor, so they do not receive cool air ventilation (Abubakar et al., 2025; Christianto & Damayanti, 2021; Putri & Winarto, 2025; Yeang, 1994).

Both buildings from Vietnam (V1 and V2) from **Table 5** do not have transitional spaces with voids, so they cannot create cross-ventilation in the building, resulting in relying on energy from the cooling load. Besides that, only V1 buildings have balconies that allow them to receive natural ventilation, even though it does not spread throughout the building, and V1 buildings do not have plants on the balconies. The relationship between the building and the landscape plays a crucial role in ensuring the building receives cool natural ventilation. Only V1 buildings feature openings and vegetation on the ground floor to facilitate the flow of cool air through the building, but their effectiveness is limited due to the absence of any voids within the structure (Abubakar et al., 2025; Christianto & Damayanti, 2021; Putri & Winarto, 2025; Yeang, 1994).

Table 5. Case Study Analysis of Tall Buildings in Humid Tropical Regions using Yeang's Principles Transitional Space and Connection with Planting and Landscape

Case Study	Transitional Spaces	Connection with Planting & Landscape
<p>[S1] Green Heart Marina One (Singapore)</p> 	<p>Voids</p> 	
<p>[S2] Skyville@Anson (Singapore)</p> 	<p>Voids</p> 	
<p>[M1] Petronas Twin Tower (Malaysia)</p> 	<p>Voids</p> 	
<p>[M2] Menara Telekom (Malaysia)</p> 	<p>Voids</p> 	

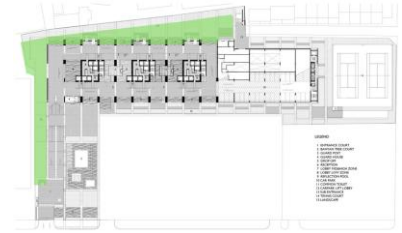
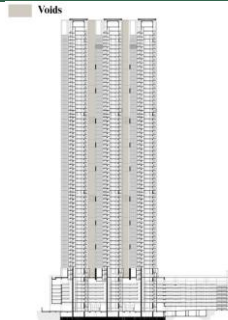
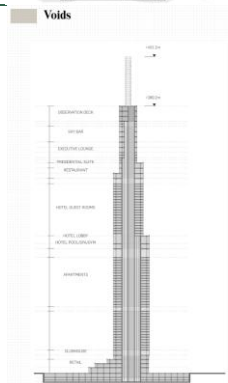
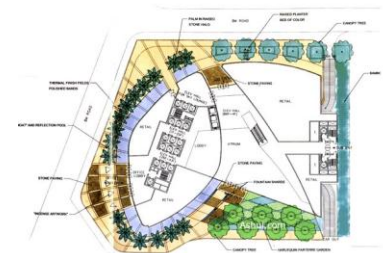
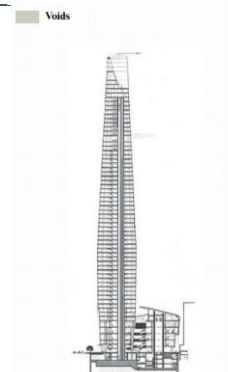
[T1] King Power Mahanakhon (Thailand)**[T2] The Met (Thailand)****[V1] Landmark 81 (Vietnam)****[V2] Bitexco Financial Tower (Vietnam)**





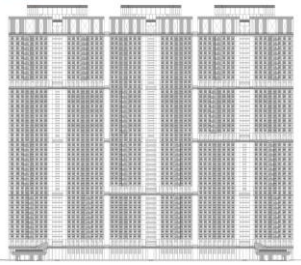
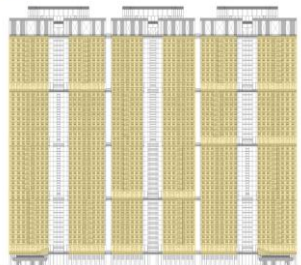

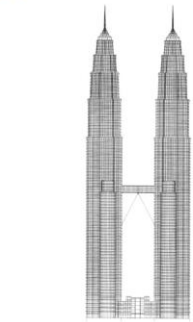
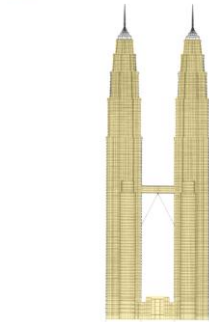

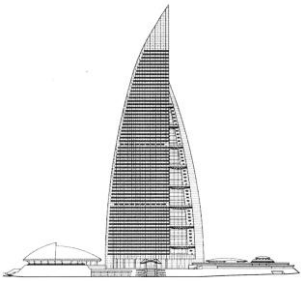

Image source: Ashui.com, 2010; *Green Heart | Marina One Singapore / Ingenhoven Architects*, n.d.; *MahaNakhon Tower / Büro Ole Scheeren*, 2021; *Pelli Clarke Pelli Architects · Petronas Tower*, n.d.; *Petronas Twin Towers – A Malaysian Dream*, 2010; *SkyVille / WOHA*, n.d.; *The Met / WOHA*, n.d.; *Vincom Landmark 81: Case Study*, n.d.; “*Vincom Landmark 81 Tower Landscape Ho Chi Minh City, Vietnam*,” 2017; Khai, 2018; Techakraisri, n.d.; Yang et al., 2015

External Walls and Solar Shading

The use of solar shading devices is essential in buildings because it can reduce the heat load on the building. There are also buildings that solely utilize external walls, which serve the same purpose as passive shading devices. However, equipping the building with both passive and external shading devices can reduce the heat load more effectively than using just one. In Table 6, both buildings from Singapore, such as **S1** (Green Heart Marina One) and **S2** (Skyville @ Anson), only use solar shading devices in the form of overhangs, so they don't comply with Yeang's principles. Besides that, both buildings from Malaysia, such as **M1** (Petronas Twin Tower) and **M2** (Telekom Tower), only use solar shading devices in the form of overhangs. Because of that, neither of the buildings adheres to Yeang's principles, which use both the external walls and shading devices. Both buildings from Thailand, such as **T1** (King

Power Mahanakhon) and T2 (The Met Office), only use an overhang solar shading device, so they are less in accordance with Ken Yeang's design principles. Meanwhile, buildings from Vietnam, such as V1 (Landmark 81), do not have any external walls but still have some overhang shading devices. While V2 (Bitexco Financial Tower) does not have any shading devices, it still has external walls. Because of that, both buildings are not in accordance with Yeang's design principles, which recommend the use of external walls and solar shading devices (Abubakar et al., 2025; Christiano & Damayanti, 2021; Putri & Winarto, 2025; Yeang, 1994).

Table 6. Case Study Analysis of Tall Buildings in Humid Tropical Regions using Yeang's Principles External Walls and Solar Shading

Case Study	External Walls	Solar Shading
<p>[S1] Green Heart Marina One (Singapore)</p> 	<p>External Walls</p> 	<p>Solar Shading Devices</p> 
<p>[S2] Skyville@Anson (Singapore)</p> 	<p>External Walls</p> 	<p>Solar Shading Devices</p> 
<p>[M1] Petronas Twin Tower (Malaysia)</p> 	<p>External Walls</p> 	<p>Solar Shading Devices</p> 
<p>[M2] Menara Telekom (Malaysia)</p> 	<p>External Walls</p> 	<p>Solar Shading Devices</p> 

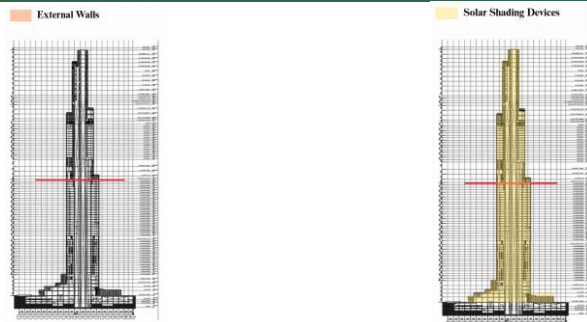
[T1] King Power Mahanakhon (Thailand)



[T2] The Met (Thailand)



[V1] Landmark 81 (Vietnam)



[V2] Bitexco Financial Tower (Vietnam)



Image source: Ashui.com, 2010; Compass Office | Bitexco Financial Tower, 2 Hai Trieu Street, Ben Nghe Ward, District 1., n.d.; Green Heart | Marina One Singapore / Ingenhoven Architects, n.d.; “MahaNakhon - Data, Photos & Plans,” n.d.; Petronas Towers, n.d.; SkyVille / WOHA, n.d.; The Met / WOHA, n.d.; Vincom Landmark 81: Case Study, n.d.; Khai, 2018; Yang et al., 2015

SUMMARY

Based on the analysis results found, most contemporary tall buildings that are considered iconic in humid tropical cities have implemented Yeang's principles. However, some specific adjustments have been made, meaning that not all contemporary tall buildings fully implement this principle.

- The majority of contemporary tall buildings analyzed in the case studies utilize a central core. Yeang's principle recommends using a double-sided core to prevent heat or sunlight from entering the building. Despite that, the core still serves as a buffer zone, reducing direct heat input and promoting natural ventilation within the building.
- The building's orientations are split equally, with one facing northwest to southeast, while the rest face southwest to northeast. Although the orientation is not dominant to the north-south, there could be some adjustments that affect the orientation, such as different land sizes and shapes, following the wind and sun direction to maximize natural ventilation, and reducing direct solar heat.

- Most tall buildings feature window openings, particularly on their east and west sides, and incorporate shading devices to reduce solar radiation, minimize glare, and improve aesthetics, aligning with Yeang's principles. However, some buildings lack openings, resulting in increased energy consumption.
- Apart from that, most buildings still use balconies to reduce incoming solar radiation and provide natural ventilation, adhering to Yeang's principles of using balconies to introduce natural ventilation into the building.
- Most of the buildings overlook voids, which prevents them from creating cross ventilation within the building and thereby consumes energy from its cooling load. Most buildings find it sufficient to only use a balcony to receive some natural ventilation, although it may not spread throughout the entire building.
- Every tall building features openings and vegetation on the ground floor, allowing cool air ventilation to circulate throughout the building due to voids. If there aren't any voids, ventilation air only flows on the ground floor and cannot cross-ventilate.
- Most buildings use overhangs as solar shading instead of external walls, as they find it more affordable to use overhangs and find it excessive and costly if they use both.

CONCLUSION

This research concludes by dissecting the design of 8 iconic contemporary tall buildings in humid tropical climates to identify Ken Yeang's principles (8 principles). The results of the analysis indicate that the criteria most aligned with Ken Yeang's principles are the window openings, placing balconies, and solar shading (Figure 5). These elements are consistently applied because they can be integrated into the building envelope with relatively minimal impact on the overall building's form and structural system while still providing significant climatic benefits, such as reducing solar heat gain and enhancing natural ventilation, demonstrating a strong alignment with Yeang's principles. There are also several criteria that are only partially fulfilled or not fully aligned with Yeang's principles due to several adjustments to the building's form and structure that prevented full implementation. This includes core position, building orientation, connection with planting and landscape, transitional space, and external walls (Figure 5). For the core positions, most buildings use central cores instead of double-sided cores due to several considerations, such as design needs, spatial efficiency, building function, and land conditions. Besides that, central cores provide more stability and even load distribution, while double-sided cores need additional strengthening at the edge (Figure 5). Apart from that, most buildings don't face north-south due to several considerations, such as limited land, urban planning requirements, and user needs, as well as structural calculations to overcome expansion and contraction due to significant temperature changes and resist strong wind loads (Figure 5). The connection with planting and landscape, as well as transitional spaces, is essential for strengthening the relationship between the building and its surrounding environment, yet in practice this varies, as some buildings successfully provide comfortable and naturally ventilated spaces while others prioritize functional efficiency. Ideally, transitional spaces include internal voids and ground-floor openings to enhance natural airflow, but structural constraints often limit their size and placement because oversized or poorly positioned openings can reduce stiffness, increase deflection, and compromise building stability (Figure 5). Most buildings don't use external walls because climatic control is already effectively addressed through the use of solar shading. As a result, additional external wall layers are considered less necessary and potentially inefficient, as they may increase structural loads without providing significant additional environmental performance (Figure 5).

STRONG ALIGNMENT	CONSTRAINED IMPLEMENTATION (FORM & STRUCTURE ADJUSTMENT)			
	CORE POSITIONS	BUILDINGS ORIENTATION	TRANSITIONAL SPACES + CONNECTION WITH PLANTING & LANDSCAPE	EXTERNAL WALLS
WINDOW OPENINGS	<ul style="list-style-type: none"> • Building's Form <ul style="list-style-type: none"> ◦ Design Needs ◦ Spatial Efficiency ◦ Building Function ◦ Land Conditions • Building's Structure <ul style="list-style-type: none"> ◦ Central Core <ul style="list-style-type: none"> ▪ More Stability ▪ Even Load Distribution ◦ Double-Sided Core <ul style="list-style-type: none"> ▪ Additional Strengthening 	<ul style="list-style-type: none"> • Building's Form <ul style="list-style-type: none"> ◦ Limited Land ◦ Urban Planning Requirements ◦ User Needs • Building's Structure <ul style="list-style-type: none"> ◦ Structural Calculations <ul style="list-style-type: none"> ▪ Thermal Expansion & Contraction ▪ Resisting Strong Wind Loads 	<ul style="list-style-type: none"> • Building's Form <ul style="list-style-type: none"> ◦ Prioritize Function and Space Efficiency • Building's Structure <ul style="list-style-type: none"> ◦ The Placement and Size of Voids can: <ul style="list-style-type: none"> ▪ Reduce Structural Stiffness ▪ Increase Deflection ▪ Compromise Building Stability. 	<ul style="list-style-type: none"> • Solar Shading is sufficient to reduce heat and improve comfort without needing External Walls. • Building's Structure <ul style="list-style-type: none"> ◦ Adding External Walls could: <ul style="list-style-type: none"> ▪ Increase Structural Loads without significantly improving environmental performance.
PLACING BALCONIES				
SOLAR SHADING				

Figure 5. Diagram of Key Findings on the Application of Yeang's Design Principles

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