Green Architecture for Sustainable Hotel Design in Sosromenduran

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Abstract

Yogyakarta, a city experiencing substantial domestic and international tourism, faces environmental challenges due to the associated increase in greenhouse gas emissions from human activities and tourism infrastructure. The impact of global warming, as manifested in rising temperatures and pollution, necessitates eco-friendly development. The burgeoning demand for tourism accommodations, coupled with the threat of global warming underscores the importance of Green Architecture in Yogyakarta's hotel industry. Green Architecture is implemented to mitigate the negative environmental impacts of buildings, particularly in contributing to global warming, and to enhance resource efficiency. The chosen design strategies prioritize energy conservation through maximizing natural ventilation and integrating solar power systems. Additionally, rainwater harvesting is employed to supplement the water supply and reduce groundwater depletion. Beyond these environmental benefits, Green Architecture upholds the principle of environmental respect. Building design strategies focus on aligning building orientation and form with solar patterns and optimizing the provision and utilization of green spaces. This approach yields buildings that adapt to their environment and climate, maximizing natural ventilation, minimizing microclimate temperatures, and facilitating efficient spatial planning. Energy efficiency is further enhanced through the optimization of natural lighting and the implementation of rainwater harvesting systems, which reduce the exploitation of groundwater.

Keywords: Building orientation, Energy efficiency, Green Architecture.

I. Introduction

Yogyakarta is one of Indonesia's major tourist destinations [1], experiencing significant growth in both domestic and foreign tourist visits every year. Data from the Statistic DIY[2] states that the number of visits for domestic tourists in 2024 increased by 23.67% from 2023, while visits by foreign tourists increased by 21.93%. This number indicates that Yogyakarta, such as Malioboro, remains a popular tourist destination in Indonesia, attracting both domestic and international tourists. Malioboro is an iconic tourist destination in Yogyakarta. The Malioboro area, the heart of the city, combines history, education, shopping, and culinary tourism in one area [3]. From a colonial trading center to a cultural corridor with social and economic value. Due to the large number of tourists visiting Malioboro, various activities and happenings have sprung up around it. The increased number of tourists has also led to increased traffic around Malioboro [4].

With the increase in tourist arrivals, the demand for tourism facilities, particularly hotels, is growing. Hotels are a major component of tourist destinations. The hotel is a temporary stop for tourists, including room service and food, and drinks[5]. The increasing number of visitors has led to a rise in demand for hotel rooms, driving the construction of new hotels across various categories, from budget hotels to five-star hotels. This has positively impacted the high demand for hotel rooms, as illustrated in Figure 1. The data shows a rising trend in hotel room demand over the past five years, although there was a decline in 2019-2020 due to the COVID-19 pandemic. The pandemic had a direct negative impact on the growth of the tourism sector in Yogyakarta due to restrictions on public mobility [6]. On the other hand, this can also be seen as a crucial opportunity to reflect on and overhaul the tourism system, which has been unsustainable.[7]

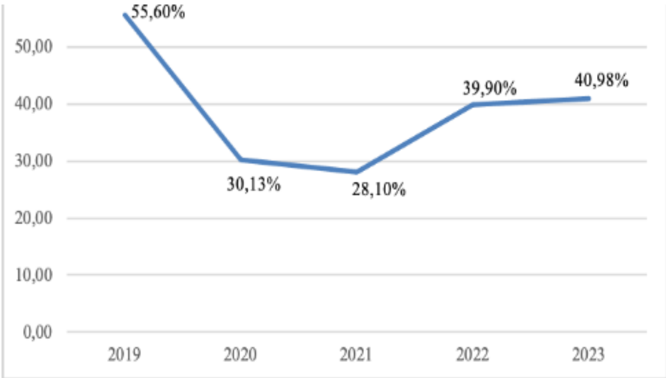
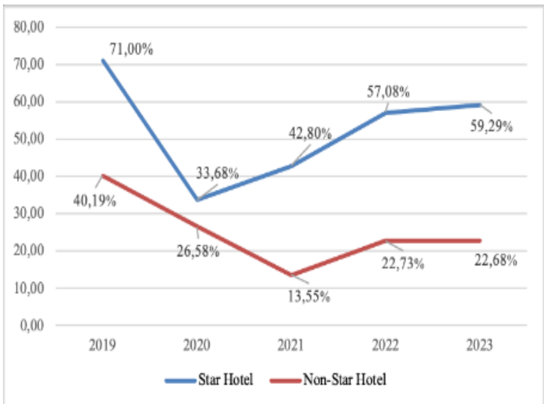


Figure 1 Hotel Occupancy Rate in DIY in the Last 5 Years (2019-2023) [2]

Figure 1 shows the hotel occupancy rate in the Special Region of Yogyakarta (DIY) over the past five years (2019–2023). In 2019, the hotel occupancy rate peaked at 55.60%, but declined sharply to 30.13% in 2020 and reached a low of 28.10% in 2021, likely due to the impact of the COVID-19 pandemic on the tourism sector. Since 2022, a recovery trend has been observed, with the occupancy rate increasing to 39.90% and then rising slightly to 40.98% in 2023. However, the rate has not yet fully returned to pre-pandemic levels.



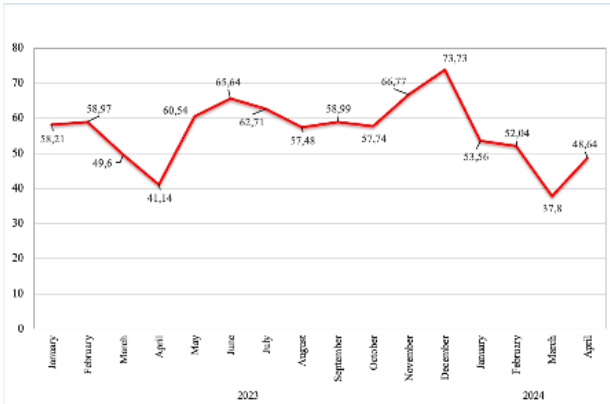


Figure 2 Demand for Hotel Rooms (2019-2023) [2] Figure 3 Hotel Star Occupancy Rate in 2023-2024[2]

For a more detailed breakdown of the increasing demand for hotel rooms based on star rating, please refer to Figure 2. This figure shows that, in general, higher-star hotels with higher prices are more in demand, indicating a strong willingness among Indonesian people to allocate substantial funds for tourism. Figure 3 illustrates the fluctuations in hotel room demand from January 2023 to April 2024. This figure demonstrates a higher demand for hotel rooms during specific seasons [2].

Tourism activities in Malioboro and its surroundings are increasingly developing, indirectly encouraging the growth of the surrounding area [8]. However, the rapid growth of the accommodation industry also has a significant impact on the urban environment. Especially in tourist hubs like Malioboro, large-scale hotel development increases energy consumption, exploits groundwater, and reduces green open space. Furthermore, hotel buildings that are not designed with sustainability in mind tend to result in higher microclimate temperatures, increased energy waste, and air pollution [9].

A hotel must be designed in a more environmentally friendly manner to address these circumstances. Green Architecture is a design approach that combines energy efficiency, water conservation, the use of environmentally friendly materials, and occupant comfort. By adhering to these principles, hotel development in Yogyakarta will help preserve the environment and the quality of life of the Yogyakarta community, while also meeting tourist demand. "Green building" is a sustainable building concept that aims to harmonize with the environment and create a balance between building users and the environment [10]. This concept can also be defined as an effort to adapt buildings and sites to the community, culture, local climate, and environment in which they are built. The concept of green building aims to reduce the use of resources, particularly non-renewable resources, while simultaneously enhancing the quality of life for people living in buildings.[11]

The implementation of green architecture offers substantial contributions to environmental sustainability by safeguarding natural resources and preserving ecosystems. A primary objective of this approach is to foster eco-friendly architectural designs that facilitate sustainable development. Consequently, the emphasis in green architecture is on tailoring building designs to specific environmental contexts [9]. A forecast by Jones Lang LaSalle indicates a forthcoming shift in the property market towards green buildings, with a growing number of organizations willing to incur premium costs for such structures. The benefits extend beyond environmental stewardship, encompassing enhanced occupant well-being due to improved indoor air quality and reduced operational expenses arising from energy efficiency. Given these advantages, the adoption of green building principles is particularly pertinent in urban centers that attract a high volume of visitors [12].

A hotel is a commercial establishment providing temporary lodging in rooms, often within a building or complex, and may offer additional services such as food, beverages, and entertainment [13]. Star-rated hotels are classified based on a standardized system of facilities and services, ranging from one to five stars. To elevate the standards of the Indonesian hospitality industry, a paradigm shift towards environmentally friendly architectural principles is imperative. Such an approach can mitigate the pressing issue of global warming. One significant contributor to this global challenge is the proliferation of high-rise buildings, which disrupt air circulation patterns and impede wind flow. Moreover, glass-facaded structures exacerbate the urban heat island effect by reflecting solar radiation. These factors underscore the critical need for the adoption of green architecture in Indonesian hotel development to ameliorate the impacts of climate change [14].

The comprehensive implementation of green architecture principles encompasses all phases of a building's lifecycle, from initial planning to ongoing maintenance. The overarching goal is to cultivate a positive environmental impact by conserving natural resources, enhancing indoor air quality, considering the environment throughout the construction process, using non-toxic materials, and prioritizing the health of its occupants, all of which adhere to sustainable principles. Green architecture also serves as a guiding principle in designing environmentally friendly buildings.[15] Green buildings are typically constructed with meticulous attention to detail, incorporating features that prioritize energy efficiency and sustainability. These design choices equip both the building and its occupants to adapt to the challenges posed by climate change. Numerous studies have highlighted the profound impact of the built environment on human health and well-being. The World Health Organization has identified poor indoor air quality as a leading cause of respiratory diseases, accounting for three of the top five causes of death globally. By implementing green architecture principles such as optimized natural lighting, improved indoor air quality, and increased vegetation, it is possible to create healthier and more sustainable living spaces. Another significant advantage of green architecture is its potential to reduce energy consumption and operating costs. By leveraging renewable energy sources as an alternative to fossil fuels, green buildings contribute to mitigating climate change and global warming and demonstrate a commitment to environmental stewardship [16].

According to the Indonesian Minister of Public Works and Housing Regulation Number 21 of 2021 on the Performance Assessment of Green Buildings, a Green Building is defined as a building that meets the technical standards for buildings and exhibits a significant measurable performance in saving energy, water, and other resources through the application of green building principles appropriate to its function and classification at every stage of its development[17]. The principles of green buildings encompass a comprehensive set of strategies aimed at promoting sustainability and environmental responsibility throughout a building's lifecycle. These principles begin with the formulation of shared goals, mutual understanding, and actionable plans to ensure alignment among stakeholders. A core objective is to reduce the use of resources, including land, materials, water, and natural resources, as well as human labor, thereby minimizing environmental impact. Equally important is the reduction in waste generation, both physical and non-physical, alongside the reuse of previously utilized materials and the utilization of recycled resources to support circular economy practices. Green buildings also prioritize the protection and management of the environment through deliberate conservation efforts.

Based on these principles, the design process of a building should begin with a shared goal and understanding of green architecture concepts, where the building will use natural resources as efficiently as possible. This can start with determining the building's massing that responds to solar orientation and maximizes both human and natural air circulation. Subsequent efforts in implementing Green Building principles include the use of rainwater harvesting systems (RWHS) and interconnected photovoltaic (PV) systems. RWHS is a system for conserving groundwater through the collection and utilization of rainwater to meet non-potable water needs. This system offers numerous benefits, such as reducing groundwater usage and emissions, thereby mitigating climate change and global warming. The system typically consists of a closed loop that channels rainwater from gutters to a percolation well. On the other hand, interconnected PV systems, also known as grid-connected PV systems, generate electricity from solar radiation. As the name suggests, these systems are connected to the electrical grid to optimize the utilization of solar energy through solar modules or photo[18]. Thus, the development of hotels that adhere to the principles of green architecture is crucial in addressing the surge in tourist visits, ensuring that the growth of the tourism sector does not compromise the city's ecological carrying capacity.

II. Method

This study employed a qualitative-descriptive design approach. It began with literature research on green architecture theory and sustainable hotel design standards in Yogyakarta. The literature was utilized to develop a design strategy that was environmentally friendly, energy-efficient, and environmentally sustainable[19]. The subsequent fieldwork included site observations in Sosromenduran. This involved analyzing the microclimate, socio-cultural conditions, accessibility, and spatial characteristics of the area. The purpose of the site analysis was to evaluate the physical and non-physical potentials and constraints that could influence the design. This data was then synthesized to determine environmentally responsive design measures, including the use of cross-ventilation, optimal natural lighting, and the use of local flora to lower building temperatures and improve air quality.

Green architecture concepts were implemented into the hotel's spatial plan after the analysis was conducted. Some design strategies include the use of local and recycled materials, a rainwater management system, self-contained wastewater treatment, and the implementation of renewable energy systems such as solar panels. The design results are expected to produce a hotel that will preserve the environment and strengthen Sosromenduran's local identity. In general, the design mindset can be seen in Figure 4.

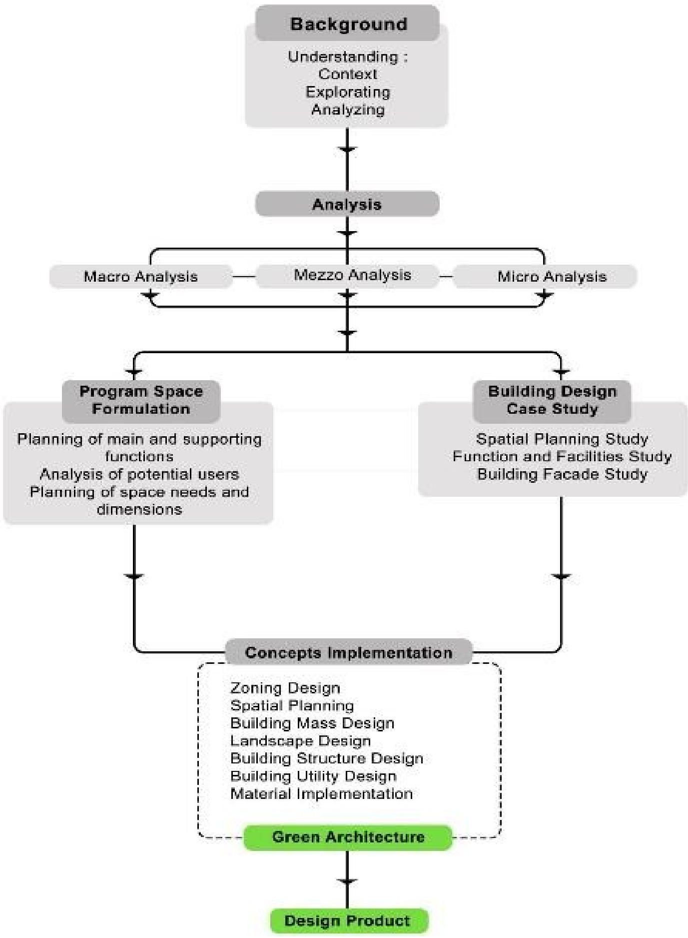


Figure 4 Mindset Framework

The site is located at Jl. Sosromenduran, GT I No.285, Pringgokusuman, Gedong Tengen, Yogyakarta City, Special Region of Yogyakarta (Figure 5). Gedong Tengen subdistrict is one of the 14 subdistricts in Yogyakarta City that holds a unique appeal for visitors. This area is one of the central shopping and tourism districts in Yogyakarta City, with distinctive areas such as Malioboro, Tugu Station, and the international village of Sosromenduran. Therefore, this area, located in the heart of Yogyakarta City, has great potential to become a major tourist destination.

Figure 5 Site Location

According to the Yogyakarta Detailed Spatial Plan (RDTR) [20], the design site is located in a commercial and service zone with an area of 5,223.66 m². The land use intensity policy on the site is as follows: a maximum Building Coverage Ratio (KDB) of 90%, a maximum Building Floor Area Ratio (KLB) of 6.4, a minimum Green Space Ratio (KDH) of 10%, and a Building Setback Line (GSB) of 5 meters.

III. Results and Discussion

The implementation of green architecture principles in hotel design in Sosromenduran, Yogyakarta, presents a comprehensive response to the environmental challenges posed by rapid tourism development. Each design element, from circulation layout to material selection, has been tailored to reduce energy consumption, enhance environmental sustainability, and promote user comfort.

A. Circulation Design

The site is easily accessible from Jalan Gandekan, a one-way street heading north towards Tugu Yogyakarta Station. The site's location on Jalan Sosrowijayan is an advantage as it is easily accessible from the Malioboro area. However, its location at a crossroads necessitates careful consideration of the site's design, particularly in terms of its entrances and exits, to prevent traffic congestion in the surrounding area. This can be anticipated by placing the main entrances and exits for visitors on the eastern side of the building, facing Jalan Gandekan. At the same time, Jalan Kemetiran Lor can be used for service vehicles or the management area. An illustration of this planning can be seen in Figure 6.

Figure 6 Circulation Design

B. Reducing Electricity Consumption through Solar Orientation Response

The site is predominantly surrounded by 1 to 2-story buildings, resulting in excellent solar exposure from morning to evening. This condition needs to be considered in the design of spaces, identifying which areas require high and low levels of natural lighting [21]. This is addressed by designing a slender building mass to maximize natural lighting, especially in residential zones, and by orienting the building mass considering energy efficiency on one hand and utilizing the building envelope as a medium for solar panel placement to generate solar power as a backup energy source. An illustration of this strategy can be seen in Figure 7.

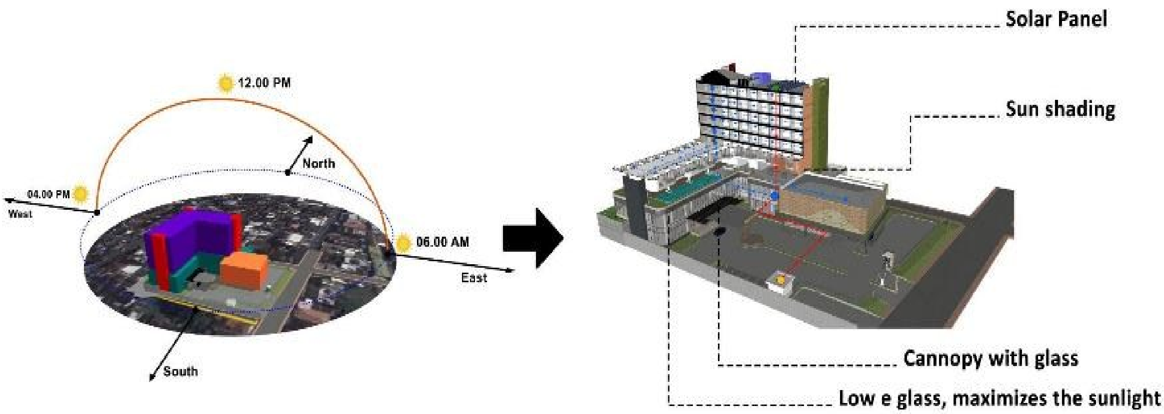


Figure 7 Response to Solar Orientation

The implementation of this concept aligns with the design of the Lankuaikei Agriculture Development (LAD) Headquarters in Shanghai, designed by MVRDV, which analyzes carbon life-cycle and solar cycles for the utilization of solar panels and the form of the building mass. The solar panels incorporated into the building design will operate at maximum capacity as the building's primary energy source. Additionally, there are terraces that help facilitate more efficient natural ventilation [14].

C. Reducing Electricity Consumption Through Wind Orientation Response

Wind blowing towards the site is quite strong, with an average speed of more than 11.9 km/h. This potential can be utilized for natural ventilation. The wind blowing during the day tends to feel hot due to the site being located in a dense urban area with various types of air pollution and minimal vegetation in the surrounding area. However, at night, the wind tends to be comfortable with temperatures within a comfortable human range. Wind energy is utilized for natural ventilation, using a cross-ventilation system and cooling the incoming air temperature into the building using passive cooling greenscape techniques in the form of vegetation [22]. To reduce excessive wind into the building and to help condition the microclimate, the landscape is provided with several dense-leaved vegetation, although due to limited land, in some parts this vegetation is arranged in the form of climbing plants, as illustrated in Figure 8.

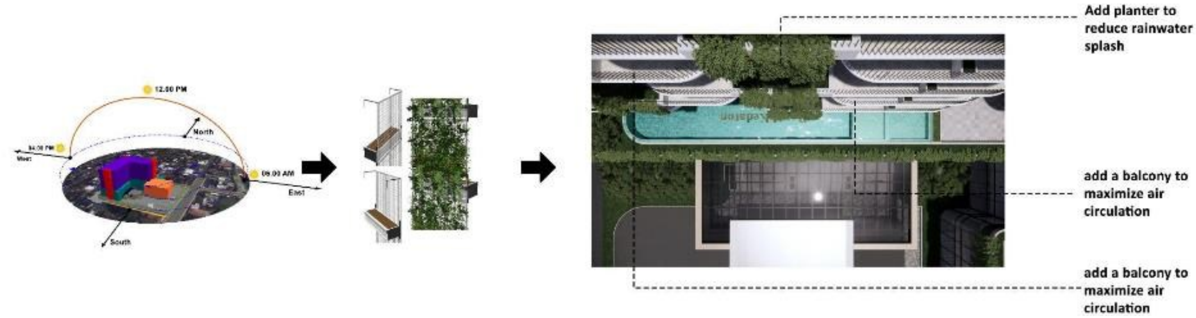


Figure 8 Response to Wind Direction

D. Utilizing Recycled Resources Through Rainfall Response

The design area has quite high rainfall in January, with an average rainfall of 296 millimeters. The least rainfall occurs in August, with an average rainfall of 33 millimeters. The strategy to respond to this condition is the application of rainwater harvesting aimed at reusing water for non-potable purposes, such as irrigation. The high rainfall in certain periods is also responded to with the principle of zero runoff, namely by designing several infiltration wells to collect and infiltrate rainwater runoff within the site, thus enriching the groundwater within the site. An illustration of this response can be seen in Figure 9.

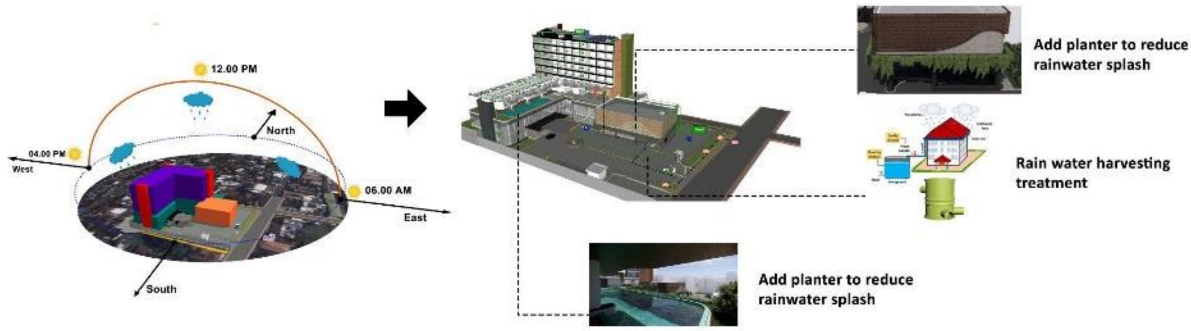


Figure 9 Response to Rainfall

This perspective is consistent with Sastrowardojo's (2022) view that rainwater harvesting represents a sustainable and environmentally responsible approach to water provision, which has been successfully implemented across various communities worldwide. In regions characterized by high rainfall intensity, rainwater harvesting systems function not only as an alternative water supply but also as an effective strategy for integrated water management. By capturing and storing rainwater, these systems significantly reduce surface runoff during rainfall events, thereby minimizing the risk of flooding and soil erosion. Furthermore, rainwater harvesting contributes to groundwater recharge, decreases pressure on municipal water infrastructure, and supports long-term water security, making it particularly suitable for sustainable building and urban design applications.

E. Design Development

In accordance with the applicable building intensity policy, the proposed hotel design applies a land coverage ratio of 60%, while the remaining 40% of the site is deliberately allocated as open space in alignment with green architecture principles. This open space functions not only as a buffer for environmental balance but also as an area for landscape elements, natural ventilation corridors, and rainwater absorption, thereby enhancing the site's ecological performance. The primary building mass is oriented along an east–west axis, with its main façades facing north and south, as a strategic passive design approach to reduce direct solar radiation exposure on the building envelope. This orientation minimizes heat gain during peak sunlight hours, contributes to improved thermal comfort within interior spaces, and reduces reliance on mechanical cooling systems. As illustrated in Figure 10, the orientation and massing configuration reflect an integrated response to climatic conditions, energy efficiency considerations, and sustainable architectural design objectives.

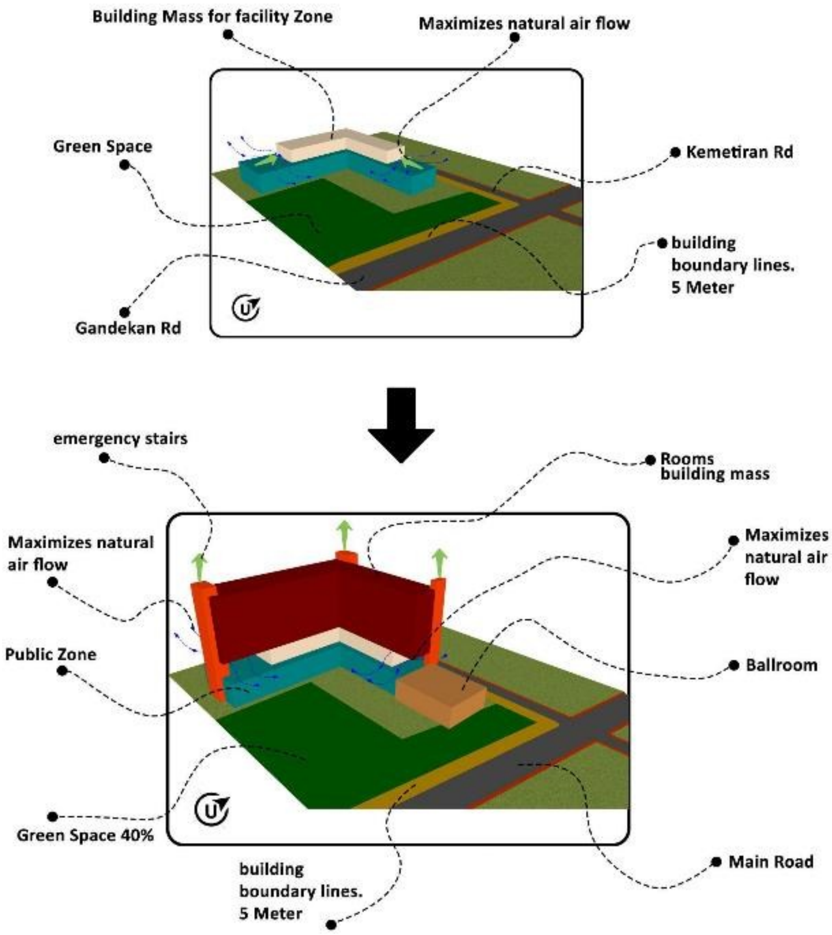


Figure 10 Building Mass Development

Figure 11 shows that the first floor of the building is dominated by public spaces such as the lobby and other 4-star hotel facilities like restaurants and coffee shops, indicated by the blue color in the figure. The hotel features two lobbies: the main lobby, which serves as the primary entrance to the hotel and is located adjacent to the green area within the hotel, and the sub-lobby, which acts as a secondary entrance to public areas such as the ballroom and restaurant. The red block in Figure 11 shows the location of the building's utility areas, including plumbing and electrical areas, as well as service rooms such as warehouses and loading docks.

On the second floor, the spatial program consists of a ballroom and a series of management offices, as indicated in blue in Figure 12. The management offices are intentionally grouped within a separate zone to prevent cross-circulation between hotel staff and guests, thereby supporting privacy, security, and efficient operational flow. In addition, a relatively large void is positioned above the main lobby on this level as part of a passive design strategy. This void is designed to maximize vertical air circulation from the first floor to the second floor, enhancing natural ventilation and improving indoor thermal comfort. By facilitating the movement of air between floors, the design reduces reliance on artificial air-conditioning systems, which in turn contributes to improved energy efficiency and sustainable building performance.

On the third floor, the hotel's supporting and recreational facilities are accommodated, including a swimming pool, gym, and bar. This level is intentionally designed as an open and semi-outdoor zone to maximize natural air circulation and enhance thermal comfort for users. Passive cooling is further supported through the strategic placement of vegetation, which helps lower ambient temperatures, filters air, and creates a more pleasant microclimate. With natural breezes maintained at a comfortable human temperature, the third-floor facilities require little to no artificial ventilation, thereby significantly reducing electricity consumption and supporting energy-efficient building operation. Similar efforts to minimize reliance on mechanical ventilation are applied to the residential zones on the fourth to seventh floors. Each guest unit is designed with large, operable openings that allow occupants to regulate airflow naturally according to their comfort needs. These openings function as an effective alternative to artificial ventilation, promoting cross-ventilation, improving indoor air quality, and reinforcing the overall sustainable and environmentally responsive design approach of the hotel.

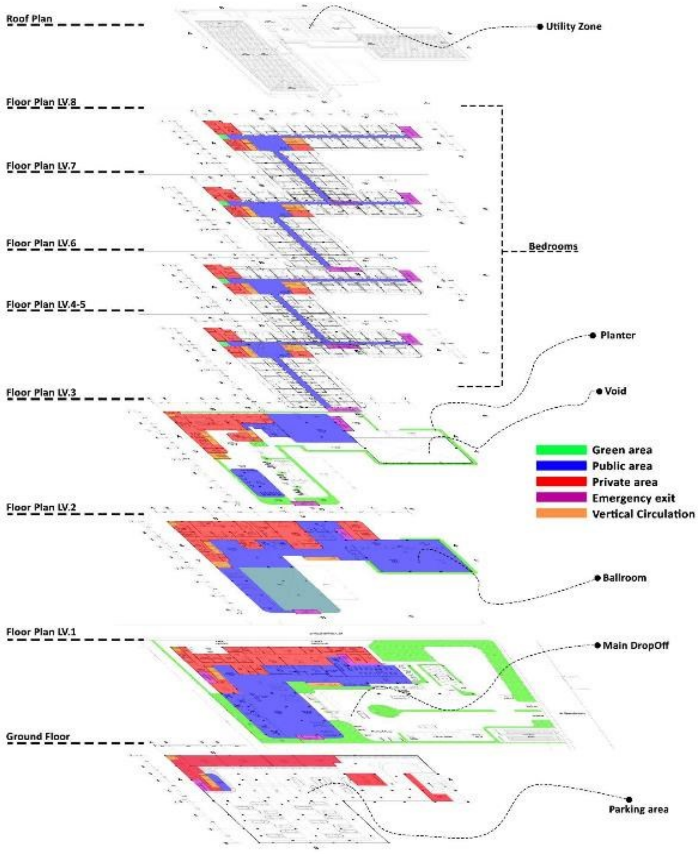


Figure 11 Building Plan Axonometric

F. Utilization of Recycled Resources through Rainwater Harvesting

Rainwater harvesting is a system of groundwater conservation through the collection and utilization of rainwater to meet water needs for sanitation. This system has many benefits, including reducing groundwater use and reducing emissions, thereby mitigating the impacts of climate change and global warming. The implementation of this concept in building design involves collecting rainwater that falls on the building and site [23]. The building roof is slightly sloped to direct rainwater towards the roof drain. In some parts of the building roof, a gable roof with a slope of about 25 degrees is used to facilitate the flow of rainwater to the collection plumbing[24], as shown in Figure 12. Collected rainwater is stored and reused for non-potable purposes. Rainwater runoff on the site is infiltrated to enrich the groundwater on the site. The rainwater utilization scheme can be seen in Figure 13.

Figure 12 Schematic Design of Rainwater Utilization

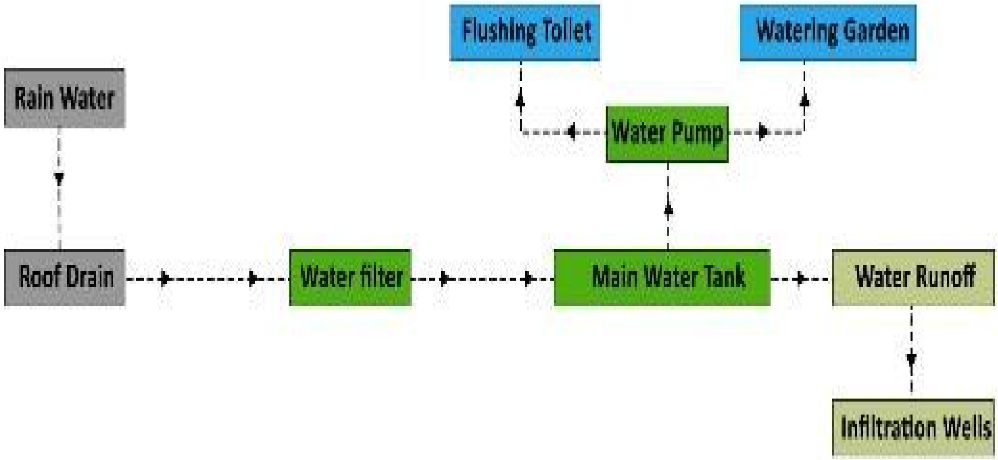


Figure 13 Rainwater Utilization Scheme

This building employs a down-feed system for a clean water supply, where water is initially stored in an underground tank and then pumped to an overhead tank located on the roof before distribution (Figures 14 and 15). Gravity assists in water distribution. This system aligns well with the concept of green architecture due to its advantages, including: the pump does not operate continuously, resulting in increased efficiency and durability and clean water is consistently available.

Figure 14 Schematic Design of Clean Water Supply System

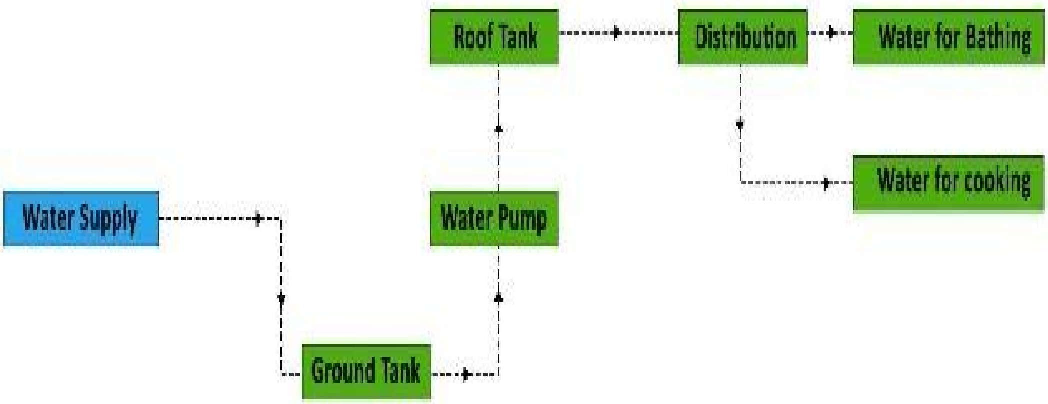


Figure 15 Schematic of Clean Water Supply System

G. Reducing Electricity Consumption through Backup Power Generation

The building's electricity is sourced from the public utility company and supplemented by an on-grid photovoltaic (PV) system, implementing the concept of green architecture (Figures 16 and 17). This system generates electricity using solar radiation and is connected to the public grid to optimize the utilization of solar energy through solar modules or photovoltaic modules [25] that generate maximum electricity.

Figure 16 Schematic Design of Electrical Energy Supply

The prefabricated building-integrated photovoltaic (BIPV) concept integrates both the aesthetic and functional aspects of photovoltaic (PV) technology into architectural design [26],[27]. In line with green architecture principles, PV panels are not merely additional components but are incorporated as integral elements of the building envelope, such as façades, roofs, or shading devices, while simultaneously serving as a renewable energy source. This dual function enhances the visual coherence of the building and optimizes land and material use. Furthermore, the application of automated prefabrication in the production and installation of BIPV systems significantly improves construction efficiency and consistency of product quality. Such systems reduce on-site labor requirements, shorten construction time, and minimize material waste, thereby supporting more sustainable, cost-effective, and environmentally responsible building practices.

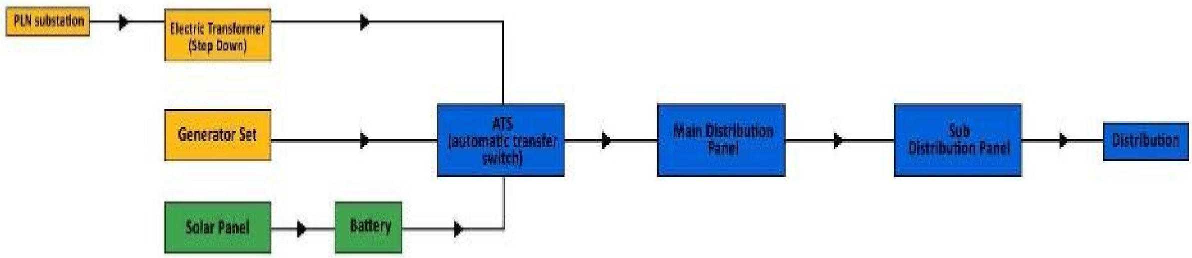


Figure 17 Schematic of Electrical Energy Supply

H. Environmental Management through Landscape Design

To support effective microclimate conditioning, the landscape design incorporates a variety of shade-providing vegetation strategically distributed throughout the site. These plantings help reduce direct solar radiation, lower surrounding surface temperatures, and create cooler outdoor and semi-outdoor environments. In addition, thermal comfort in certain building zones is enhanced through the use of vegetation as a natural air-conditioning aid. Plants that function as air filters, such as climbing or hanging species like the Lee Kuan Yew plant, as well as vertical garden systems, are integrated into the architectural elements of the building. These forms of vegetation contribute to improving air quality, reducing heat buildup, and enhancing visual comfort. The diversity and placement of vegetation types employed in the overall design are illustrated in Figure 18, demonstrating their combined role in supporting environmental sustainability and occupant comfort.

Figure 18 Landscape Thematic Concept

I. Material Selection

The selected materials are carefully chosen to align with the building's overall thematic concept while prioritizing the use of eco-labeled products. Material selection is guided by sustainability considerations, particularly the use of legally sourced raw materials obtained from responsibly and sustainably managed resources. This approach ensures compliance with environmental regulations, reduces negative ecological impacts, and supports sustainable supply chains. As illustrated in Figure 19, the applied materials not only enhance the visual and functional quality of the building but also reinforce its commitment to environmentally responsible and sustainable architectural design.

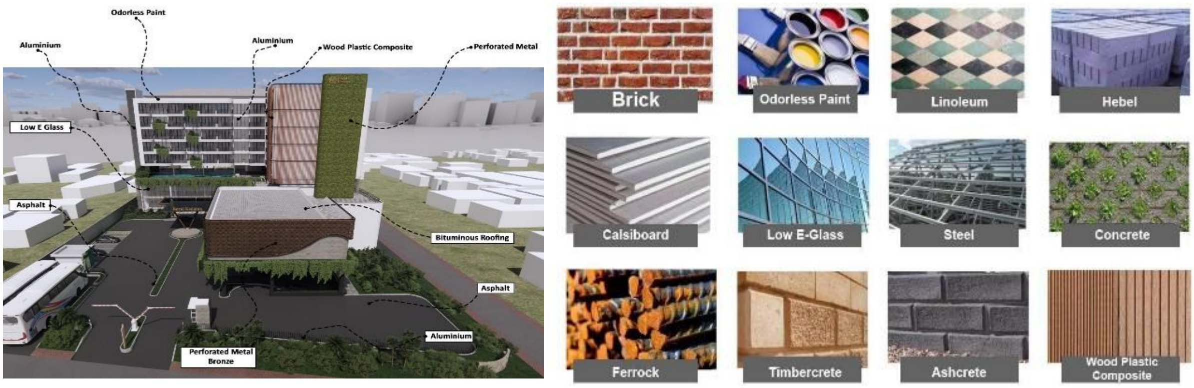


Figure 19 Material Variations in the Building

IV. CONCLUSION

The pressing issue of global warming necessitates a heightened focus on sustainability in building design. Green Building Integrating sustainability into building design is becoming more and more necessary in response to the pressing issues brought on by global warming. The goal of sustainable design is to improve tenants' quality of life while lessening the impact on the environment. This can be accomplished by carefully incorporating design techniques that support energy efficiency and blend in with natural systems. One important strategy is to reduce the amount of land covered by the building so that more rainwater may percolate into the ground, promoting groundwater replenishment and lowering surface runoff. Another important factor is building orientation; Buildings should be oriented west to east to reduce solar heat intake, particularly during the hottest hours of the day. Interior areas should be arranged to meet their unique lighting requirements, balancing the amount of natural light with the kind of activities being carried out. Residential units with wide apertures can have flexible lighting and ventilation, which improves tenant comfort while using less energy.

Another essential element is sustainable water management. Installing a rainwater collection system helps keep groundwater levels stable and offers an additional non-potable water source. Solar panels can be incorporated to support these initiatives by capturing renewable energy and lowering dependency on the main power grid. Last but not least, adding vegetation to the design helps to create healthier, more resilient spaces by conditioning the microclimate, purifying the air, and softening the built environment. These tactics work together to create a comprehensive approach to sustainable building design that improves human well-being while addressing environmental issues.

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