Integrating ecology and zero runoff in a vertical village residential design in West Jakarta

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Abstract. Diminishing availability of urban land in metropolitan cities such as Jakarta resulting in high-density settlements, which impacted the quality of life of the urban village communities. One of the government’s efforts to solve this problem is by building subsidized apartments. However, this effort mainly focused on the land scarcity and the required housing aspects, while ecological and environmental roles toward the life quality of the dwellers are often set aside though very influential. On the other hand, Jakarta is very vulnerable to natural disasters related to water, such as flooding caused by stormwater runoff which cannot be accommodated by the insufficient capacity of the surrounding environment. Therefore, the development of urban settlements in Jakarta has to pay more attention to integrate ecology and zero runoff management from the design conception phase. A vertical village residential design in West Jakarta that integrates these two aspects through ecological architecture elements (nature, water, human and environment) was proposed as a role model design for vertical village housing. Various water design features have been creatively designed and integrated into the landscape and building elements resulting in zero runoff and an ecologically significant built environment.

1. Introduction

As a metropolitan city, Jakarta attracts many people from all around Indonesia to come and try to seize the opportunities offered by various businesses and infrastructure developments. Since 1980 the population of Greater Jakarta has doubled from 11.9 million to 28 million. Due to rural-urban migration, an estimated 250,000 people relocate to the city [1]. Many of these people belong to the low-income group who do not have a decent place to live in Jakarta. Their financial limitations and diminishing availability of urban land in Jakarta resulted in the development of high-density settlements, which impacted the quality of life of the urban village communities. One of the government’s efforts to solve this problem is by building subsidized apartments. These efforts have contributed to reduce the housing backlog and provide an option of affordable housing. However, there are still some issues about the program qualities, especially in ecological and environmental roles toward the life quality of the dwellers, which are often set aside though very influential.

The pressures from urbanization and population growth also impacted land coverage and adequate stormwater drainage, worsening the city’s vulnerability to flooding. The high urbanization rate has decreased the ability of water bodies to accommodate stormwater. In addition, the topography of Jakarta increases the flood risk. Jakarta is located on a low plain on the northwest coast of Java, and the greater
Jakarta area is enclosed by several mountains, which form the upstream catchment areas of the 13 rivers flowing through Jakarta. The majority of forests that existed upstream have been transformed into residential and agricultural areas over the past several decades, which resulted in the upstream catchment areas sending their stormwater to Jakarta.

Meanwhile, the city’s river catchment has difficulty preventing flooding because of sedimentation in the existing rivers, illegal settlements along the riverbanks and poor waste management, which caused the waterways to be blocked during heavy rainfall, thus even worsening the flood risk. Most of the city is prone to muddy and flooded conditions, especially during the rainy season (typically from October to April). Figure 1 shows a map of Jakarta and the floodwater levels during the February 2007 flood event per subdistrict level. As seen, locations with the highest flood level (dark red) are adjacent to the Ciliwung, Pesanggrahan and Sunter Rivers [2]. Figure 2 contains a map of 3 significant flood events in Jakarta in 1996, 2002 and 2007. It can be seen that more recent floods took place in larger areas and consequently impacted more people.

A recent flood event from 31 December 2019 until 1 January 2020 caused flooding across the Greater Jakarta area, including some areas in West Java and Banten provinces. Hundreds of districts and sub-districts were flooded. The event is worse in terms of water volume and scale compared to the 2007 flood. In 2007 around three-quarters of Jakarta's particular region was immersed, and almost half of a million people were affected.

Impacts of flooding events happening in Jakarta give the city government urgency to prioritize flood risk management in urban settlements. By understanding the causes and effects of flood impacts and designing, investing in and implementing measures to minimize the impacts must become part of development thinking and be embedded into broader development goals [1]. However, the conventional strategy commonly implemented by governments to mitigate the impacts of flooding was to send stormwater away from built areas by the construction of storm sewers/channels or detention basins which have become increasingly difficult because of minimal land availability, especially in high-density urban settlements in Jakarta's village, and the high proportion of paved surfaces and roofs as well as the reduction of green open spaces in these areas. Studies were done in several vertical housing (rumah susun or rusun) in Jakarta, such as in Rusunawa Muara Baru, Rusun Cinta Kasih Cengkareng, and Rusunawa Jatinegara Barat [4] mentioned that stormwater management mainly was still done by channeling rainwater to the nearest water body or city's stormwater channel.
The low ability of the land to accommodate, hold and store stormwater caused high runoff and increased flood risk, making the conventional strategy not following the natural water cycle because the stormwater would end up in the sea and mix with seawater, thus requiring more extended time to supply the needs of freshwater for agriculture and the people living inland, especially in the cities. It represents a linear system instead of a circular system as the water cycle should be. In the water cycle, the precipitation is supposed to infiltrate the soil, refill aquifers or be stored in surface inland water bodies for various uses. On the other hand, less than half of Jakarta's population has access to piped water which means that most residents and activities must rely on groundwater for their freshwater demand. This draining of groundwater aquifers contributes to land subsidence. Jakarta was stated to subside up to 15 cm/year, making it one of the fastest sinking cities globally. Therefore, the development of urban settlements in Jakarta needs to pay more attention to integrating ecology and zero runoff management from the design conception phase. This study aims to design vertical village residential in West Jakarta that integrates these two aspects through ecological architecture elements (nature, water, human and environment) to be a role model design for vertical village housing.

1.1. Vertical village

The problems with the urban village are mainly about the lack of infrastructures and facilities to support the high-density population living there, mostly living in semi-permanent or non-permanent housing with minimum sanitation services and minimum natural lighting and natural lighting ventilation, thus lowering their quality of life. On the other hand, these urban villages, better known as "kampung" in Indonesia, have unique, intense social and cultural interaction characteristics. That is why these kampungs or urban villages need particular attention, mainly through design and re-organization or maybe revitalization in certain parts, including architectural solutions, especially in areas that have become slum areas because this will significantly affect the life quality of the people who live there. The role of architecture becomes essential to create a solution to answer those problems and tackling the problem of limited land availability by designing a vertical village with ecological architecture approach.

The vertical village is a more humane idea of vertical housing for low-income communities, which maintains the community's character, activities, and culture without eliminating their local wisdom but can still contribute to the environment's development. It can also accommodate facilities to improve the community's wellbeing by supporting the informal economy and entrepreneurship. In a vertical village, the housing function could represent the village (kampung) image in a "vertical form" and solve the decreasing availability of urban space, such as Jakarta, which has the highest population density in Indonesia. However, there are differences between the common kampung typology and the vertical village typology, so the design of vertical village housing should accommodate and represent the existence of the verticalized kampung without losing its essence, nature or character.

1.2. Ecological architecture

There are two shaping forms in ecological architecture, namely the biotic and abiotic environments, interacting with each other in the ecosystem. The ecological architecture integrates four ecosystem elements, i.e., nature, water, humans and the environment, to create a harmonious and friendly ecosystem [5]. Van der Ryn and Cowan [6] have a similar concept in their design principles of ecological architecture by emphasizing solutions grown from the place and people, design with nature, and make nature visible in the design. These elements will be used as the vertical village design reference. In general, ecological architecture has a balancing role in harmonizing human and nature and human and its built environment through the design parameters that relate to harmonizing and balancing the created space’s functions.

Ecological architecture means the combination between architecture and environment, which regard or pay special attention to the harmony between man and his environment. Several strategies to integrate ecological architecture in the design of vertical village housing emphasize the integration of surrounding
(the design environment context) ecological conditions, climate’s influence on building, and building function-oriented toward the behaviors of urban village communities (such as solid social interactions).

Table 1. Elements and principles of ecological architecture.

| Elements                                           | Principles                                                                 |
|----------------------------------------------------|-----------------------------------------------------------------------------|
| Building materials use                             | • Minimize non-environmentally friendly materials                           |
|                                                    | • Prioritizing use of sustainable and reusable materials                    |
|                                                    | • Improving efficiency of materials use                                    |
| Building renewable energy use                       | • Use solar panel                                                          |
|                                                    | • Minimize energy use from ventilation and lighting through passive design |
|                                                    | • Optimize building energy use                                             |
| Environmentally friendly waste management          | • Eliminate air, water and soil pollution                                  |
|                                                    | • Use organic, reusable or biodegradable materials                         |
| Improving adaptive functionality                   | • Apply Zero Runoff concept in site planning                               |
|                                                    | • Take into account materials and water flow in the ecosystem that will be |
|                                                    |   shaped/formed in the design area                                         |
|                                                    | • Preserve biodiversity created in the environment                        |

The above principles listed in Table 1 are further applied as ecological architecture design parameters among others in these aspects:

1. Sustainability of green areas in design location for infiltration
2. Choice of design site that does not disturb nature’s sustainability
3. Encourage use of natural materials
4. Improve ventilation as passive design response
5. Implement Zero Runoff in design area
6. Use wall materials that minimize Urban Heat Island Effect

2. Methodology

This research was done using qualitative and quantitative approaches such as direct observation in case study areas, literature review, interviews with relevant stakeholders, collecting secondary data to support analysis, and simulation software. Results from this analysis were evaluated and then applied to the design process. Before the study area was chosen, a suitability analysis was done to select the location from 3 site alternatives, then micro and macro site analysis was performed on the selected site. A volumetric study was also conducted for three alternatives of masses for the chosen site to obtain the design mass, which will be developed and designed according to the intended design concept and strategies. The design concept can be seen in Figure 3.
2.1. Study area

The object of this research was RW 016 Kapuk (West Jakarta), which has the worst slum status in DKI Jakarta and compared the conditions/characteristics with one of the existing and similar urban vertical housing complexes in Jakarta, namely Rumah Susun (Rusun) Conver Kemayoran.

RW 016 Kapuk is the most densely populated area in Jakarta having in average around 300 family cards (KK or Kartu Keluarga) in one Rukun Tetangga (RT) and there are 25 RTs in RW 016 (total 9433 KK). Most of its residents (about 80%) are migrants working as factory workers or in informal sectors.

![Figure 3](image-url)

**Figure 3.** Design concept used in this research.

![Figure 4](image-url)

**Figure 4.** Existing conditions at study areas: RW016 Kapuk (a) and Rusun Conver Kemayoran (b). Source: personal documentation.
Rusun Conver Kemayoran is located in Jalan Conver 3 no 101 RT 12 RW 16 Kebon Kosong, Kemayoran district, Central Jakarta. It has a total area of 11,845 m². In the beginning, it was built for the low-income urban community, disaster victims and relocated families, but then the residency has changed to middle-up economy classes until now. In this study, Rusun Conver Kemayoran is used to be a precedence case study as the vertical village that is already existing and be a reference for the vertical village that will be made in RW 016 Kapuk.

2.2. Ecological conditions

Table 2. Comparison of existing conditions at study areas.

| Aspect                        | Rusun Conver Kemayoran | RW 016 Kapuk |
|-------------------------------|------------------------|--------------|
| Area                          |                        |              |
| Total area: 11,845 m²         | Total area: 220,000 m² |
| Street area: 1728 m² (15 %)   | Street area: 12,535 m² (5.7 %) |
| Green area: 4621 m² (39 %)    | Green area: 38,935 m² (17.7 %) |
| Roof area: 5496 m² (46 %)     | Roof area: 169,070 m² (74.4 %) |
| Water body area: -            | Water body area: 4,920 m² (2.2 %) |
| Building shape and structure  |                        |              |
| Clustered layout forming a void used as open spaces in ground floor | Irregular grid layout of each building forming small corridors for circulation |
### Aspect

| Lighting and ventilation system | Rusun Conver Kemayoran | RW 016 Kapuk |
|---------------------------------|------------------------|--------------|
| Each unit has enough openings for light and ventilation | Non-permanent houses and very crowded condition, mostly have minimal openings | |

| Response to climate | Buildings have responded to climate | Most houses have not responded to climate |
|---------------------|-------------------------------------|------------------------------------------|
| Drainage system     | Closed drainage channels and good layout (available in every block). Drainage channels discharge to bigger channel (1 m diameter) under the pedestrian walkway and then go to the city’s sewer in front of the rusun. | Open drainage channels, smell bad, very dirty and muddy most of the time, even when it did not rain. In the rainy season very often flooded (>50 cm deep) |

| Design considering nature | Already considered green spaces | Very crowded and minimal green spaces |
|---------------------------|-------------------------------|--------------------------------------|

### 3. Result and discussion

The design concept for this vertical village housing came up from the problems happening in high-density settlements, which impacted the quality of life of the urban village communities. The government’s effort to solve this problem by building “rusun” (vertical housing) has not given enough
attention to ecological and environmental sustainability, particularly the impacts from disturbed water cycle on the environment and life quality of the communities.

Implementation of ecological architecture concept in this research was done through simulations, calculations and analysis of the four elements (nature, water, human and environment) resulted in Table 3.

| No | Elements                          | Design application                                                                |
|----|----------------------------------|-------------------------------------------------------------------------------------|
| 1  | Kampung structure interpretation | Housing design tried to interpret the horizontal structure of kampung into vertical structure. |
| 2  | Building form follows context     | Building form responded to the context pragmatically.                               |
| 3  | Use of renewable energy          | Solar panels are used as alternative energy source for lighting and irrigation pumps (automatic drip system). |
| 4  | Ecological corridors in building | Place various kinds of vegetations in every floor to create a living ecosystem on each floor. |
| 5  | Natural ventilation              | Natural ventilation for each massing/block from continuous void stretching from the lowest to highest floor. |
| 6  | Climate response                 | Orientation, form of massing and openings were simulated to respond to the climate on site. |
| 7  | Modular housing                  | Easier to construct, more economical and aesthetically better-looking building.       |
| 8  | Natural lighting                 | Natural lighting from voids and balconies creates shading during the day.            |
| 9  | Universal design                 | Public ramps were incorporated as a response to human aspect and as a form of universal design for everyone. |
| 10 | Communal area                    | Communal area on the ground floor has cross-programming characteristics to suit various occasions needed by the residents, e.g. weddings or group gatherings. |
| 11 | Steel structure for columns and beams | Steel structure has good characteristics and aesthetics, as well as recyclable.   |
| 12 | Urban green area                 | Green areas have lots of voids between densely populated settlements around the design site. |

The modular form was chosen to represent interpretation and response to the context of “kampung.” The modular form also created a better view for each unit and shading for other units in the lower level. It was developed from the simulation of horizontal urban villages in vertical form and aimed to obtain more effective forms of natural lighting and ventilation. The simulation was also done to determine practical mass orientation to maximize natural daylighting during the day. Design calculation can also maximize the roof space to set up solar panels, contributing to 20-25% of electricity consumption in the design site.

Roof space can also be used for urban farming and communal area for socialization. The green open space in the middle of the site is intended to create bonding between masses and provides a better view from each unit. The terraces formed on each floor also add to the central green open space in the middle. The accessibility and connectivity in the building were also considered ecologically friendly and healthier for everyone by encouraging people to walk and interact with each other between blocks. Provision of the communal area is an interpretation of urban village sociocultural and implementing the ecological concept. The landscape area was designed to become a communal area or improve the aesthetics and function as an infiltration and rainwater management area. The integration of ecological architecture and zero runoff in this vertical village housing design can be seen in Figure 5.
The ecological corridors were embedded in the buildings through terraces (green facades), rooftop gardens, parks, and grass blocks in parking lots. Total green area (excluding roof garden and grass blocks) amounts to 4725 m² (KDH = 50% of total area), more extensive than the regulation for building’s KDH (Koefisien Dasar Hijau = 20%). These green spaces naturally improve the potential of Zero Runoff on the site. By linking ecological landscapes in the vertical village, rainwater does not have to flow on the streets or through the drainage channels but the green and blue landscapes/corridors as it should be. The application of Zero Runoff in this design is also supported with 11 infiltration wells receiving a calculated runoff volume of approximately 250 m³ from non-roof areas and a retention pond...
having a volume of around 370 m³ coming from the roof area (Figure 6); thus, the Zero Runoff system was designed to handle a total of 620 m³ runoff and divert it from flooding the surrounding communities.

![Figure 6. Zero runoff implementation in vertical village design.](image1)

![Figure 7. Vegetation axonometry in vertical village design.](image2)

Figure 7 shows the various types of vegetation planted on-site and the potential of increasing the biodiversity in the area, creating a rich ecosystem that improves health, well-being, and environmental quality and can be utilized as a green building envelope to reduce the Urban Heat Island effect.

Through the integration of ecology (including ecological architecture) and sustainable water management, which include Zero Runoff rainwater management, we can help nature to work more effectively, promote natural hydrologic and ecosystem processes, conserve and reuse freshwater, improve public health and well-being, and prevent disaster and losses from flooding at the same time.

4. Conclusion

Limited land availability and high urbanization rate have impacted the life quality of urban village communities in Jakarta, especially from ecological aspects. On the other hand, amplifying the development of built and impervious areas coupled with increasingly unpredictable and extreme weather causes urban villages in Jakarta to become more prone to disaster and losses from flooding.

The multidimensional analysis done in this study has shown that integrating ecology with Zero Runoff in the design of vertical village housing has great potential to be a solution to rectify these problems and simultaneously improve the quality of life and environment.

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