# An assessment of sustainability in architecture based on sustainable building framework – Case study: Mesvara house, Yogyakarta, Indonesia

**B. Sakina**

Architecture Department, Faculty of Engineering, Bina Nusantara University, Jakarta, Indonesia 11480

bunga.sakina@binus.ac.id

**Abstract**. Architecture contributed in global warming by consuming non-renewable energy and producing waste. Sustainability has become one of the major issues in the building industry, as it can help reducing the environmental impact. Therefore, it is vital for architects to apply sustainable design principles. This study aims to see the sustainability awareness of architects by assessing an architectural firm's project based on the sustainable building framework. The case study was Mesvara House in Yogyakarta designed by Vignette. Data were collected through direct observation and interviews, and analysed using the sustainable building framework as the assessment tool. Result of the study revealed that Vignette has shown that they are aware of sustainability issues in architecture by implementing all objectives in the framework such as recourse conservation for environmental sustainability, cost efficiency for economic sustainability, and design for human adaptation for social sustainability. For resource conservation, the architect applied effective construction method, using local materials, applied innovative watering system and using a non-arable land. For cost efficiency, the strategies implemented was low budget project, maximizing passive energy, utilizing easy-to-maintenance materials, and future expansion preparation As for design for human adaptation, this house applied thermal comfort and anticipated from fire, natural hazard and crimes.

**Keywords :** Architecture, sustainability, assessment, sustainable building framework

## 1. Introduction

Architecture, as part of the building industry, has a major contribution in global warming. The building materials, construction phase, and building occupation consume energy. Not only that, buildings also produced waste on a huge scale. Architects, as the designer of the buildings, had an important role in designing more energy-efficient and environmental-friendly buildings, yet they had to be functional and aesthetic. Therefore, it is vital for architects to understand and implement the sustainable design principles in their buildings.

Sustainability has become popular topics among many disciplines. The essence of sustainability is how to utilize resources for today's interest in the wisest possible way to ensure its sustainability and existence for the future [1]. The idea of sustainability involves enhancing the quality of life by improving social, economic and environmental conditions[2].

There are several studies discussing sustainability design principles in architecture[2, 3, 4, 5].Akadiri et al [2] did a literature review and proposed a sustainable framework and methods that can be applied during the life cycle of building projects. Grierson & Moultrie [3] examined typology of sustainable building design by mapping several sustainable principles used by architects interviewed. Kim &Rigdon[4] also proposed sustainable principles and focused on pollution prevention.Setiawan&Sakina [5] focusing in ecological design and green architecture concept and used them to examine an architectural project.

This paper therefore complimenting previous studies discussing sustainability, and use its principles to assess an architectural project. A private house designed by an architectural firm will be assessed based on the sustainable design framework by Akadiri et al [2]. This sustainable design framework and methods was used as assessment tools because it was more applicable in terms of analyzing a small scale project, such as a private house. From this research, it is expected to have a view on the awareness of architects in designing a sustainable building from the environmental, economy, and social issues.

## 2. A Sustainable Building Framework

The essence of sustainability is how to utilize resources for today's interest in the wisest possible way to ensure its sustainability and existence for future [1]. A sustainable building has social, economic and environmental aspects[3]. Social in terms of adding quality of life for people as the users, economic in terms of enhancing wealth, and environmental in terms of reducing the impact on the natural environment. All dimensions should be considered in a complimentary way.

Akadiri et al [2] has proposed a framework of strategies and methods for implementing sustainability in buildings, which related to sustainability issues (environmental, economic, and social). The framework includes objectives such as Recourse Conservation (environmental issues), Cost Efficiency (economic issues), and Design for human adaptation (social issues). Each objective has strategies and methods to facilitate sustainability in building projects from a life-cycle perspective. In this study, the sustainable building framework will be used to examine and analyse the case study. The overall sustainable building framework proposed by Akadiri et al [2] can be seen in Table 1.

**Table 1.**Sustainable Building Framework

| Sustainability Issues | Objectives | Strategies | Methods |
|---|---|---|---|
| Environmental Sustainability | Resource Conservation | Energy conservation | 1. Choice of materials and construction methods<br>2. Insulating building envelope<br>3. Design for energy efficient deconstruction and recycling<br>4. Design for low energy intensive transportation<br>5. Developing energy efficient technological process<br>6. Use of passive energy design |
| | | Material Conservation | 1. Design for waste<br>2. Specify durable material<br>3. Specify natural and local material<br>4. Design for pollution prevention<br>5. Specify non-toxic material |

| | | | |
|---|---|---|---|
| | | Water conservation | 1. Using water efficient plumbing fixtures<br>2. Design for dual plumbing<br>3. Collecting rain water<br>4. Employ re-circulating systems<br>5. Designing low-demand landscaping<br>6. Pressure reduction |
| | | Land conservation | 1. Adaptive reuse of existing building<br>2. Locate construction project close to existing infrastructure<br>3. Development of non-arable lands for construction |
| Economic Sustainability | Cost Efficiency | Initial Cost (purchase cost) | 1. Use locally sourced materials<br>2. Employ cost saving technology that can be managed locally<br>3. Utilize modular design and standardize components<br>4. Use less expensive building materials and reduce time required to assemble materials on sit<br>5. Use readily available materials<br>6. Use recycled and reclaimed materials |
| | | Cost in use | 1. Design for regular cleaning, maintenance, and repair<br>2. Ensure availability of skills required and labour supply.<br>3. Choose minimum-maintenance materials<br>4. Ensure service life requirements of materials and components<br>5. Protecting materials from destructive elements (sun, temperature variations, rain, etc.)<br>6. Provide easy to understand access control for occupants |
| | | Recovery cost | 1. Recycling potential and ease of demolition<br>2. Adaptive reuse of an existing project<br>3. Reusing building materials or components |

| | | | |
|---|---|---|---|
| Social Sustainability | Design for human adaptation | Protecting human health and comfort | 1. Thermal comfort<br>2. Acoustic comfort<br>3. Day lighting<br>4. Natural ventilation<br>5. Functionality<br>6. Aesthetics |
| | | Protecting physical resources | 1. Design for fire protection<br>2. Resist natural hazards<br>3. Design for crime prevention |

Akadiri et al (2012)

Resource Conservation means achieving more with less; it's how human manage to use the natural non-renewable resources efficiently in order to provide maximum benefit. This objective includes strategies such as conservations of energy, material, water and land. Cost Efficiency is how to minimize total project and the building's life-cycle cost, and also how it will continue to meet the occupier's requirement. Building is a large and long-lasting investment. The strategies of this objective are the initial cost (purchase cost), cost in use, and recovery cost. Design for Human Adaptation is how to provide healthy, comfortable and safe environments for human activities. This last objective includes protecting human health and comfort, and protecting physical resources[2].

## 3. Research Method

This research is a descriptive-qualitative research [6]. Assessment and analysis are conducted and the result will be discussed through descriptions. The data collection is done through interview with Vignette, the architectural firm, and also with the client, who is the owner of the research object. Direct observation also conducted in order to receive better visual and perspective about the object. The data was assessed and analysed based on the sustainable building framework by Akadiri et al [2].

## 4. Case Study

Mesvara House belonged to a client named Mrs. RisaKurniawati and her family. This house is designed by Vignette, an architectural firm based in Yogyakarta, Indonesia. This house wa built in November 2017 and finished in May 2018. This house is located in Gang Antasena no. 42, Jl. CandiGebang, Sleman, Yogyakarta. The site location and exterior of the house can be seen in Figure 1 and 2.

**Figure 1.** Site Location

**Figure 2.** Exterior of Mesvara House

The U-shaped house has a Scandinavian concept, which is clean and simple. It used natural elements such as bricks, exposed concrete and natural colors like white, brown, grey, etc. The 2-storey house was

built on a 91 m2 land. The ground floor area is 40 m2 and the rest 51 m2 areas left was provided for open spaces. Mesvara house has a living room, family room, 1 master bedroom, 1 guest bedroom, 2 bathrooms, 2 kitchen, and this house is also facilitated by an office for the husband to work. The architect gave many openings and open spaces for natural day lighting and ventilation. The roasters and bricks on the 2nd floor became the main vocal point of the house. The Mesvara house floor plans and elevations can be seen in Figure 3-4.

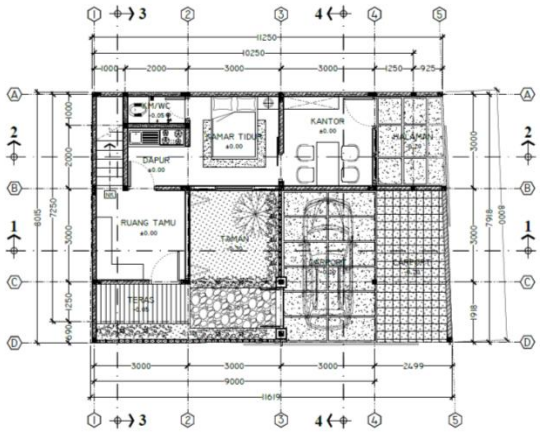


**Figure 3.** 1st floor plan of Mesvara House

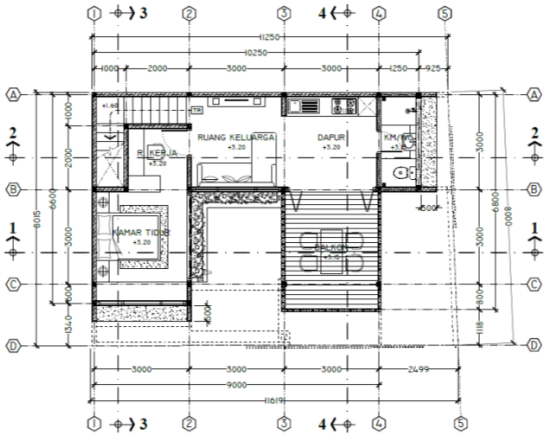


**Figure 4.** 2nd floor plan of Mesvara House.

## 5. Result and Discussion

This part of the study will try to examine the case study based on the previous sustainable building framework, including its objectives and strategies. There are three aspects of sustainability to discuss: environmental sustainability, economic sustainability, and social sustainability.

### *5.1. Assessment on Environmental Sustainability : Resource Conservation*

Certain resources are becoming rare and the use of remaining stock must be treated cautiously. Thus, the conservation of natural resources has vital importance for a sustainable future. Non-renewable resources that are mainly used for construction project are energy, water, material, and land

*5.1.1. Energy Conservation.*Vignette tried reducing energy consumption and waste by effecting the preparation for construction phase. They tried to be as effective as possible in choosing their construction methods (Figure 5). The tools used for constructing, like batter board, plywood and roofing for the workers shelter were used from previous project. They also used the same wood for casting the building main structures (columns, beams, etc.). This way they could minimize the construction waste. The house also tried to minimize the consumption of energy (air conditioning and artificial lighting) at day time by providing openings towards the garden and oriented the face of the building to north-east, which allows natural ventilation and day lighting to enter the building. The light bulbs used in this house were all LED (light emitting diode), which were more energy-efficient.

**Figure 5.** Construction Progress of Mesvara House

*5.1.2. Material Conservation.* Vignette aware that architecture, as part of the construction industry, is one of the major waste generators. One of the biggest wastes in construction is the building materials. Since the early construction phase they tried to minimize waste, by re-using tools and materials from previous project.Glass doors and granite flooring constructed in the building are examples of re-used materials. The house also located near building materials manufacturing. The roaster and bricks on the second floor, paving for outdoor area, and steel for building structure are materials manufactured near the building site. Vignette also chose local materials for the building structure, like sands and stones for foundations. This action hopefully can help shorten transport distance, thus minimizing air pollution produced by vehicles. Some local materials used in this project can be seen in Figure 6.

**Figure 6.** Somelocal materials used in Mesvara House(roaster and bricks)

*5.1.3. Water Conservation.* The architect created watering systems innovations for the house. The pipe sizes for plumbing declining, from the water source in the upper water tank to the tap for water use. Pipe from water tank measuring 4 inch, then shrink to 2 inch pipe, passing through top of ceiling, the pipe size declined to 1 inch, until finally measuring ¾ inch for taps. This system relies on gravity, and the water that comes out becomes so swift that the occupant does not need to use a water booster. In addition, the architect created an automatic watering system (see Figure 7). The occupants just need to turn on a single tap to water the plants at once. Water pipes are placed around the greeneries, and then they gave small holes to the pipes. In this way, when the tap is turned on, the water will come out through the holes to water the plants. It wasan effective solution that was considered water-efficient. The house also has many open spaces for rainwater water absorption and rainwater storage.

**Figure 7.** The innovative water systems for watering the plants

*5.1.4. Land Conservation.* This project was built on a non-arable land, a land that is unsuitable for farming. The land used is purposely meant for building construction. This house used ground water from the well, which means that the architect aware of the land condition. Vignette also placed an existing tree to the house. They did not cut it, but they re-located it to the garden area of the house.

*5.2. Assessment on Economic Sustainability : Cost Efficiency*
As mentioned before, building is a long-lasting investment; thus cost effectiveness is the main interest for its owner. Clients wanted to minimize the total project cost and consider how much a building will cost over its life cycle. Cost efficiency includes initial cost, the cost in use, and the recovery cost.

*5.2.1. Initial Cost (Purchase Cost).*Vignette claimed this house as a low budget project. They chose affordable material prices yet have good qualities and durable for years. Selections of available materials close to the site and locally manufactured were cheaper, plus it has minimum transport cost. The materials used for the building structure, such as stones for foundation and bricks for walls are also considered low budget. This house also re-used materials and building components which reduced project cost. A simple yet attractive design, with modular system was effective and can save cost and construction time. Thus, it also effected the minimum workers' payment.

*5.2.2. Cost In Use.*The architect minimized the operational cost by providing passive comfort into the building. The openings for day lighting and natural ventilations will reduce the consumptions of energy by minimizing the use of air conditioning and artificial lighting. The innovative water systems applied in this house are also effective and easy to-use for the occupant. Therefore, an inefficient use of operational energies can be avoided.

*5.2.3. Recovery Cost.*This house has a recycling potential by having good quality and easy to maintain materials and components. It also has a simple structure and modular building systems which eases the future demolition or even development such as renovation.The architect already prepared the structures for future expansion and already planting a waterway system for plumbing development. This way they calculated that they can reduce additional material and cost in the future.

5.3. Assessment on Social Sustainability : Design For Human Adaptation
Users are the people who will be using the building. Therefore, this social aspect is crucial in order to maintain the building's sustainability. A sustainable building must provide healthy, comfortable, and safe living environment for its users.

*5.3.1. Protecting Human Health and Comfort.*Mesvarahouse has many openings which allowed natural ventilation and day lighting to enter the building (Figure 8). The house also located near existing fish pond (Figure 9 and 10), which filters and brings cool air to the building. The orientation facing north-east made the house received morning sun light that support health for the occupants. The architect's thoughtful consideration on layout planning also made this house has smooth operation of the activity. Another attempt for psychological comfort is by designing an aesthetic living environment. Mesvara house has pleasing visual and has many natural elements like bricks and plants. The unique roaster on the second floor also made as a vocal point of this house.

**Figure 8.** Protecting users health and comfort by passive energy and aesthetic design

**Figure 9.** Fish pond near Mesvara House helps filtered the hot air

**Figure 10.** The fish pond located on the east-side of the house

*5.3.2. Protecting Physical Resources.*Vignette applied a linear circulation to the building plan and also made numerous openings. It also has modular layout with simple and rigid modules. Therefore, this house has prepared for mitigation in facing neither natural nor hand-made disasters such as fire incident and earthquake. In terms of crime prevention, this house has followed crime prevention design approaches, such as natural access control, natural surveillance, and territorial behavior. Access control by using doors, fences, and other physical design elements to discourage access to an area by all but its intended users; Surveillance by placing windows, and providing adequate lighting and landscaping that allow unobstructed views for observing intruders; Territory by placing sidewalks,

landscaping and elements that establish between the public and private areas.These approaches create a safe living environment.

*5.4. Analysis Result of Sustainable Building Framework*

Based on the descriptions above, Mesvara Housedesigned by Vignettehas implemented almost all of the methods in the sustainable building framework from Akadiri et al [2]. Thus, Vignette as one of the architectural firm in Indonesia had shown that they are aware of the sustainability issues and applied some of the sustainable methods to their design. The implemented methods are from three aspects of sustainability which are environmental, economic, and also social. The framework objective for environmental sustainability is Recourse Conservation; economic sustainability is Cost Efficiency, and as for social sustainability, the objective is Design for Human Adaptation.

In terms of Resource Conservation, Vignette has efficiently conserved non-renewable resources such as energy, material, water and land. They applied the methods of choosing the energy-efficient materials and construction methods and also minimizing the use of artificial cooling and lighting by maximizing on passive energy design. They also achieved material efficiency by designing for waste minimization, specify natural and local materials to the building, and designing for pollution prevention. Some of the consideration of selecting material for green construction was reusability, embodied energy, and waste reduction factor [7]. Reusability means reusing materials for other project, embodied energy means choosing local materials and products that has low energy production, and waste reduction means choosing a minimum waste and efficient material. As for water conservation, Vignette utilized the house with innovative water-efficient plumbing fixtures, collecting rainwater system, and designing a low-demand landscaping. In land conservation, the house was built on a non-arable land. This contributes to sustainability as it does not reduce the presence of fertile soils for agriculture.

Vignette aware that efficiency in building life-cycle cost is crucial for client. Building is a long-lasting investmentfor them. Cost effectiveness of buildings is the common interest for the owner, the user and society[2].The architectural firm has proven their thoughtful consideration on the cost of the building from its initial cost, cost in use, and recovery cost for the end of the building's life-time. For the initial cost reduction, Vignette has optimize the use of locally available materials, saving cost for construction technology, utilize modular design and standardize components, use less-expensive, readily available, and recycled materials. For cost in use, Vignette provided an easy to understand access control for the occupants such as watering systems and minimizing the use of artificial features by using passive energy design. Utilizing passive energy is needed as it saves both in energy and costs[8]. As for recovery cost, Vignette has considered about recycling potential and ease of demolition and also the potential of reusing building materials or components for future development of the house.

Designing for human adaptation is important in designing residential buildings, living environment for the occupants. Vignette tried to design a house that provided health, physiological comfort, satisfaction, safety and also productivity. The house was designed to protect the users' health and comfort by applying thermal comfort, day lighting, natural ventilation, functionality through accommodating the users' needs, and also designing an aesthetics building. The house also protect physical resources and avoid harm to its occupants or the environment by designing for fire protection, resisting natural hazards like earthquake, and has crime prevention design. A study by Marzbali et al.[9]stated that crime prevention strategies are effective methods towards achieving sustainability. Designing out crime approaches are in line sustainability aspects, not just social, but environmental and economic as well.

## 6. Conclusions

Designing a sustainable building is considered a way to minimize the energy consumption and waste production. It's a form of contribution from the building industry in achieving a sustainable future. The issue of sustainability has gained wider attention especially for construction practitioners. Designing a sustainable building is a way to foster the economy of the building industry, while minimizing environmental impact and improving the quality of life of humans.

Vignette, as one of architectural firm in the building industry in Indonesia, has applied the sustainable principles into their building. The case study in this research has been assessed based on sustainable building framework form Akadiri et al [2]. Based on the assessment and the analysis, Mesvara House, a private house designed by Vignette, has applied the methods for sustainability principles in resource efficiency, cost efficiency and design for human adaptations. The Architectural firm has shown their innovative ways and thoughtful consideration in applying the sustainable methods from the conceptual stage until planning for the building's development and demolition.

It is a challenge for other designers and practitioners to create other innovative ways in terms of designing and constructing sustainable buildings. A sustainable building framework, consisting strategies and methods, can be used as a tool to help improve in implementing sustainability in projects. By using these tools, creating sustainable buildings which support the environmental, economic and social issues will become more realized.

Because this is an initial research, in practice the results of this research still need to be tested and confirmed in subsequent studies. Nonetheless, the findings of this study can be a reference for academics and practitioners in sustainable building design.

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