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A Biodiversity Conservation Area Using Holistic and Modular Architecture

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Abstract Green architecture and engineering aim to minimize the use of available resources by maintaining and protecting the ecosystem and optimizing its benefits to humans and the ecology. The rich biodiversity of Mindoro Island, Philippines has always been on the pipeline project of the province. However, strategies for maximizing the benefits of a small area imposed challenges and hindered many conservation projects. This study utilized modular architecture, biophilia, and biomimesis as design concepts. The design implemented the use of inverted pyramid-shaped modules supported by pilotis to lessen the interaction of the construction project to the proposed site. Five modules are built accordingly and strategically connected by a modular bridge for accessibility. The body of the Mindoro dwarf buffalo is represented by the container van used as the mainframe of the modules; the legs are represented by the pilotis used as structural columns, and the body-built is represented by the inverted pyramid-shaped single-pile structures. The administration building was also inspired by the sturdy built of Mindoro Dwarf Buffalo (Bubalus mindorensis) and designed to cater the administrative functions and activities, while the proposed shops and commercial areas are designed to boost the local economy.

Keywords Biomimesis, Biophilia, Modular Architecture, Mindoro Dwarf Buffalo, SIMBOLIKHA

1. Introduction

As technology and the economy continue to prosper, the need to maintain the natural environment has been the subject of much research. The role of sustainability in maintaining the present Earth's condition for future generations is becoming a growing concern for many environmentalists, engineers, and architects. Sustainable and eco-friendly architecture and engineering aim to promote better life and to move towards eco-friendly earth [1] as it strives to maximize the resources with limited environmental impacts [2]. Sustainable development considers the whole and balanced ecosystem, supporting biological diversity and global environments, empowering social participation, and enhancing economic growth [3]. With the massive industrialization and globalization experienced by the Earth, biodiversity has been given limited consideration and conservation remains a pressing environmental challenge [4]. Humans acknowledged that our dependency on biodiversity is the key player for survival and the innate relationship brings compassion to protect the ecosystem [5, 6].

Engineering and architectural concepts are gaining much attention in the various approaches to biodiversity conservation. The concept of modular design focuses on the use of functional subsystems, interfaces, and sub-members that form parts of a bigger group. The modular approach offers flexibility in the design and lessens the project cost by maximizing the innate system's characteristics [7]. The use of fabricated modules offers a promising and high-tech approach to reducing construction costs [8], reduces the overall construction schedule, offers more improved quality, and reduces resource wastage [9,

10]; and can be applied in a housing project varying from single to multiple dwellings [11]. A new concept of modular housing focusing on residential areas explores the capability of cold-formed steel structures based on the functional structure of the house, sound management of the circulation areas, optimization of living spaces and minimalistic design, and conformity to the appropriate design standards [12]. The modular constructions are fabricated in a highly extensive process and the modules are delivered and assembled to the site maintaining the structural integrity [13]. Further, the modular approach offers economic benefits as it provides improved productivity in terms of life cycle cost [14], energy performance, and environmental impacts [15]. Therefore, modular construction can offer strategies to achieve sustainability [16, 17].

Another promising approach in architectural design is biophilic architecture which believes humans have an intrinsic relationship with nature and the human tendency to explore and associate him with the natural world [18], considering sustainability and low environmental impacts and offering a restorative design [19]. Biophilic design can be achieved by incorporating plants, water, and animals in the natural built-in environment; using patterns and materials that depict nature, and describing how humans act accordingly with spatial arrangements [20]. With the increasing environmental awareness, designers shifted their concerns in relating their creations to the mitigation of climate change impacts and prevention of natural/environmental degradation [21] considering the thermal performance, air and water quality, proper sound insulation, noise reduction, provision for stormwater and wastewater management, and the protection of the biodiversity [22,23]. Strategies in applying biophilic design include the following considerations: the building of water fountains, ponds, aquariums, and rainwater facilities and optimizing the natural water features to enhance the water sources and create a sense of closeness to water sources [24,26]; use of operable windows, vents to increase the natural ventilation [24-26]; use of glass walls, skylights atria, and reflective materials to allow the natural lighting; use of green roofs, green walls, and façade and placing of indoor potted plants to increase the green space and encourage positive and light mood [27]; imitating the contour and built of organisms in building forms, structural system and components to create connections with the environment and challenging the designer's creativity [20,28].

This study investigated literature discussing the importance of green engineering and architecture sustainability, natural light and ventilation, and appropriate strategies to achieve eco-friendly design. Biophilia design described as the natural connection of humans with nature and the way of imitating nature's designs and processes to solve human problems [29] was the main focus of the study. The proposed design tries to incorporate the biophilic design considering the health and well-being of present occupants in the study area [30], and the recommended list of biophilic design qualities emphasized that the human body and mind developed senses based on the surrounding environment [31]. The biophilic design was applied in an interior design of a health center by applying 52 of Kellert's list of biophilic design attributes covering the landscape and architecture application considering the wind direction, thermal comfort, and air quality [32]. Results of the study showed that sound space management can be provided to people by adding green and sustainable patterns and elements of the built-in environment [33]. An in-depth analysis of biophilic design as connectors of humans to the built-in environment was investigated and found that biophilic design is not just an addition of green design but takes into consideration the physique, symbols, patterns, and origins [34-35]. Further, the biophilic design was applied in river restoration in a Southern European river and transformed into canal and culvert pipes using regenerative sustainability by implementing green and blue infrastructure and providing a retention basis for water storage considering the reduction of climate change risks [36].

The Philippines belongs to the 18-mega biodiverse countries of the world and two-thirds of the earth's biodiversity can be found in the country. However, the unique biodiversity supported by a large variety of ecosystems, landscapes, and habitats is facing challenges from human activities with 24% land area of the country gradually declining [37]. Mindoro Island is considered as the smallest among the faunal regions in the country 62 species of mammals, 273 birds, 62 reptiles, and 15 amphibians with 149 species can be found in Mt. Halcon, Mt. Calavite, and Mt. Iglit- Baco [38]. At present, Mindoro island houses 354 animal species, 35 of them are endemic, and 24 were named by the World Conservation Union for the threats of extinction. More so, the island's ecological condition continues to decrease in the past decades affecting its biodiversity. In 1900, it was at 70% old-growth forest; 1920 it was 60%; in 1960 it was at 40%; 1987 at 23.7%; 1998 at 22.2 %; 2003 at 8% [39]. The unique biodiversity of Mindoro Island offers challenging opportunities for other unnamed and unrecognized animal species. Mindoro is famous as the home of the Mindoro dwarf buffalo (Bubalus Mindorensis), a small hoofed mammal endemic to the province and the only endemic Philippine bovine, and is now a critically endangered species [40]. The proposed site for the development of a conservation area is the only place in Mindoro where the remaining species of the Mindoro dwarf buffalo is can be seen. To help the Mindoro dwarf buffalo Conservation Program in the province, the researchers offer a development plan exploring the natural built-in environment in Mt. Iglit Baco necessary for the protection and survival of remaining species of plants and animals.

This study aims to provide a design that offers space and area for the exploration of biodiversity using modular architecture and biophilic design. SIMBOLIKHA is a

proposed Mindoro Biodiversity Conservation area purposely designed in the foothills of Mt. Iglit-Baco National Park, Calintaan, and specifically aims to establish a facility for environmentalists for their respective endeavors by maximizing the natural characteristics of the built-in environment; design a park for leisure and recreation for educational purposes; offer an area for animal species for exhibition, study, and observation; and design a space that would respond to the rescuing needs in the wildlife such as the rehabilitation of sick, injured and orphaned animals and eventually to release them to wildlife or its natural habitat. While the biophilic design is applied by imitating the natural physique of the Bubalus Mindorensis and optimizing the natural characteristics of the built-in environment using screened walls to allow natural light and ventilation.

2. Materials and Methods

2.1. Site Inspection/Assessment

The researchers conducted a site inspection on the proposed site of the Biodiversity Conservation Area. The environmental analysis included an inventory of the present facilities, animal and plant species, and other essential facilities relevant to the realization of the proposed plan. Site Analysis is produced to present the results of the site inspection conducted. The gathering of data, site inspections, and environmental analysis was conducted from February to June 202.

2.2. Project Description

SIMBOLIKHA is a proposed Mindoro Biodiversity Conservation Area as the center for Mindoro Islands' flora and fauna discovery, exploration, and care. The proposed design offers a place for the observation, attention, and other needs of existing animal and plant species; and a place for the exploration of species to be discovered yet (Fig. 1).

Fig. 1 shows the regions included in the proposed site. A large area of the proposed site is used for the conservatory, showroom for plants and animals, fauna observatory, public viewing ponds, ranger stations, and horticulture laboratory to cater to the space requirement of the remaining species of plants and Mindoro dwarf buffalos. While the areas for souvenir shops, parking areas, admin and lecture rooms, and quarters were placed in the front of the site to ensure the natural diversity will not be disturbed by any activities incurred during the construction. The horticulture laboratories and animal veterinary rooms will be places for the biologist, veterinarians, and environmentalists to explore, investigate, and respond to the needs of the plants and animals. SIMBOLIKHA aims to generate income for the community and promote tourism through learning, exhibition facilities, flora and fauna exposure, and interactive activities. All parts of the design considered the protection of the existing ecology not to disturb, destroy or alter the naturally built environment.

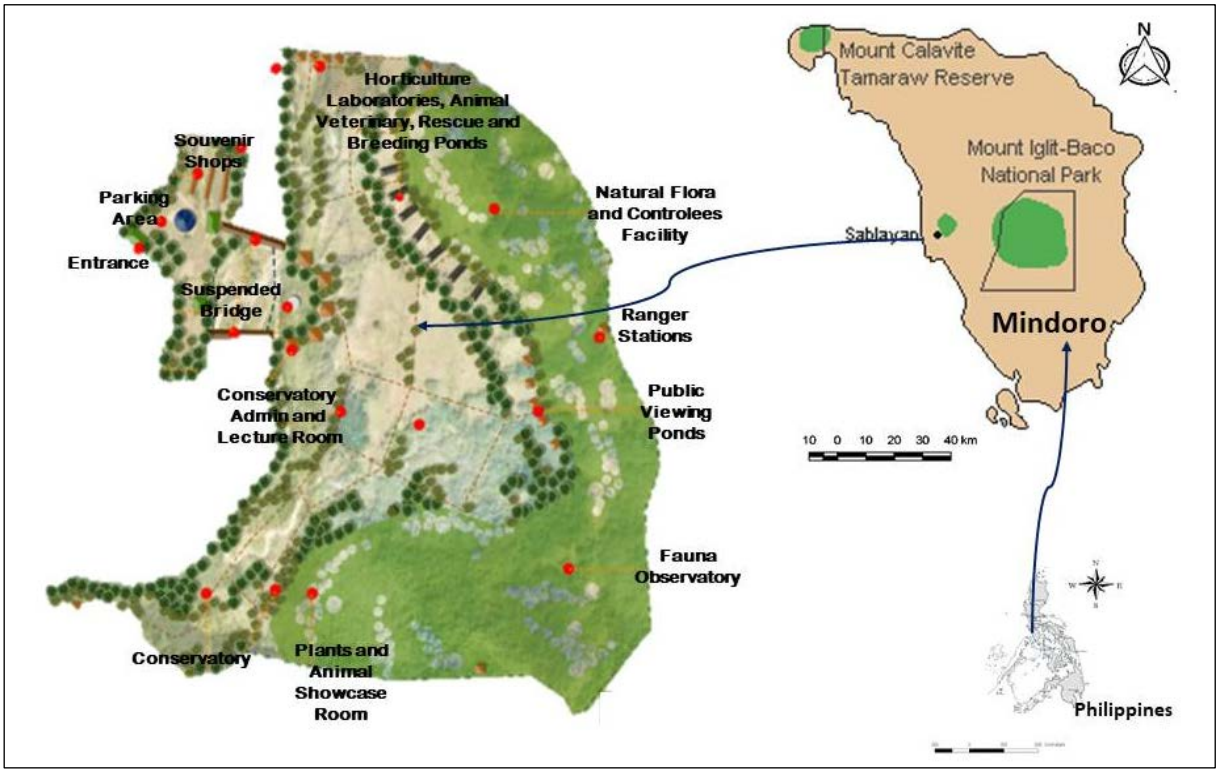

Figure 1. The geographic location of the study area in the proposed site zones of the Mindoro biodiversity conservation area

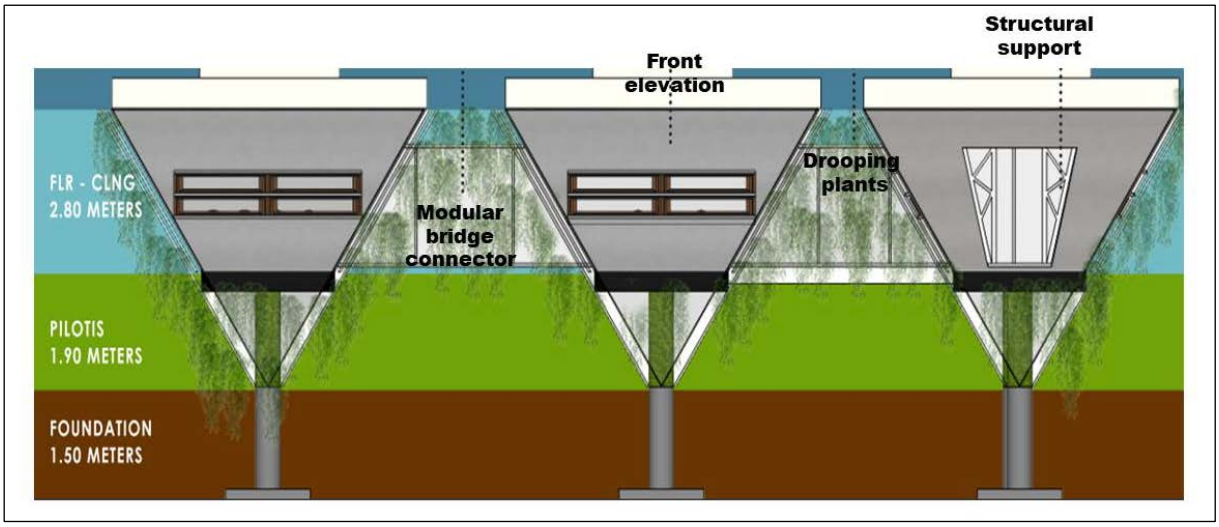

Figure 2. Elevation and connected views of the proposed project

2.3. Design and Structural Concept

SIMBOLIKHA aims to adopt a design that would blend in with the environment and make nature closer to people by promoting ecological conservation. Modular architecture is adopted in the study with consideration of the diverse environment and adaptive to the changing landforms and life needs by placing modular spaces for humans, plants, and animals. The concept of biophilia was applied considering the natural characteristics of Mindoro Dwarf Buffalo (Bubalus Mindorensis). Since the goal of the center is to help and promote growth and development and local biodiversity, the buildings are facilitated on stilts to minimize damage and disturbances during construction. The elevated buildings allow natural lighting and ventilation and encourage existing foliage to thrive and grow beneath the floor buildings. Materials to be used in the development and construction of the proposed design are locally available on the site. The capability of bamboo and other good lumber as a structural component of the facilities is optimized during the implementation of the project (Fig. 2).

Fig. 2 shows the elevated foundations of the modules. The inverted pyramid-shaped structures are designed to lessen the interaction of concrete with the natural environment. The pilotis extending to a length of 1.90m are slender columns attached to a 1.50 m x 1.50 m foundation. The pre-cast pilotis will be delivered to the site to lessen the disturbances during construction. The modular bridge connectors are made up of lightweight materials and are semi-open to allow viewing and lighting and ventilation naturally. Drooping plants will be installed to camouflage with the surrounding greeneries and lessen the distraction to animals and as the design strategies to apply biophilia. While the structural supports are made up of lightweight bridge-way modules to hold the structure in the upright position.

3. Results and Discussion

3.1. Site Presentation and Analysis

The proposed Mindoro Biodiversity Conservation Area will seat on the foothill of Mount Iglit-Baco National Park. The park covers almost 75,445 hectares (ha) situated in the center of Mindoro, Philippines bounded by the eight major river systems and characterized by minor slopes, river valleys, and flat terrain. Almost 75% of the park is bounded by the municipalities of Sablayan, Calintaan, Rizal, and San Jose while the remaining 25% covers the municipalities of Oriental Mindoro: Pinamalayan, Gloria, Bansud, Bongabong, and Mansalay [41]. The park is known as the home of the remaining population of Mindoro dwarf buffalo (Bubalus Mindorensis). The Mount Iglit-Baco National Park is considered as the proposed area since there are species that are already at the park and their welfare is the focus of the proposed biodiversity conservation area, and maximizing the potential of the park will be advantageous both for the species, researchers, biologists, and environmentalists.

The site is located at Sitio Tamisan, Barangay Poypoy, Calintaan, Occidental Mindoro, the Philippines at the foothill of the basecamp and 10km away from the municipal hall of Calintaan. The site is bounded by the municipality of Calintaan in the northeast; Mt. Iglit Baco at the east, Barangay Iriron at the west, and Barangay Tanyag in the south. The site has nearby residential areas in the south-to-west part and is surrounded by greeneries of different types of trees in the hilly area of the west to the north part. Further, the site is an interior lot with a 6.0m wide road facing the entrance of the area. There is only one road to get to the site; a 5km road from the national highway must be passed to reach the barangay hall of Poypoy and to get into Sitio Cabiagan and Sitio Akasyahan; two bridges must be passed to reach the first

landmark and signage of Mt. Iglit and finally to enter the Sitio Calamansian passing again another bridge that led directly into the site. The site can be reached by private or public transportation from San Jose and an hour ride via motorcycle or an approximate 2-hour walk to reach the site (Fig. 3).

Results of the analysis showed that the site has good characteristics for wildlife and biodiversity. In general, the soil is categorized as silt, loam containing not less than 70% silt and clay, and not less than 20 percent sand. There are also existing structures on the proposed site: cottages, small offices, and public toilets that were initially used by tourism and backpackers, and hikers. Since the site is mountainous, rainwater falls directly into the area flowing to the near river and rice fields. Due to the nearness of the site to the river, the area is susceptible to flash floods and surface water runoff. The site has moderate landslide susceptibility from the moderate slope observed in the area. The wind analysis showed that the southwest monsoon and northeast monsoon were maximized by the site orientation. The frontage of the site is facing west while the east faces the Anahaw River. The proposed site receives sufficient sun rays appropriate for animals and plants as reflected in the sun path diagram. Moreover, the result of the strength, weakness, opportunity, and threats (SWOT) analysis showed that the area has a good soil type with clean air quality and is surrounded by greeneries. Since the proposed site is located inside Mt. Iglit Baco National park, the mobilization of construction materials might delay the project's implementation. Poor mobile network signal is also experienced during the site investigation which can hinder the communication flows, and the presence of rugged and hilly roads going into the site are some of the weak points of the site. Nevertheless, the proposed project can encourage and attract more tourists and enhance the safety of the natural biodiversity.

3.2. Design Form Evolution

The design form of the proposed project is inspired by the major inhabitant of Mt. Iglit-Baco, the Mindoro dwarf buffalo (Bubalus mindorensis). Biophilia is shown from the orientation of the buildings and facilities integrated into each other based on the degree of their functions to humans; the use of the form concept considering the structure of the Mindoro dwarf buffalo. The body of the Mindoro dwarf buffalo is represented by the container van used as the mainframe of the structure and facilities; the legs are represented by the pilotis used as structural columns, and the body-built is represented by the inverted pyramid-shaped single-pile structures (Fig. 4).

The design form shown in Fig. 4 shows the imitated characteristics of the Mindoro dwarf buffalo in the proposed design, the administration building, and other facilities were rectangular –in-shaped, placed, and covered with foliage. The orientation of each container van followed the slope and elevation of the existing natural environment to lessen disturbances and construction damages. The container van will be covered with plants and other greeneries to camouflage the existing environment. The sturdy body built by the Mindoro dwarf buffalo is represented by the structural strength of the container van to withstand the temperature, wind, and other natural factors.

3.3. Architectural Design Translation

After the site analysis and formulation of the design philosophy; design criteria and design concepts were synthesized and translated into architectural designs. The following design criteria were considered in the proposed design of the Mindoro Biodiversity Conservation Area.

3.3.1. Building's Perspective

Mindoro dwarf buffalo is the main inspiration used in the development of the proposed design of buildings and facilities inspired by the strength of the animal's body; the inverted pyramid-shaped single-columned building provides the uniqueness and simplicity of the design. There are five modules reflected in the design representing the five major offices in the proposed project: Receiving room, Research and Lecture room, the Meeting room, the viewing room, and the Laboratory room. Each room is specially designed to meet the expected purpose and activities (Fig. 5).

It can be viewed in Fig. 5, the details and material specifications of the five modules of the proposed Mindoro Biodiversity Conservation Center. All rooms are intended for the use of researchers and environmentalists for their respective activities. The viewing room is intended for leisure and recreational educational purposes. All modular rooms have designed areas with light steel gauge walls; hopper windows for better flow of air and light; steel plate flooring supported with I-beam floor framing; and a 1.5 m opening leading to the modular bridge. The inverted pyramid-shaped modules are pre-fabricated, delivered, and assembled on the site. Each module seats on single pilotis with dimensions designed to carry and sustain the module loads. The modules are covered by three layers: wire mesh with a structural frame with naturally growing drooping plants that creates an illusion to animals that everything in the site is in its natural form; polyvinyl chloride (PVC) screen in the structural frame for protection from insects and unwanted penetrators; and the inner layer comprising of steel wall to guarantee the safety of the modules.

3.3.2. Assembly and Connection

The proposed modules are connected by a modular bridge designed to facilitate the flow of transactions on each module. The modules are oriented in a U-shaped to maximize the land area (Fig. 6).

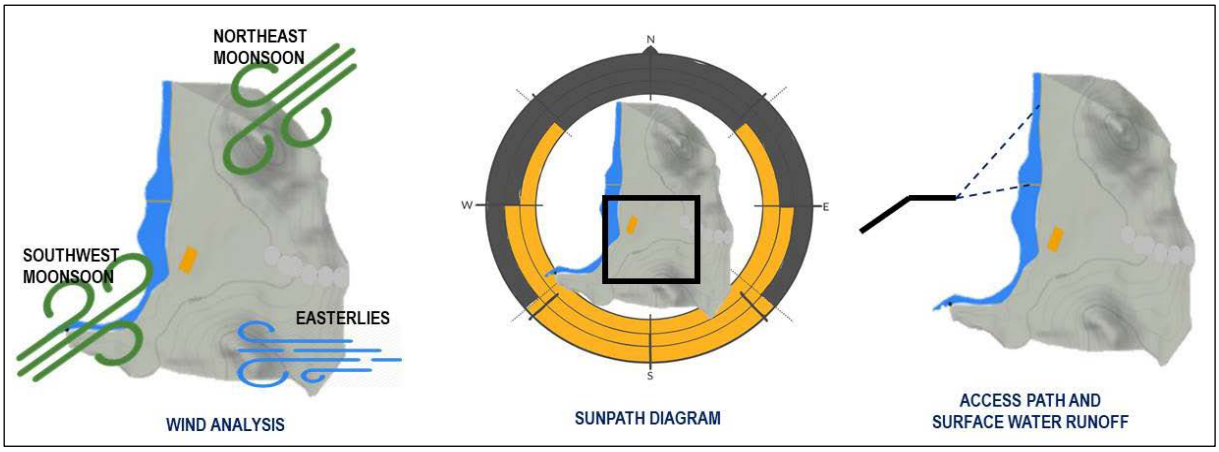

Figure 3. Site analysis of the proposed project

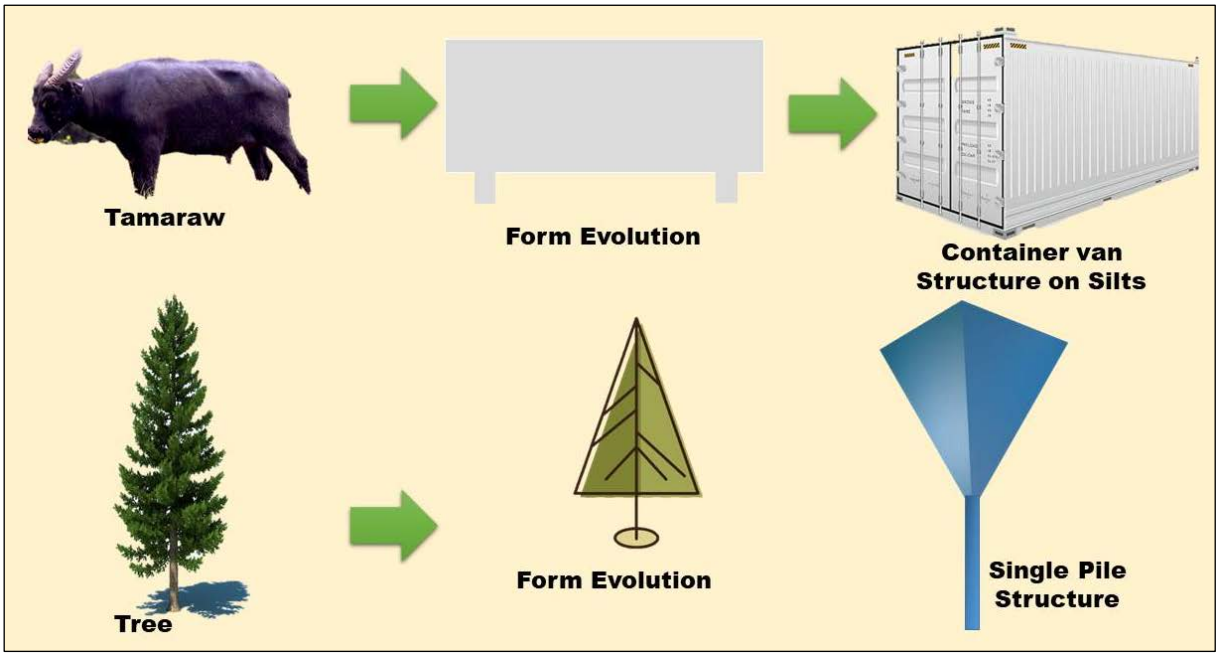

Figure 4. Design form concept adopted in the proposed project

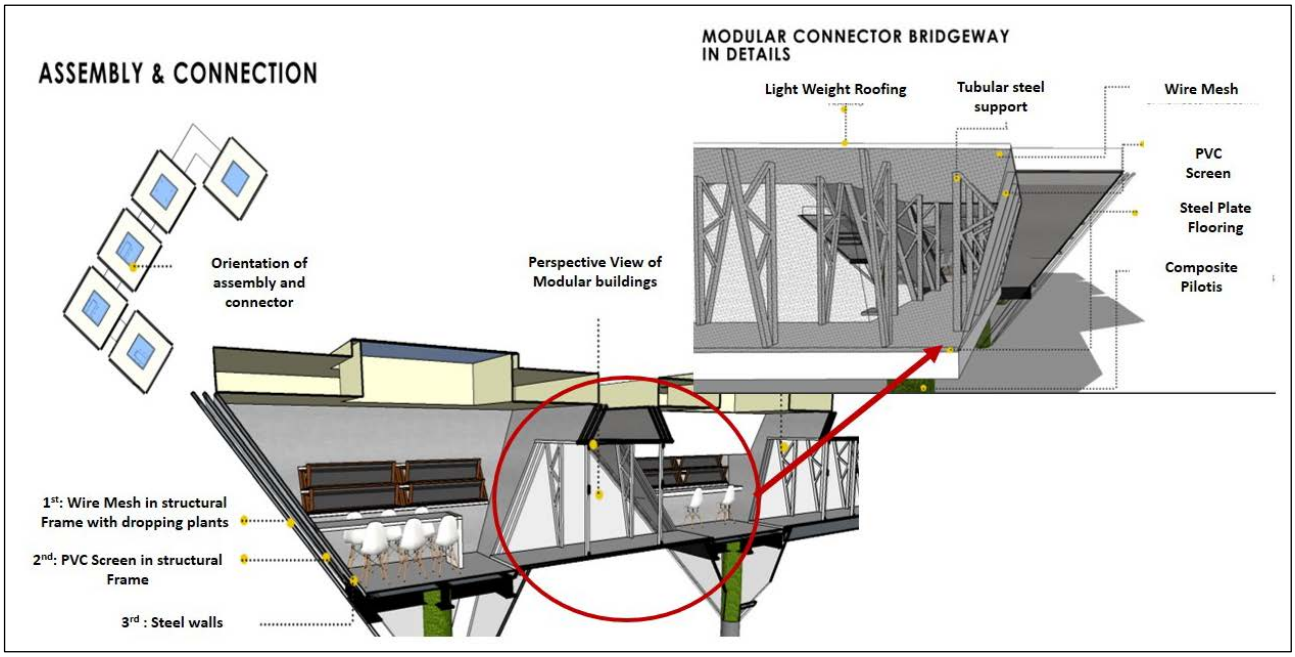

Figure 5. The building perspective and details of each module

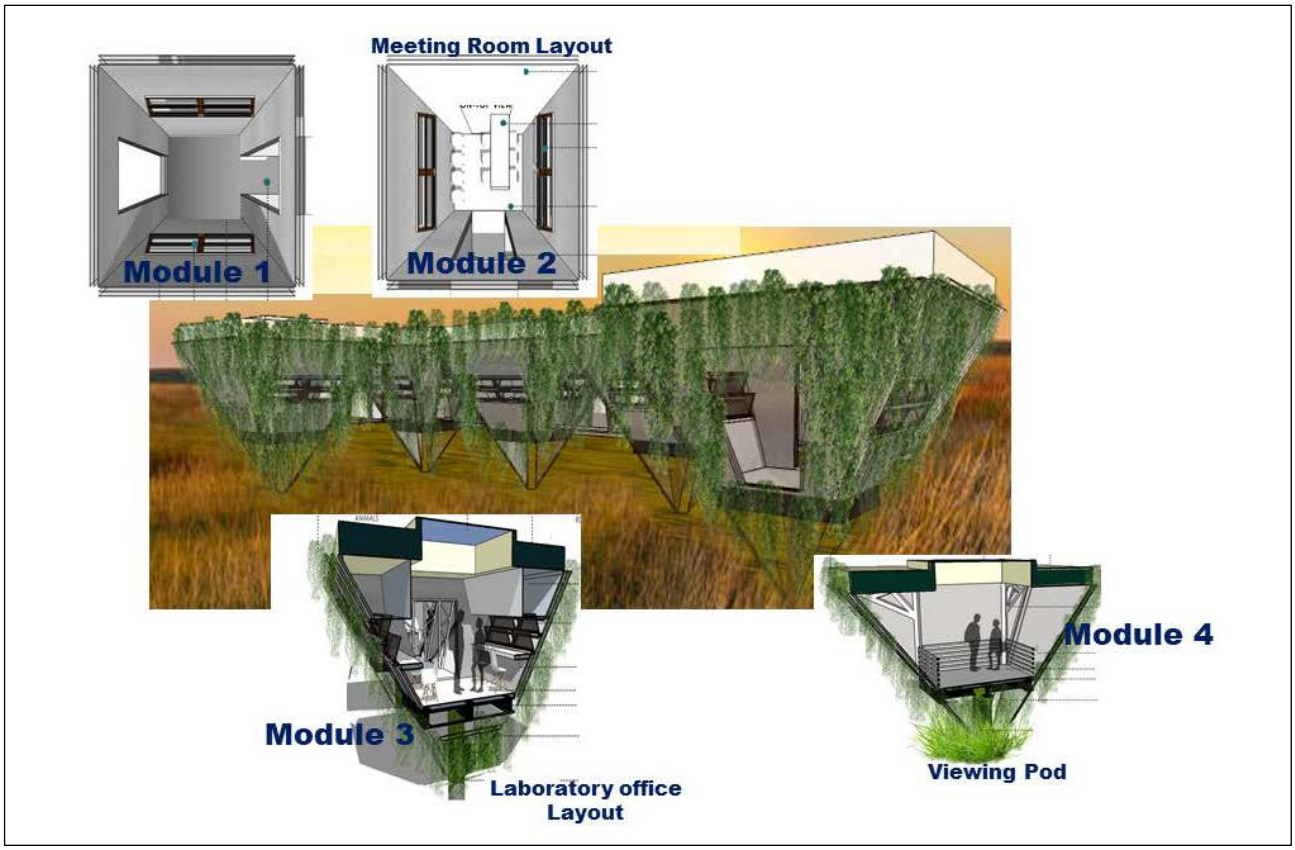

Figure 6. Proposed details of connection and modular bridge

Figure 7. Proposed administration building

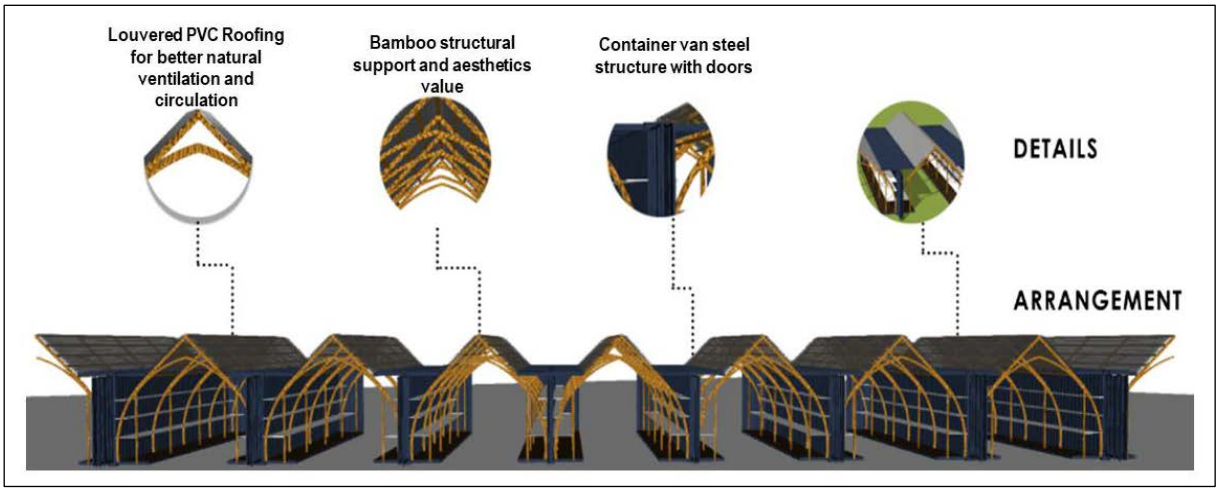

Figure 8. Details of the shops and commercial spaces

Reflected in Figure 6, the modular bridges connecting all the modules are supported by pilotis with I-section steel as reinforcement to the concrete post while the flooring is made up of steel plate supported with I-beam running through the mid and web support. A PVC screen covered with wire mesh is installed to allow the flow of natural light and ventilation. The bridge way is framed with tubular steel that provides strength and prevents the bridge way and the modules from swaying and lateral buckling. While the roofing is made up of lightweight material reinforced with steel tubular frames.

3.3.3. Administration Building

The proposed design of the Mindoro Biodiversity Conservation center provided an area for the Administration Building. The office is intended to cater to all the administrative functions and activities of the Center. The building will house the Director, the Tourism office, the Finance and Accounting unit, and the head of the general services (Fig. 7).

The administration building shown in Fig. 7 seat on a container van is strategically installed considering the natural built-in environment. Approximately, six container vans were welded together to create a better space for the Administration building. The interior of the container van is maximized to provide spaces for the office; lobby and receiving area; and comfort room. A reinforced concrete slab floor is considered in the porch area supported by steel frames to hold the container vans in place. While the entire Administration building is supported by pilotis extending

to the concrete foundation.

3.3.4. Shops and Commercial Spaces

One of the promising spaces in the proposed Mindoro biodiversity Convention Center is the shops and commercial areas, designed to provide additional features for tourists and visitors. The area is designed to market the livelihood of local products, harvest fruits and vegetables and souvenirs, and exhibit booths. The area is placed in the front of the proposed site to attract visitors upon their entrance and exit into the Center (Fig. 8).

4. Conclusions

This paper tries to introduce a design for Mindoro Biodiversity Conservation Center. The design aims to meet the need of researchers and environmentalists for their respective activities by maximizing the natural characteristics of the built-in environment. The site analysis showed that the site has good characteristics for wildlife and biodiversity as the area is still rich in flora and fauna, and natural ecology. Results of the SWOT Analysis described that the area has good soil type and is surrounded by greeneries. Since the proposed site is located inside the Mt. Iglit-Baco protected zone, mobilization of construction materials and poor network signal may compromise the implementation of the project. The design adopted the modular architecture as the design concept by dividing the proposed site zones into modules and built individually but has interrelated functions.

The biophilic design is considered in the proposed design and inspired by the natural characteristics of the Mindoro dwarf buffalo. There are five inverted pyramid-shaped modules presented in the design each with a distinct function and connected by a modular bridge. Each module is designed to serve its functions as receiving area, research and lecture room, meeting room, viewing room, and laboratory room. The inverted pyramid-shaped modules were designed to maximize the site zone so that lower portions of the modules still serve as a natural area for the ecosystem, and minimize construction damages and disturbances. The five modules were structurally supported by single columned pilotis extending to the ground and foundation. The modules are protected by three layers: wire mesh with drooping plants to camouflage the environment, a PVC screen for protection; and a steel wall in the inner layer. The modular bridge connects all the modules and is assembled strategically to facilitate the movement and activities in the modules. An Administration building is also presented in the design and built-in a 44ft. container van. Six container vans were structurally analyzed to determine the conformance to the design loads and cater to the areas for administrative functions. The container vans represent the sturdy build of the Mindoro dwarf buffalo that must stand still in all types of natural and man-made disasters. The administration building is also supported by pilotis designed to hold the modules and administration building in place. Lastly, the shop and commercial areas were designed to boost the economy of the proposed site as they offer areas to market local products, exhibits, and souvenirs. The shop and commercial areas maximized the use of bamboo in the design as structural support and web members; the body is the container van cut and placed on the sidings and walls of the booths. The proposed design successfully integrated modular architecture and biophilic design by exploring and optimizing the naturally built-in environment. The design also offers areas for commercial activities to boost the economy and promote tourism.

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