Chapter 47
Integrated Design Approach to Build a Safe and Sustainable Dual Intended Use Center in Praslin Island, Seychelles

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Abstract A flexible multi-purpose center for a dual intended use—hospitality and observation and research related to climate change—has been designed in the fragile environment of Praslin Island, Seychelles. The technical solutions adopted for a low environmental impact LCA based in the designed center during the life cycle will be illustrated: starting from the local supply raw materials, the self-disassembling construction system, the described process is compatible with the site use that the owners have foreseen. Specific logistic systems have been chosen both to the transportation of the material on the site, and to the integrated structural and architectural solutions. In addition, a reconstruction of the natural characteristics of the building site has been developed both by google-earth observation and with a survey directly on the site through processing acquired images. The multi-disciplinary perspective through which the project has been conceived shows beneficial effects in terms of reduced impact on the original and resilient natural environment. Future developments of the work will be devoted to the optimization of this multi-disciplinary approach.

Keywords Sustainable new construction · Life cycle assessment · Resilient built environment · Seychelles

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47.1 Introduction

The Seychelles is extremely vulnerable to growing threats due to the greenhouse effect.

Additionally, considered an ecological paradise for its natural beauty, the Seychelles Island attracts many tourists and hence needs to meet their increasing request for tourist accommodation service.

Tourism is an important lever for poverty alleviation of naturalistic and desirable tourist destinations (e.g., offering job opportunities for local residents). Several authors recognize the effectiveness of tourism as an adequate method to boost the economic status of local communities, such as small islands (Tsung and Fen-Hauh 2019).

The Seychelles has played a leading role in implementing all 17 Sustainable Development Goals defined by the 2030 Agenda (Seychelles National Climate Change Strategy—NCCS) (Escamilla et al. 2018).

More specifically, within the Seychelles' commitment to tackle climate change and minimize its impacts, the promotion of sustainable practices in the tourism industry plays a key role.

Among the many African certification programs, Seychelles Sustainable Tourism Label (SSTL) is one of the three developed by the Government (Sebestyén et al. 2021).

SSTL is a voluntary sustainable certification program for tourism accommodation in Seychelles, locally developed and introduced by the Ministry of Tourism in 2012. It is a points-based certification scheme, and is third-party assessed.

In order to be certified by the SSTL, a hotel needs to meet three conditions:

- satisfy all the 22 mandatory criteria;
- reach a minimum score in each category, according to business size (5 points for enterprises with rooms from 1 to 24; 6 from 25 to 50 rooms and 7 for more than 51 rooms);
- obtain an additional six points in any area.

There are 8 evaluation areas defined by the scheme: Management, Waste, Water, Energy, Staff, Conservation, Community and Guests.

Despite the scheme being recognized as good and comprehensive for tourism accommodation, it proves to be limited for different uses such as multi-purpose centers.

Sustainable construction is one of the keywords in the debate on environmental development of the most sought-after holiday destinations, which are mainly characterized by increasingly fragile contexts such as natural hazards and changing climate. In the last few years, the building life cycle impacts and energy efficiency have been examined sufficiently. A small number of them consider the environmental impacts from the view of structure design, which indeed could play an important role in reducing emissions.

Therefore, with the aim to design a sustainable and safe flexible center situated in a small location on Praslin Island, this study has adopted a multi-disciplinary approach to identify low environmental impact technical solutions taking into consideration several life cycle (LC) stages. Specifically, the LC stages analyses are: supply of raw materials, self-disassembling construction systems and a minimum-impact building site.

The method used to quantify the environmental impacts is the Life Cycle Assessment (ISO 14040-14044, EN 15804).

The final purpose is to understand how the Life Cycle Thinking approach, and in particular a Life Cycle Assessment (LCA) application can support a multi-disciplinary methodological design approach (structural and architectural), for the calculation of ecological footprints related to a flexible small center project located on Praslin Island.

47.2 Methodology Adopted at the Design Phase

The design proposal stands on a sloped site of 31.500 m^2 left in a state of total neglect.

After a first exploratory phase, focused on the analysis of the climatic context, the need to preserve the fragile island's environment and mitigation of the impact on natural resources to the maximum possible extent, was outlined in the design requirements shown in Table 47.1.

The general morphology of the plan was evaluated taking into particular consideration the natural ground feature and hence the position of the buildings which follow the shape of the ground (Figs. 47.1 and 47.2).

The key design concept was to promote a "modular" style of architecture based on a rapid assembly of structural components and consequently easier replicability (Fig. 47.3).

Table 47.1 Brief of factors and solutions satisfying design requirements

Needs	Design solutions
To reduce the amount of solar radiation	Orienting the building on the North–South axis
To promote natural ventilation	Correct choice of the position of the openings and elevating from the ground
To favor shading	Using of a single pitch sloping roof
To avoid flood problems	Elevating from the ground
To use of alternative resources	Providing tanks for water recovery
To reduce environmental impact	Using of eco-sustainable materials
To ease of assembly	Adopting of dry systems
To reuse at the end of life	Using of dry assembled materials

Fig. 47.1 Site plan (1:1000 scale)

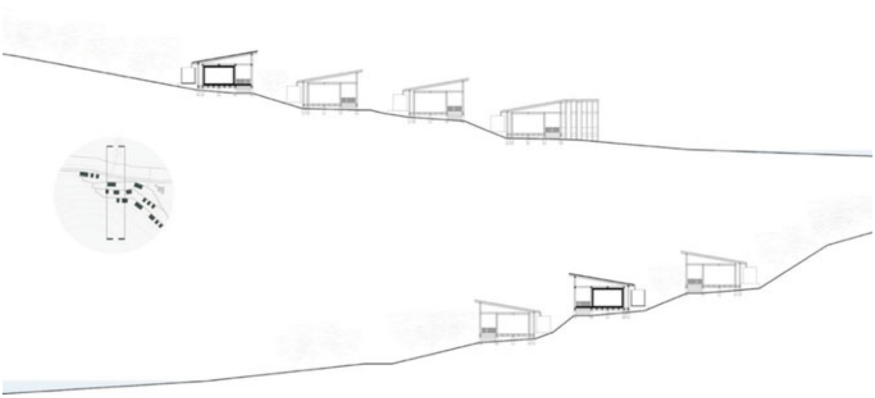

Fig. 47.2 Elevation section profile (1:500 scale)

47.2.1 Architectural and Structural Design Concepts

The environment, the climate, the morphology of the land and the scarce availability of materials on site were all considered in the choice of a modular structure that could be suitable for different uses and with a reduced environmental impact.

The pile dwelling shelter has been identified as the right building typology with the aim to improve the uncultivated and still scarcely used land. A raised structure that

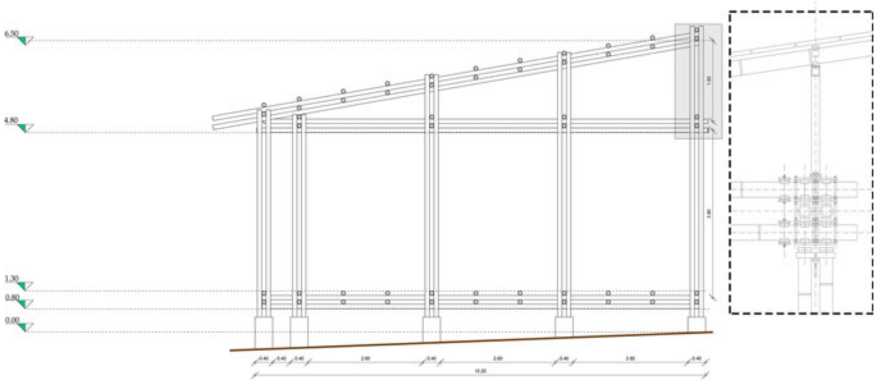

Fig. 47.3 Design schemes to illustrate the structural system realized by modular bamboo elements with a special metal joint

develops the surrounding environment without damaging it determines that earth movements or excavations on the ground are not necessary, while light materials such as wood and steel allow easy installation and quick disassembly, granting the involvement of local labor.

How can we build architecture that is aware of climate, light and air, through technical choices that are also structurally linked to the project? Lightness and slim elements shall be the main architectural features: the roofs rest on light uprights, wrapping them in minimal structures and covering transparent spaces. Permeability becomes the language of these spaces, while continuity is what they bring to the internal–external relationship: the architectures are drawn in the landscape and strengthened by their diversity. In this way a cordial and friendly relationship with nature is established, one capable of combining the use of poor and inexpensive materials (wood and steel industrialized elements, hemp fiber). Raising the house above the ground without the need for deep excavation protects the dry ground and the surrounding trees.

The structure of the module is made up of a symmetrical rectangular mesh with a constant trend and designed on a grid (6.40 × 9.70 m). All the components should be as much modular as possible with serial production in mind. The load-bearing elements (vertical and horizontal) are made up of bamboo rods and connected with a special joint—a metal cage composed of multilayer metal plates and bolts. The distances between the plates can be adjusted and adapted to the different dimensions of the raw bamboo, thus avoiding drilling holes. An elastic cushion is provided to protect the bamboo rod from the pressure exerted by the metal plate—this element increases friction, reducing the slippage and rotation of the wooden element. The vertical elements are raised and anchored to the foundation with metal brackets.

The module is designed to be used as a bedroom for guests. It has an external area, a covered and shaded patio that functions as an entrance and an internal area, with a space dedicated to the night and one to services. This module can be assembled creating different scenarios—for instance with a double or triple version—used as a tourist resort or as spaces for research and analysis labs.

This conscious design is based on improving energy efficiency so that the project provides several interventions on the building's envelope and systems, choosing a lightweight construction site and therefore technological solutions for customized industrial production (Table 47.1).

Despite the fragmentation and distribution on several levels of the settlement's lot, the modular units are spaced and rotated on the contour lines of the steep slope, creating a simple design in harmony with nature. It is a matter of designing economical buildings, which will save energy and which can easily adapt to this particular morphological connotation of the land and merge with the surroundings. It is also important to remember that the area is characterized by a tropical climate, with a high percentage of humidity and high temperatures, especially in the winter months. The construction is adapted to the needs of this particular climate—especially the needs for heat and ventilation—without resorting to artificial systems such air conditioners but instead paying close attention to the movement of the sun, the moon and seasons as well as designing buildings that can be in harmony with the movement of light and wind.

The orientation of the building and the exposure of the individual facades have a significant influence on the energy performances. By positioning the building along the North–South axis, the openings on these facades prevent direct sunlight from penetrating. In this way it is possible to keep the rooms cooler, to reduce exposure to the sun at noon and to take advantage of the winds and breezes for greater natural ventilation. To optimize ventilation and maximize breezes, in addition to lifting the building off the ground, openings such as windows and doors have been aligned to allow air flow and to minimize internal dividers for an unobstructed ventilation. The roof, with a single pitch, protrudes to shade the side walls and has a ventilated double skin.

The external skin shades the internal layer and absorbs solar heat based on its reflectivity while the cavity guarantees ventilation of the space between the roof and ceiling and acts as an insulator in the absence of winds.

In the context of the new policies for sustainable growth of Seychelles the opportunity to design an energy efficient experimental house in Praslin Island is very current and challenging. The proposal explores the potential of minimizing carbon emissions while maximizing environmental protection and natural ecological development through the use of the natural elements available in the area, such as sun, wind and natural materials (Fig. 47.4).

The end goal is to achieve a high-standard innovative house for the Seychelles context.

The topics that we have considered for the design of the module are the following:

Bamboo—a very special natural element which we use as structural for the house;
Modularity and Industrialization—modular elements to create an innovative industrialized bamboo construction system.

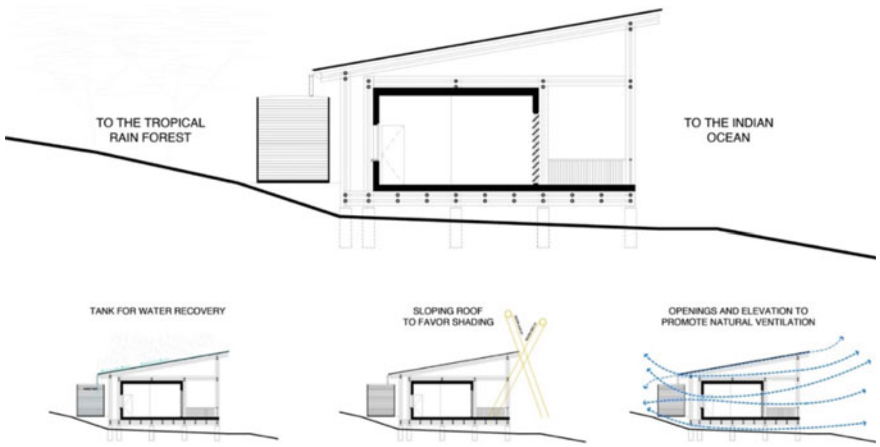

Fig. 47.4 Design schemes to illustrate the relevance of the project under sustainability point of view

Bamboo is the plant that absorbs the most carbon dioxide during its life cycle. It is strong enough after cultivation for 3 years and grows much faster than any other tree species. For the structure of the house we explored new ways of building using bamboo as a construction material. Sustainability is ensured not only by the use of natural materials such as bamboo but also by designing appropriate construction solutions—for instance dry-mounted connections that do not weaken bamboo through perforation nor fill it in with concrete and by allowing the replacement of bamboo poles if needed.

Also, an industrialized construction system can be achieved by designing light and easy to assemble aluminum connections, using same length bamboo poles and combining bamboo (known as vegetable steel) and steel together.

47.3 Choosing Materials

The aim of selecting materials including the following considerations:

- materials from renewable or replaceable sources,
- recycled materials,
- materials that are in plentiful supply,
- materials with a lower environmental impact across their whole life cycle.

The choice was thereby directed toward plant-based or local materials (Escamilla et al. 2018; Zea Escamilla et al. 2016), which consist of:

- bamboo for structural components,
- light-gauge steel produced in Africa for metal connections,

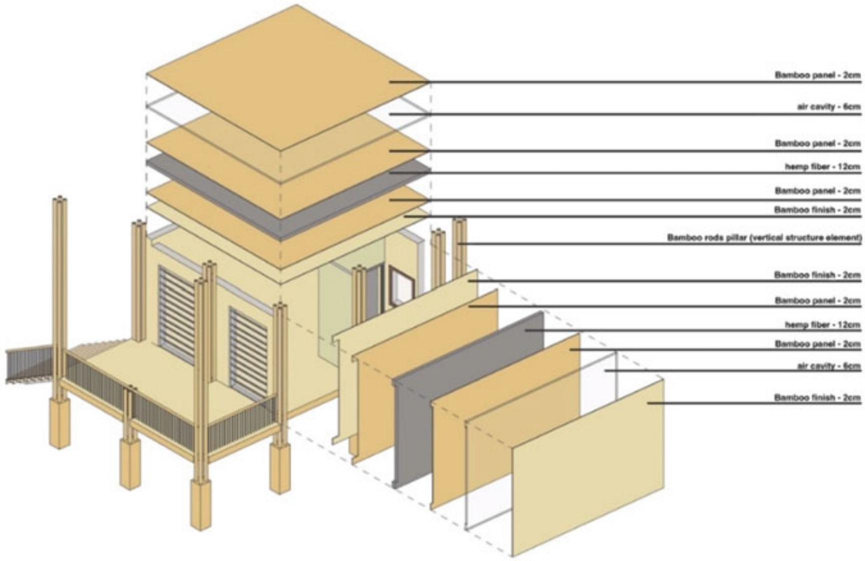

Fig. 47.5 Isometric view about technological solutions

- laminated bamboo for vertical and horizontal elements;
- hemp fiber for insulation (Fig. 47.5).

47.3.1 Life Cycle Assessment Considerations of the Case Study

To examine the environmental benefits of the constructive solutions adopted in the project, some relevant impact indicators were calculated by employing the Life Cycle Assessment method (Vogtländer et al. 2014). In particular, the aim of this additional analysis was to evaluate the environmental impact connected with the materials adopted, focusing attention on raw material supply and manufacturing process (Escamilla et al. 2018).

In this study, the use of specific impact values like Environmental Product Declaration (EPD) indicators developed by producers was preferred. The materials selected in the project were assumed to be sourced and processed locally. The data acquisition to model the Life Cycle Inventory (LCI) are shown in Table 47.2.

As there is little to no specific LCI data available for Africa, and specifically for the Seychelles, the data related mostly to EPDs of products with the same performances. Where EPD's product data was not matched with the product's performance literature data was used to determine the LCA impacts.

Table 47.2 Bill of materials for building with the mass and volume per material category for each building component

	Material	*Component*	*No. elements*	*Density* (kg/m^3)	*Volume* (m^3)	*Tot.* (m^3)
Structure	Bamboo	Beams	13	1080	0.611	7.94
		Columns	12	600	0.078	0.94
		Piles	9	600	0.026	0.23
			Thickness (m)	*Density* (kg/m^3)	*Quantity* (m^2)	*Total* (kg)
Vertical elements	Laminated bamboo	Internal wall finishing	0.02	700	61	823.5
		External wall finishing	0.02	700	61	823.5
	Hemp	Insulation	0.12	35	61	256.2
Horizontal elements	Laminated bamboo	Upper part	0.02	700	43	
		Lower part	0.02	700	43	5160
	Hemp	Insulation	0.12	35	43	180.6
Roof	Laminated bamboo	Lower part				
	Pine		0.2	450	43	5160
	Pine Hemp	Lower part	0.2	450	43	5160
		Insulation	0.12	35	43	180.6

47.3.2 LCA Data Assumption and Impacts

The GWP indicator of the designed technical solutions was assessed. Table 47.3 summarizes the LCA indicators considering the Global warming potential indicator for production and end of life phases, expressed in value impact (kg) and percentage contribution (%) to environmental impact analysis, respectively. GWP is expressed in kilograms carbon dioxide equivalents (kg CO_2 eq.) shows the problem of other gases and shows the problem of other gases (e.g., carbon monoxide, carbon dioxide, methane, HFC) standardized with reference to their lifespan in the atmosphere as compared to a unit of CO to a unit of carbon dioxide. The LCA indicators adopted in the assessment are based on EPDs' producers. According to these references, in relation to end of life phase, it was assumed the as scenario incineration for energy production. More specifically, 95% as incineration and 5% as dump (Table 47.2).

Figure 47.6 shows results of the whole building. The bars in this figure present the results for the studied technical solutions, and they represent the CO_2 emissions for each of them in the two life cycle scenarios: production and end of life (Table 47.3).

The results for the cradle-to-gate and end of life are presented in Fig. 47.6.

Table 47.3 Cradle-to-gate plus end of life impact assessment for the building component designs

Building component	Global warming potential (GWP)			
	Production		End of life	
	kg CO_2 eq	%	kg CO_2 eq	%
Structure	7949.9	65.2	−5726.3	70.4
Vertical elements	1871.7	15.4	−915.1	11.2
Horizontal elements	1181.3	9.70	−744.8	9.2
Roof	1181.3	9.70	−743.0	9.1
Total	12,184.3	100	−8131.1	100

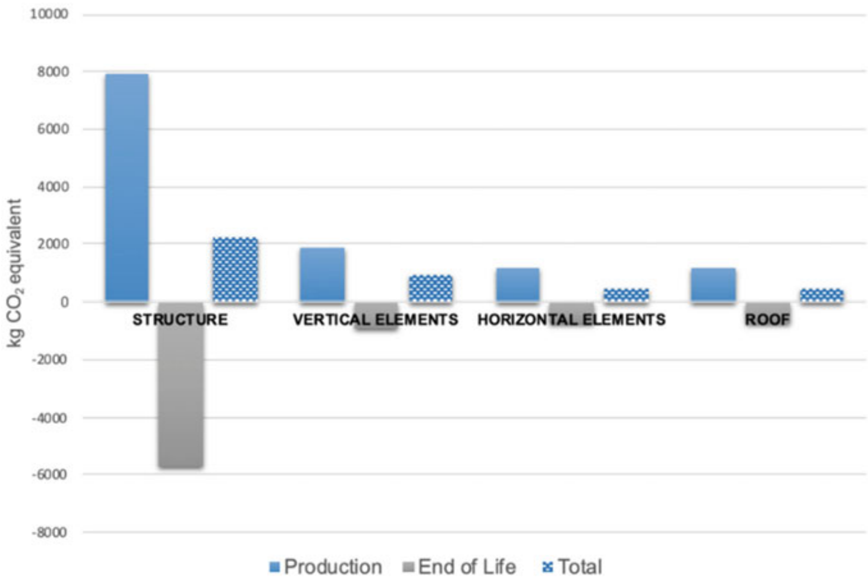

Fig. 47.6 Environmental impact in kg CO_2 equivalent

As can be observed in Table 47.3 and Fig. 47.6, for the bamboo-based structure (assumed for structural components like columns, beams and piles), the contribution from the life cycle phases ranges from 65% (production) to 70% (end of life) of their total environmental impact, whilst the laminated bamboo-based construction materials (adopted for walls) contribution ranges from 9.7% (production) to 15% (end of life) of the total environmental impact. These results support the idea that in order to obtain low carbon, it is necessary to optimize the amount of reuse materials post demolition, whereas the material production would require the optimization of manufacturing process.

Fig. 47.7 Sustainable dual intended use center development in Praslin Island, Seychelles

47.4 Conclusions

LCA-based design may have a great impact in approaching new solutions respectful European green deal. Climate change and environmental degradation are an existential threat to Europe and the world. To overcome these challenges, the European Green Deal will transform the EU into a modern, resource-efficient and competitive economy, ensuring: no net emissions of greenhouse gases by 2050; economic growth decoupled from resource use; no person and no place left behind.

The technical solutions adopted for a low environmental impact LCA based in the proposed designed center during the life cycle is a possible example of a new approach of conceptual design in fragile environment (Fig. 47.7).

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