Experiences in the development of sustainable design methodology for a residential complex La Piedra in Maracaibo, Venezuela

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ABSTRACT: Several bioclimatic design strategies, among them solar control and wind utilization, have been integrated within architecture projects in the city of Maracaibo, Venezuela. These are an integral set of considerations addressed within a sustainable design process. Nonetheless, no experience has been documented in regards to the inclusion of other sustainable considerations in an integral manner, e.g. water and energy efficiency among others. This paper presents a case study of the inclusion of environmental sustainable principles into the design process of a residential complex in the city of Maracaibo. This paper describes the methodology followed by the design team (architects, engineers and consultants) in order to improve a design process which considers various aspects of sustainability while taking into account the limitations and opportunities of the local context. The process evolves through several discussions of: a) sustainability and the local context, b) assessment of current international methods, c) potential strategies, d) integration into design, and e) design evaluation. The results serve both: as a first step into further incorporation of sustainable concepts into Maracaibo’s architectural design practices, and highlight the environmental results obtained and expected from including these concepts.

Keywords: Sustainable integrative design, case study, Maracaibo

1. INTRODUCTION

1.1 Geographic characteristics

Maracaibo, the capital of the state of Zulia, due to its geographical location, is characterized as a hot and humid climate with maximum annual average temperatures in the range of 32°C to 34°C and respective minimum humidity levels around 50% to 60%. The maximum average relative humidity is over 90%. In the last decades the city has experienced a fast urban growth, from 957,888 to 1,219,927 inhabitants from 1990 to 2001 [1], causing profound changes in its environmental quality.

In order to implement appropriate architecture into the city, two bioclimatic strategies have been applied and studied: natural ventilation, and solar control [2, 3, and 4]. Nonetheless, these are not applied by all architects as there is a tendency to rely on air conditioning to overcome the discomfort levels.

1.2 Global tendency towards integrative design

It has been noted that for projects to correctly tackle sustainable design concepts the project team should follow a different methodology than conventional practice. Kibert [5], describes the phases to carry out a sustainable project, or high-performance building, into: a) selection of the project team, b) conduct design workshop to discuss the sustainability aims of the project, c) design process, d) construction implementing all sustainable considerations from design process and e) commissioning and delivery of product. In this manner the workshop, or the charrette, with the design team members and client is the key to an integrative design.

During the workshop, discussion and brainstorming should be generated in issues such as site selection, environmental performance in the area of water, energy and material, indoor air quality and health. This step is vital in order to assess the building performance at later stages [6]

1.3 Motivation on the case study

Ever since the Ordinance on Thermal Quality for Buildings in the Municipality of Maracaibo [7] was created (2006), in an effort to improve thermal quality and reduce energy consumption, architecture firms have started to pay more attention to the thermal efficiency of the building’s envelope; thus a first step into tackling energy as an important aspect of a sustainable design. A local architectural consultant firm RVM & Asociados, with more than 30 years of experience, is part of the few firms where all projects aim to excel the local Ordinance by at least 30% of the minimum requirement.

Over the past year, due to their involvement in applying the Ordinance, the firm has discussed what it means to design an energy efficient building (in terms of envelope), but also what other considerations should be taken into account, e.g. water use. Furthermore, the questions have developed into what constitutes a sustainable
architecture design, what should be considered and what actions must be taken to take that path.

RVM’s project La Piedra was selected the case study in the development of a sustainable design methodology. This paper describes the methodology followed by the team: their design process, and encountered experiences and challenges; all with the commitment to create a better design and construction process and pave the way for further sustainable projects in the city.

2. BACKGROUND

2.1 Design process

The business as usual practice in most local architecture firms follow an iterative design process where disciplines keep only to their expertise with no, to little, inter-communication. The general process can be resumed as:

1. Architect develops scheme design
2. Client approves preliminary design
3. Architect sends drawing to civil and structural engineer to calculate structure
4. Architect sends base drawing to consultant, e.g. mechanical, electrical and sanitation engineers
5. Architect has individual meetings with consultant in relation to their specific interventions
6. Architect compiles and integrates all information for final drawings and documentation for council approval

The aforesaid although providing the necessary solutions to the client's requests, rarely includes considerations related to a sustainable design or seeks input from various expertise in order to synergies interventions. Even if such considerations are taken into account it lacks the effective communication for the entire design team to take them into account, e.g. energy calculations carried out by the mechanical engineer might not include shading strategies done by the architectural side. Although changes are occurring, in the topic of thermal comfort, an integral change in the design process is needed.

2.2 Sustainable design principles

The most accepted definition of Sustainability: “meeting the needs of the present without compromising the ability of future generations to meet their own needs” does not directly address the various actors and disciplines (e.g. architecture), their role and how to aim for such concept. An alternative definition for architecture design is one which “creates communities and buildings that advance enduring public and environmental well-being.” [8]

In this latter it is important to stress the need to focus on three basic principles: Economy of Resources, Life Cycle Design and Humane Design. Jong-Jin [9] proposes and develops these principles in more detail, taking them to strategies and methods.

<table>
<thead>
<tr>
<th>Table 1: Sustainable Design Matrix (from Jong-Jin)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Economy of Resources</td>
</tr>
<tr>
<td>Energy Conservation</td>
</tr>
<tr>
<td>Water Conservation</td>
</tr>
<tr>
<td>Material Conservation</td>
</tr>
</tbody>
</table>

The project La Piedra has involved throughout its design process the discussion and considerations implied within these principles, looking for ways to create synergies in a manner which have not been documented at the local level in commercial residential projects.

3. METHODOLOGY

3.1 Sustainability and the local context

In the context of the city of Maracaibo sustainable design is still consider an abstract concept. Most academic courses still discuss a sustainable design from a bioclimatic response to architecture, addressed under course titles as Environmental Conditioning, Ecology and Urban Environment, Habitat and Sustainable Urban Development [10, 11], all of them offered in the early years of study.

When analyzing non-academic professional practices, the theme of sustainability is not being addressed. Only recently, due to the implementation of the Local Ordinance on Thermal Quality [12] for the city of Maracaibo has the construction sector started to take into account concepts of a sustainable design, i.e. energy efficiency of the building.

In this manner one of the objectives of La Piedra is the development of a methodology adapted to the local context which starts to consider and integrate the principles of a sustainable design. Thus, the ideal place to incorporate these principles is, and especially in architecture design, the design process.

As part of the methodology followed in the project, five main phases were defined:

- Project aims and mission
- Assessment of international practices
- Strategies and considerations
- Design Integration, and
- Design evaluation

3.2 Project aims and mission

In order to develop an integrated design system, RVM sought the support professionals whom showed an alternative vision and experience to the design process.

The first task of the architecture team was the buy-in from the client into developing a design which embraced and promoted the concept of sustainability. A second step was the integration from the engineers and consultant to the project. In this regard a special meeting was scheduled with the presence of a client representative, architects, mechanical engineers, civil
and structural engineers, electrical and plumbing engineer, landscape, architectural lighting and a sustainability design consultant. The meeting evaluated the considerations needed to define and create a project under sustainability principles and the role of the design team to produce an integrated design.

The outcome of the meeting produced a statement which was used as the evaluation criteria throughout the process to see if the project was meeting it mission. The statement drafted was:

*To produce a methodology that sets the standard in the sustainable development of the city and brings as a consequence a tangible benefit to the final user.*

### 3.3 Assessment of current international methods

A review of international methodologies was performed on products such as LEED (Leadership in Energy and Environmental Design) from the United States, Green Star from Australia, BREEAM (BRE Environmental Assessment Method) from the UK and SBAT (Sustainable Buildings Assessment Tool) from South Africa. The ones studied for La Piedra were SBAT, with some aspects of LEED, due to their adaptability and broad aspect considerations of economical, environmental and social issues.

The SBAT (Sustainability Building Assessment Tool) was discussed and some aspects were adapted to the local context of Maracaibo, providing a framework on which to integrate and assess the various interventions. During this process the expected outcome was a set of considerations which could be applied to any building project (commercial, residential, other). Table 2 shows the resumed version of the considerations. This considerations matrix helped the architectural design team to give shape to a building design in which people can live harmonically and in an environmentally friendly environment.

**Table 2:** List of considerations and strategies criteria benchmarked against La Piedra’s design process (adapted from SBAT).

<table>
<thead>
<tr>
<th>Social WELLBEING</th>
<th>Environmental</th>
<th>Economic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Occupant Wellbeing</td>
<td>Water Use</td>
<td>Local Economy</td>
</tr>
<tr>
<td>Natural Daylighting</td>
<td>Water</td>
<td>Local Materials</td>
</tr>
<tr>
<td>Ventilation</td>
<td>Runoff</td>
<td>Local components</td>
</tr>
<tr>
<td>Density</td>
<td>Water treatment</td>
<td>Contracting</td>
</tr>
<tr>
<td>Views to outside</td>
<td>Landscaping</td>
<td>Efficiency</td>
</tr>
<tr>
<td>Inclusive Environment</td>
<td>Energy</td>
<td>Capacity</td>
</tr>
<tr>
<td>Signaling Space</td>
<td>Biomimicry strategies</td>
<td>Occupancy</td>
</tr>
<tr>
<td>Recreation</td>
<td>Equipment</td>
<td>Communication</td>
</tr>
<tr>
<td>Representative</td>
<td>Systems</td>
<td>Daylight Autonomy</td>
</tr>
<tr>
<td>Accessibility</td>
<td>Renewable Energy Waste</td>
<td>Materials</td>
</tr>
<tr>
<td>Public Transport</td>
<td>Recycling</td>
<td>Energy Autonomy</td>
</tr>
<tr>
<td>Public services</td>
<td>Reuse</td>
<td>Net Present Value</td>
</tr>
<tr>
<td>Parking</td>
<td>construction waste</td>
<td>Efficiency</td>
</tr>
<tr>
<td>Cycling/walking</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Participation &amp; Control</td>
<td>Site</td>
<td>O&amp;M Costs</td>
</tr>
<tr>
<td>Environmental control</td>
<td>Vegetation</td>
<td>Users</td>
</tr>
<tr>
<td>Social spaces</td>
<td>Site pollution</td>
<td>Consumption</td>
</tr>
<tr>
<td>User groups</td>
<td>Heat Island effect</td>
<td>Security</td>
</tr>
<tr>
<td></td>
<td>Light pollution</td>
<td>Net Present Value</td>
</tr>
</tbody>
</table>

### 3.4 Potential strategies and considerations

Each consideration and strategy from table 1 seeks to have an impact which contributes to the mission of the project to set a standard in the sustainable development of the city and brings as a consequence a tangible benefit to the end-user. The considerations matrix was then evaluated based on investment costs, site limitation, surrounding communities, necessary construction equipment, and increment on square meter selling cost.

During the discussion phase it was noted that, for the context of Maracaibo’s local construction, various activities presented a challenge that demanded greater expertise and investment than available, e.g. use of renewable energy. Another example is the way buildings are deliver to the final user, frequently these do not include the HVAC units and other internal finishes (floors and woodwork) which makes difficult to assure the implementation of some considerations, e.g. VOC emissions.

Nonetheless, as this is a first step, it was proposed that items under the ‘responsibility’ of the end-user were to be included and developed within a user’s manual providing recommendations on how to improve such items, such as:

- Selection of a high efficiency HVAC unit, increase indoor ventilation and refrigerant type with less ozone depletion potential
- Selection of energy efficient lamp and fixtures to provide adequate lux level and reduce energy consumption
- Selection of adequate internal and external finishes

All recommendations are to be presented in a way to educate and create consciousness on the link between the built environment, the personal wellbeing and the natural environment.

Moreover, the team realized that several of these considerations although discussed during the design phase, would be done and evaluated during the construction phase, thus it was critical to understand the implications in both phases and their challenges.

As an example are the loose guidelines in which contractors follow considerations and recommendations related to the construction management processes, e.g. minimize waste materials from construction, use of local materials and components.

This exercise allowed the design team to fully think about each point, and look for ways to implement them of set possible scenarios to tackle them in the future. Among the most important aspects that were discussed in the design phase were energy and water consumption, and user comfort.
3.5 Integration into design and design evaluation

The next critical step was to properly include all the consideration into the design process itself. The inclusion of the sustainability design consultant sought for synergies between the considerations and communicated them to the architects who were the pivoting members of the design team. They carried out specific meetings to prepare the documentation required to communicate these potential synergies to the engineers and receive their feedback. The engineers on their side would come back with their recommendations. This iterative process occurred frequently, until it was thought the consideration had been satisfied or it was not possible to achieve it.

The evaluation process demanded more thought, as there is no local methodology in place from which to benchmark the one followed with La Piedra. At the same time, the team wanted to develop a methodology with a self assessment component that would allow periodic reviews, in order to adapt to unexpected changes during the design phase (i.e. time schedule to introduce drawings to council) and construction phase (i.e. potential challenges and consideration to carry out the project that way it was designed).

In this specific point, it was agreed to use the evaluation tool proposed in SBAT as it would allow for periodic revisions and visually observe in which areas the project was going better and in which areas more attention was needed or no interventions could be done. Figure 1 illustrates the way the SBAT tool presents the evaluation which shows the project performance in a scale from 0 to 1, identifying the most positively affected considerations for an advance design stage. The tool was divided in the same number of categories as in table 2.

![Figure 1: SBAT assessment of La Piedra. Showing the best performing areas with values closer to 1 and areas where few considerations were implemented closer to 0.](image)

Similar assessments should also be performed during the construction phase.

4. CASE STUDY: LA PIEDRA

4.1 Description of La Piedra and project conceptualization

La Piedra is a low-rise residential project, located in Maracaibo, Venezuela. It is based on 2 buildings of 3 stories high each with a central garden that will serve as a recreational and social gathering space. 16 apartments of 87 square meters plus 32 apartments of 76 square meters conform the 5115 square meters of construction (fig 1), with a loft type of internal distribution to maximize the connections to the exterior spaces.

The central garden possessed an architectural landscape design which introduces indigenous plants and integrates the kid’s playground, outdoor barbeque, and meeting area within itself (fig 2). This space will served as the main focus point for the complex, having the entire apartments looking into it by almost all the places inside the loft.

![Figure 1: La Piedra site development and apartment distribution](image)

![Figure 2: 3D visualization of La Piedra](image)

The project was conceptualized to provide an ambience of sharing and mixing to the users, a place to relax and enjoy within the safe environment of a residential complex. This concept was supported by a central garden with social and recreational spaces to promote the gathering, in addition, the sustainable design strategies introduces a unique sense of conservancy to the build environment, something that the users will have in common and hopefully will ignite the interest of potential users in the near future.
irrigation purposes, views to outdoor areas and high percentage of green areas for rest and leisure.

4.3 Project criteria integration

The underlying premise is for La Piedra to follow a design methodology which integrated various social and environmental aspects. In this regard the integration of the consideration into the design was critical. During the consequent team meetings discussions evolved around the best ways to create synergies among the various considerations. Among them:

Material selection: The initial idea was to select a steel frame for the project with the objective of reducing construction time, site impact and material and construction waste (reduce wood coffers and concrete use) with 15cm brick blocks with external insulation. This later changed to a conventional structure of concrete columns with external walls made of M-two (wall system that uses polyurethane insulation between two concrete layers); this would provide excellent thermal properties reducing construction time.

Energy performance: The aim was to reduce as much as economically possible the overall U-value of the building taking into account bioclimatic considerations as orientation, façade color finish, window shading coefficient and solar control strategies. This work was done jointly between the architects, the mechanical engineer and a sustainability design consultant. Moreover, all the HVAC units will be recommended to work under an eco-refrigerant, i.e. low Ozone Depletion Potential.

User comfort: The design hopes to encourage the mix use of air conditioning and natural cross-ventilation depending on local conditions, placing operable windows on opposite side of the space allowing the air flow coming from the NE to flow through the V-shape building design. Also, via a loft design provide direct outside views from almost all areas of the apartment space (except bathrooms). Consideration was also taken in estimating natural daylight availability during the day hours (fig 3).

Water use: In Maracaibo, plants and grasses require a great amount of water; nonetheless there are critical times of the year where the city’s water supply is rationed making landscape irrigation the first to suffer. In this manner a grey water treatment system was design as to provide 100% of the irrigation water needed, reducing potable water consumption for irrigation thus reducing a load on the system on critical months.

4.4 Design assessment and overall performance

The design performance was evaluated against local regulations and researched international references. Of the considerations considered and performed during the design phase following were the best perceived:

Cooling capacity: Various iterations were done in regards to the efficiency of the design, the different spaces to be conditioned and the interactions with other considerations. The combinations of the energy interventions allow the design to reduce its cooling capacity by as much as 40% compared to the base case design (conventional construction). The simulations were carried out in 6 apartments located in the most unfavorable building; two first floors (PB1 and PB2) and 4 loft types (Loft 1, 2, 3 and 4); one having three of its external walls exposed to the East (loft 4), another one with its external walls to the west (loft 1), and the remaining two being within the building (loft 2 and 3).

The one with the greatest reduction in cooling capacity was loft 1 as its external walls faced West, with 40% in cooling capacity reduction. The rest of the spaces presented a reduction of around 20% (table 2).
Table 2: Comparison of cooling capacity required between the base and design cases and the percentage in reduction for the different space types.

<table>
<thead>
<tr>
<th>Space</th>
<th>BTU/h Base</th>
<th>BTU/h Design</th>
<th>(%) reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>PB1</td>
<td>20664</td>
<td>16192</td>
<td>21.64</td>
</tr>
<tr>
<td>PB2</td>
<td>19432</td>
<td>16144</td>
<td>17.08</td>
</tr>
<tr>
<td>LOFT1</td>
<td>23426</td>
<td>14041</td>
<td>40.06</td>
</tr>
<tr>
<td>LOFT2</td>
<td>15817</td>
<td>12088</td>
<td>23.57</td>
</tr>
<tr>
<td>LOFT3</td>
<td>16209</td>
<td>12471</td>
<td>23.06</td>
</tr>
<tr>
<td>LOFT4</td>
<td>19480</td>
<td>13748</td>
<td>29.43</td>
</tr>
</tbody>
</table>

Heat Island Effect: The issue of heat island effect was an important one as day maximum temperatures are also attributed to the heat expelled by the air conditioning units and the amount of dark surfaces in the city. In this regard it was the intention to reduce the thermal gradient of roof and non-roof surfaces to minimize this effect of the micro-climate. The measures taken were: a) the parking space to be of a material with high reflectivity index (e.g. weathered white concrete with a SRI=45) and also to have parking areas of an open grid spacing system, b) the roof would also present a high SRI (i.e. white coating SRI=80) and areas with vegetated roof.

Envelope efficiency: The design is expected to achieve a Gold recognition within the incentives awarded by the local authority (Oficina Municipal de Planificación Urbana, OMPU), which regulates the thermal efficiency of the envelope by measuring an overall thermal heat transfer coefficient (VTTG). The design’s VTTG achieves a 35% reduction from the maximum required. Also the windows selected presented a shading coefficient of 0.53 reducing greatly the heat gains from the outside.

These interventions were communicated to the mechanical engineer as to properly size the HVAC units, thus reducing the energy consumption, the monthly energy cost to the final user and indirectly reducing the emissions to the atmosphere as the electricity is provided by gas turbines.

Table 3: Comparison of base case typical envelope configuration, design envelope configuration and ASHRAE design criteria for Maracaibo’s climate type.

<table>
<thead>
<tr>
<th>Nivel</th>
<th>Opaque elements U-value W/m²</th>
<th>Glazing U/SHGC</th>
</tr>
</thead>
<tbody>
<tr>
<td>floor</td>
<td>1.27</td>
<td>NE 5.98 / 0.69</td>
</tr>
<tr>
<td>roof</td>
<td>0.9</td>
<td>SE 5.98 / 0.69</td>
</tr>
<tr>
<td>walls</td>
<td>2.07</td>
<td>SO 5.98 / 0.69</td>
</tr>
</tbody>
</table>

Solar strategy: Since a design premise is to provide plenty of views to the outside, while still reducing solar heat gain, the solar strategy for the design of the solar protection was of importance. Calculations were done to all windows from all facades to estimate the best louvers size, depth and number of divisions to have close to 100% projected shade over the window (fig 5) during the most critical hours where the radiation gains are the highest (9.30 to 10.30am for the NE, E and SE facades, 12.30 to 13.30 on the N and S facades, and 3.30 to 4.30 on the NW, W and SW facades).

5. CONCLUSION

The results serve both as a first step into further incorporation of sustainable concepts into Maracaibo’s architectural design practices, and highlight the environmental results obtained from including these concepts.

The experience during the design process was marked by interesting findings, among them:

1. Mechanical engineers provided more input on the variables that affect HVAC unit sizing during the design phase, e.g. selection of materials to decrease the overall U-value of the design. Also the architects were demanding the energy calculation include the impact of the shading devices and the window type.

2. The local misconception that engineers are not interested in environmental effects was challenged by the fact that the electrical engineers provided input to the structural engineer on how to minimize material waste during construction. Consultants engaged differently the project when explicitly asked to offer insight on environmental considerations.

3. The architects felt that including these considerations into their process did not slow down their work as their initially thought. Moreover, it provided more interesting creative thinking opportunities to challenge the design as to be able to include some of the considerations.
4. The various team meetings (architects and consultants) were considered a success by all involved. Their comments were positive, as that they were able to give input and thoughts on how other areas could be improved and jointly work together to get better results.

5. The process allowed measuring directly the results of the interventions from an environmental impact perspective. Still the team faced various challenges in the process for which no solution was immediately found, the most important being the integration of the construction company to carry out all the proposed interventions. As it is common practice the construction company during construction phase proposes different alternatives as to make the process faster, or might not carry out the specifications expected as a waste management plan during and after construction. Another challenged encounter is in regards to eco-friendly materials and products, as there is no market of this kind establish at a local level. Thus making it difficult to provide assurance that wood is grown on sustainable managed forests, pains and adhesives contain low VOCs, and products which consume fewer resources (e.g. water fixtures and energy efficient appliances).

Finally by recording these experiences, the case study aims to expand the available knowledge on the inclusion of sustainable strategies within a design methodology in the context of developing countries where such considerations are still new.

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