

Application of Passive Bioclimatic Strategies for Glamping in Xul-Há, Quintana Roo

Aarón Manuel Salas Cortés

*Universidad Autonoma Metropolitana Unidad Azcapotzalco,
Av. San Pablo 420, Col. Nueva Rosario, Azcapotzalco C.P. 02128, Ciudad de México*

Hector Ramses García Marquez

*Universidad Autonoma Metropolitana Unidad Azcapotzalco,
Av. San Pablo 420, Col. Nueva Rosario, Azcapotzalco C.P. 02128, Ciudad de México*

Roberto G. Barnard Amosurrutia

*Universidad Autonoma Metropolitana Unidad Azcapotzalco,
Av. San Pablo 420, Col. Nueva Rosario, Azcapotzalco C.P. 02128, Ciudad de México*

Abstract: This article presents the development of a glamping complex in Xul-Há, Quintana Roo, designed to meet the needs and expectations of tourists while providing thermally comfortable indoor conditions without relying on mechanical air-conditioning systems. Given the region's high ambient temperatures, a set of passive bioclimatic strategies was implemented, including appropriate façade orientation and a comprehensive climate analysis focused on local wind patterns and climatic conditions.

A fundamental aspect of the project was the careful selection of construction materials, considering both their thermal properties and environmental impact. The proposed materials were rigorously evaluated using Design Builder®, which enabled the simulation and analysis of the thermal performance of the glamping units under different climatic conditions and design scenarios.

Throughout the research and design process, the approach to the conception and development of the glamping units evolved significantly in response to the results and lessons obtained from the simulations conducted with Design Builder®. The hottest month (June) and coldest month (January) of the region were evaluated. In June, the implementation of passive design strategies resulted in a reduction of up to 8 °C in indoor temperature compared with the initial design conditions. In January, the resulting indoor conditions remained within the established thermal comfort range of 22.5–27.5 °C. These findings demonstrate the potential of passive bioclimatic strategies to improve thermal comfort in glamping facilities while reducing or eliminating the need for conventional air-conditioning systems.

Keywords: bioclimatic reconditioning, thermal comfort, solar control devices, heliodon, Ener Habitat, Design Builder.

1. Introduction

In 2020, life as it was known began to evolve due to the major global pandemic, which led to the confinement of millions of people around the world. Society quickly adapted to the emerging needs, eliminating an innumerable number of everyday activities and reconsidering the ways in which people worked, shopped, and vacationed.

From an environmental perspective, there was considerable discussion about a “breathing space” for the planet due to the reduction in everyday activities. The decrease in factory operations and in land, air, and maritime transportation systems resulted in lower greenhouse gas emissions during the first months of confinement. A few months later, it was observed that the absence of people contributed to the improvement in the clarity of the canals in Venice and to better air quality in China [1].

Regarding the negative impacts of the pandemic, León [2] points out that, in addition to the millions of people who died, there was a setback in economic activity at both the global and national levels. Tourism was one of the sectors that was severely affected. In Mexico, tourism GDP decreased by 25.4% in comparison with 2019. By 2021, tourism GDP had partially recovered; however, it remained 13.0% below the 2019 level. By 2022, the gap between tourism-related economic activity and pre-pandemic levels had narrowed to approximately 3.0%.

The impact of restrictions on hotel activities as part of the measures implemented to manage the COVID-19 pandemic resulted in a decrease of 6.0 percentage points in the occupancy rate compared with 2019, falling

from 62.9% in 2019 to 56.9%. Tourist beach destinations have proven to be particularly active, as have destinations along the northern border [3].

Little by little, cities have returned to the “new normal”; however, nothing remains the same. After two years of coping with the effects caused by the virus, remote work proved to be more profitable for many companies internationally. Working from an office involved various expenses, such as rent, electricity, and other resources. These benefits for companies extended to employees, who found a better quality of life through remote work by prioritizing their financial well-being, mental health, and time management.

With this new work modality, the tourism market found a new opportunity to attract people with this profile: digital nomads.

Over the past year, Mexico has implemented policies favorable to this type of “tourist,” who can enter and leave the country without significant restrictions. In other countries, such as Norway, Portugal, and Spain, special visas have been introduced allowing digital nomads to work from these countries under certain conditions [4]. Mexico, however, has not adopted a similar approach.

Within this current phenomenon, proposals must be developed that contribute to the continued growth of tourism in Mexico without turning it into a problem of foreign overpopulation, which directly affects the development and well-being of Mexican citizens by displacing them from their homes and workplaces within cities.

In this regard, tourist destinations should be strengthened in ways that allow visitors to stay for considerable periods of time without negatively affecting residents, while directly contributing to the preservation of these destinations and preventing significant environmental impacts.

Tourism has evolved over the years and has developed into different forms, including cultural tourism (urban, archaeological, literary, etc.), nature tourism (ecotourism, agrotourism, etc.), active tourism (adventure, sports, space, sexual, medical, religious, etc.), business tourism (business, conventions, events, incentive travel, etc.), and others [5].

Based on the above, it can be established that each of these forms can give rise to additional categories or even be combined with one another. Nature tourism, for example, encompasses various concepts derived from this activity, including Natural Tourism, Rural Tourism, Wilderness Tourism, Anthropological Tourism, Travel with Mother Nature, Adventure Travel, Jungle Tourism, Cultural Tourism, Ecotravel, Green Tourism, Appropriate Tourism, Sustainable Tourism, Ecotourism, Socially Responsible Tourism, Ecoventures, Nature Vacations, Wilderness Tourism, and Ethical Travel [6]. Although these terms represent different approaches, they converge around a common objective: minimizing environmental impact during a visitor’s stay in any natural destination. In this context, and considering the characteristics and expectations of new travelers, the possibility emerges of developing a different model of ecological tourism: glamping.

Glamping is a term composed of two words: glamour + camping. The concept of glamping emerged from the need to experience close contact with natural environments without sacrificing the benefits associated with staying in a hotel, including various services that make the experience more comfortable and enjoyable [7].

Both in Mexico and worldwide, glamping remains a relatively unexplored alternative. Nevertheless, it is a form of tourism that is expected to continue growing as a result of technological advances. An increasing number of people may join the ranks of digital nomads, encouraging unprecedented mobility between locations as remote work becomes more widespread. In this context, it is necessary to develop proposals that keep the environmental impact of this growing form of tourism as low as possible.

2. Objective

Based on the needs arising from this new form of tourism, this study proposes the analysis of a glamping facility from a bioclimatic perspective, with the aim of maintaining the indoor operative temperature within the thermal comfort zone through the implementation of bioclimatic strategies. This approach is based on the thermal evaluation of the materials comprising the building envelope during two periods of the year.

3. Method and Material

The project is located 1.57 km from the center of Xul-Há, in the municipality of Othón P. Blanco, Quintana Roo, Mexico, at a latitude of 18.56° N and a longitude of -88.453°, and at an elevation of 17 m above sea level. According to the Köppen–García climate classification system [8], the site belongs to Group A, Warm-Humid climate. The mean temperature of the hottest month is 29.2 °C (June), and the total annual precipitation is 1,308.7 mm. Therefore, the bioclimatic classification corresponds to a “Warm-Humid” climate, with a neutral temperature (T_n) of 26.1 °C, an upper comfort-zone limit (UCZL) of 28.6 °C, and a lower comfort-zone limit (LCZL) of 23.6 °C. The minimum and maximum temperatures are 22 °C and 29 °C, respectively, resulting in a thermal amplitude of 5 °C.

For this study, the case study is an Ekhológica glamping unit located in Xul-Há. The ground floor includes a 13.89 m² sleeping area with a pine wood floor and sloped roofs (54°). The roof consists of an inner 12 mm pine wood layer, an air cavity, and an outer pine wood layer, resulting in a total thickness of 30.40 cm. The walls use the same construction system as the roof, with a total thickness of 12.40 cm. The windows have wooden frames and 3 mm clear glass, with a total area of 0.77 m². The 50 m² outdoor area has a wooden floor and is furnished for social activities.

The upper floor has a 14 m² sleeping area. The roof uses the same construction system as the ground floor and includes a 4 m² window with wooden frames and 6 mm glass. The walls also include wooden-framed windows with 6 mm clear glass and a total area of 1.38 m². The 50 m² floor is made of wood, and the structural system consists of 20 × 28 cm wooden beams, as shown in Figure 1.

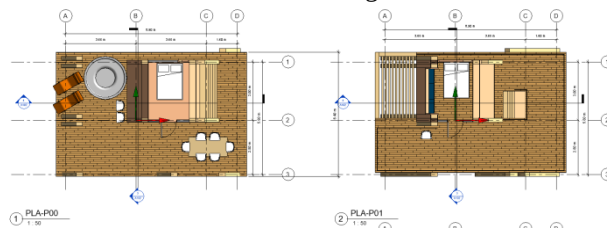


Figure 1: Ground Floor and Upper Floor

3.1 Solar Radiation Analysis

A solar radiation analysis was conducted to determine the mean solar radiation incident on the different elements of the building envelope according to their orientation. The analysis was performed using Revit 2020® and its Insight 2020 plug-in for the coldest and hottest periods, corresponding to January and June, respectively.

Figure 2 shows the hottest period (June) for the southeast (SE) orientation. The highest mean solar radiation occurs on the upper floor, mainly on the roof, with values ranging from 227 to 398 Wh/m².

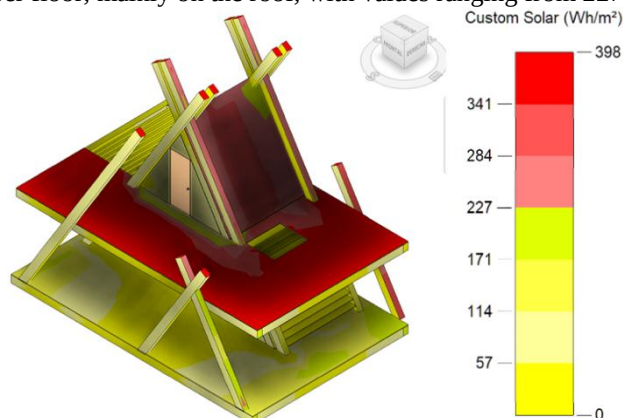


Figure 2: June—hottest period, mean solar radiation, southeast orientation

According to the analysis, the difference in solar radiation is 300 Wh/m², indicating that solar heat gain varies depending on the location within the glamping unit. Since temperatures are high during most of the year, the construction system should be thermally adapted to the site by minimizing direct solar heat gain.

A series of modifications were made to the proposed construction system and solar-control devices, resulting in the following configuration:

- Pitched roofs: 12 mm Pine + 276 mm Polyurethane + 12 mm Pine
- Wall: 12 mm Pine + 100 mm Polyurethane + 12 mm Pine
- Floor: 10 mm Pine + Polyurethane
- Solar-control devices: Overhang with lateral protections on the north facade window. East and west facades feature louvers inclined at 53°.
- Based on the above, a model was created in the Design Builder tool to run a simulation and compare the results with the As-Built model.

The modification shown in the Figure 3



Figure 3: Glamping with passive bioclimatic strategies

3.2 Thermal analysis

Thermal analysis was conducted using Ener Habitat and Design Builder® software to compare the building's behavior with the outside temperature and ensure that comfort criteria are met. The building must remain in the comfort zone for the user during an occupancy schedule from 7:00 to 23:00 h. For the evaluation, the operative temperature was used as the main indicator of indoor thermal performance, considering a comfort range between 22.5 °C and 27.5 °C. The simulations were performed for the annual period, with particular emphasis on January and June, corresponding to the coldest and hottest months, respectively. The results were analyzed by comparing the conventional construction system with the proposed bioclimatic strategies and the additional solar-control device. This comparison allowed the effect of the proposed strategies on the reduction of indoor operative temperature to be identified, particularly during the periods of highest external thermal load.

The thermal performance of the proposed Glamping was evaluated by comparing different construction configurations with and without the implementation of bioclimatic strategies. The simulations were conducted using DesignBuilder®, considering three configurations: the conventional construction system, the system incorporating bioclimatic strategies, and the bioclimatic system complemented with a shading device. This comparison made it possible to identify the influence of the proposed strategies on the operative temperature and to determine their effectiveness in improving indoor thermal conditions.

The comparison also included the addition of a solar-control/shading device (awning) to the bioclimatic configuration. The thesis reports that the use of solar-control devices produced a particularly significant effect during June, resulting in an overall reduction in indoor temperature of approximately 8–9 °C during the hottest month. In January, the same strategy helped maintain the operative temperature within the established thermal comfort conditions. Therefore, the simulations demonstrate a clear difference between the Glamping unit evaluated with the conventional construction system and the configurations incorporating bioclimatic strategies. The results indicate that the combination of appropriate thermal materials, bioclimatic design strategies, and solar-control elements improved the thermal performance of the Glamping unit.

4. Results

A more significant difference was observed during June, identified as the hottest month at the study site. Under the conventional construction configuration, the operative temperature increased considerably above the established comfort range. When bioclimatic strategies were incorporated, the operative temperature was reduced, and the simulation showed that the Glamping could enter the comfort zone even during the period of maximum temperature at approximately 15:00. The study reports a reduction of up to 8 °C compared with the conditions without the implemented strategies.

The operative temperature variation of the proposed glamping structure during January for three construction configurations is presented in Figure 4. Thermal performance was evaluated against the adaptive comfort band defined between 22.5 °C (Lower Comfort Limit) and 27.5 °C (Upper Comfort Limit).

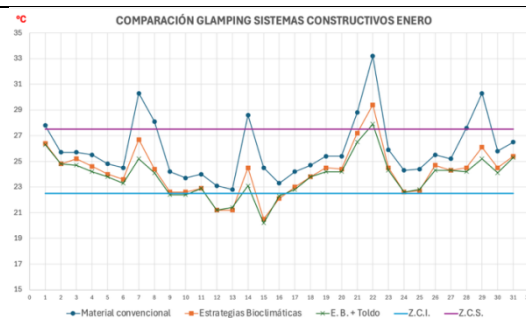


Figure 4: Comparison of Glamping Construction Systems – January

Conventional System: Exhibited severe overheating, consistently exceeding the upper comfort threshold on peak radiation days (e.g., days 7, 8, 14, 21, 22, and 29) and reaching a maximum peak of 33.2 °C on day 22.

Bioclimatic Strategies: Significantly attenuated indoor thermal peaks. The implementation of passive design strategies effectively maintained operative temperatures within the comfort range for most of the month, reducing peak temperatures by up to 3.8 °C relative to the conventional base case.

Bioclimatic + Solar-Control Device (Awning): Demonstrated superior thermal stability, suppressing thermal spikes even further during critical solar exposure periods (e.g., day 22 at ≈ 27.8 °C) and keeping the indoor environment near or within the comfort bounds throughout the entire period.

The integration of passive bioclimatic strategies combined with external solar shading substantially optimizes indoor thermal performance, effectively mitigating overheating risks during winter peak conditions, as show in the Figure 5.

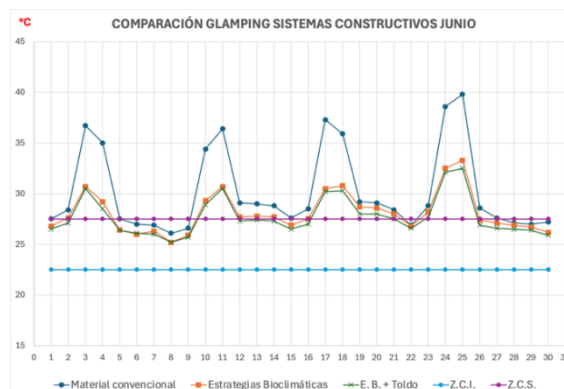


Figure 5: Comparison of Glamping Construction Systems – June

Figure 5 compares the operative temperature of the Glamping during June under three construction configurations. The conventional material configuration presents the highest temperatures, reaching approximately 40 °C, considerably above the upper comfort limit of 27.5 °C.

In comparison, the implementation of bioclimatic strategies significantly reduces the operative temperature, with maximum values of approximately 30–32 °C. The addition of a shading device further contributes to reducing thermal gains during the hottest periods. According to the study, the bioclimatic strategies achieved reductions of up to 8 °C, allowing the operative temperature to reach the comfort zone during the period of highest temperature, as show in the Figure 6.

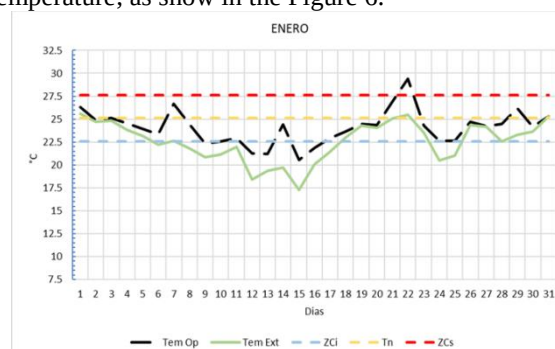


Figure 6: Graph of glamping with bioclimatic strategies applied to January

The Figure 6 illustrates the daily thermal performance during January, comparing the indoor operative temperature (Tem Op) with the outdoor ambient temperature (Tem Ext), alongside the established adaptive thermal comfort criteria.

The proposed envelope strategies effectively increase and stabilize indoor temperatures above outdoor ambient temperatures, demonstrating favorable passive thermal performance. These strategies help maintain indoor conditions within the established thermal comfort range for the majority of the winter period.

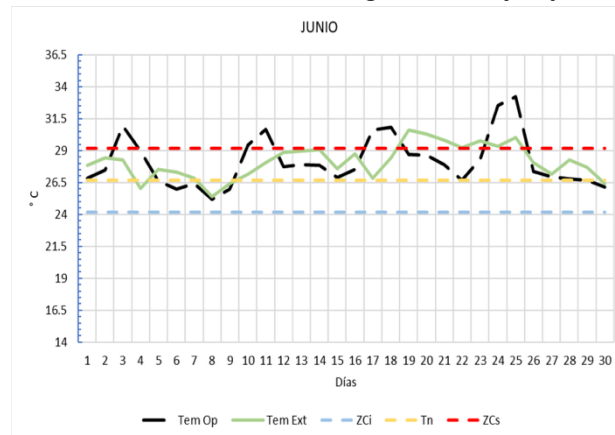


Figure 7: Graph of glamping with bioclimatic strategies applied to June

The Figure 7 shows the daily indoor operative temperature (Tem Op) compared to the external outdoor temperature (Tem Ext) throughout June, evaluated against adaptive thermal comfort limits.

The proposed strategy demonstrates significant thermal buffering capacity during summer conditions, successfully maintaining indoor temperatures within or close to the adaptive comfort band for the majority of June and mitigating peak heat transfer from the external environment.

Daily indoor operative temperature (Tem Op) versus outdoor ambient temperature (Tem Ext) during June relative to the lower comfort limit ($Z_{Ci} \approx 24.2^\circ\text{C}$), neutral temperature ($T_n \approx 26.7^\circ\text{C}$), and upper comfort limit ($Z_{Cs} \approx 29.2^\circ\text{C}$).

5. Conclusions

The research revealed that the key to achieving success lay in adapting and tailoring design strategies and material selection to meet the specific demands of our context. Through the integration of bioclimatic design techniques and the application of materials with appropriate thermal and insulating properties, it was possible not only to reach, but also to maintain, an optimal operative temperature within the glamping space. This adaptation process successfully fulfilled the comfort criteria while yielding additional benefits in terms of energy efficiency.

Furthermore, the study highlighted the importance of flexibility and responsiveness in architectural and development design. The ability to identify and address context-specific challenges is fundamental to the long-term success of any initiative.

Based on the climate analysis presented for the two representative periods (cold and hot), the difference in solar irradiance between these two periods is 66 Wh/m^2 . This indicates a similar level of solar gain between the coldest and hottest months, suggesting that temperatures remain elevated throughout most of the year in the region of Quintana Roo. Differences in solar incidence are more pronounced across orientations, reaching their lowest values on the NW (northwest) orientation and their highest on the SE (southeast) orientation. Nevertheless, both orientations exhibit high irradiance levels due to solar incidence during the solstice of the hottest period at the latitude of the proposed site.

Consequently, the construction system must thermally adapt to the site by mitigating direct solar gains. This was achieved through shading elements—such as awnings, overhangs, and strategic vegetation—which significantly reduce the amount of solar radiation reaching the building surfaces. Additionally, employing construction materials with high thermal insulation performance helps keep the interior cool during the hottest months and warm during the cooler period.

Designing the building with careful consideration of orientation and the solar path is critical to maximizing energy efficiency and thermal comfort. Incorporating double-glazed windows and controlled ventilation systems can also contribute to minimizing unwanted heat gain and enhancing fresh air circulation. In

summary, achieving effective thermal adaptation to the site requires addressing both local solar characteristics and passive design strategies that optimize overall building energy performance.

The construction system, composed primarily of timber for the building envelope and glass for the fenestrations, proves efficient during cold periods. The architectural envelope is effective, as the number of days within the Comfort Zone (CZ) increases for the Operative Temperature (OT) compared to the Exterior Temperature (ET). In addition to lowering indoor temperatures, this envelope exhibits an acceptable thermal swing.

However, during the hottest month, the architectural envelope is less efficient. During this period, the number of days within the CZ for the OT is lower than for the ET, accompanied by a significant thermal swing.

In conclusion, the proposed construction system—featuring a timber envelope with polyurethane insulation—demonstrates strong efficiency in cold periods, providing adequate thermal regulation and indoor comfort. Nonetheless, during hot periods, this system can lead to indoor overheating, thereby reducing its effectiveness. To mitigate this issue during warm months, supplementary cooling and shading strategies are required, such as natural ventilation, exterior shading devices, and reflective materials, to maintain comfortable indoor temperatures and prevent excessive heat accumulation.

The implementation of solar-control devices on the glamping unit proved highly effective, successfully preventing significant solar gains. Consequently, a notable reduction of 8–9 °C in indoor temperature was achieved during June, the hottest month in the case study. Furthermore, these devices maintained a stable operative temperature within the comfort zone during January, the coldest month. This temperature reduction contributes significantly to occupant thermal comfort and energy efficiency, reducing reliance on mechanical air conditioning systems. Therefore, the implemented solar-control devices successfully enhanced the livability of the glamping unit, demonstrating their importance and utility in the design and operation of sustainable accommodations.

This work provides a solid foundation for future research regarding material performance and solar protection in this typology of buildings for the tourism sector.

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