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Methodology for informed design of sustainable tourism accommodation in Chile's 9th Region the Gateway to Patagonia

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Abstract

Lying between Chile's agricultural Central Valley and the wilds of Patagonia, the micro region of Araucanía Andina, is seeing a rise in both national and international tourism. With its snow-capped volcanoes, national parks, native forests and indigenous Mapuche culture, the region offers a wide range of activities to the Special Interest Tourist. The development of winter sports facilities and the growth in Northern Hemisphere visitors during the austral winter is extending the season, in what was previously predominantly a destination for Chilean summer holidaymakers. The tourism infrastructure must therefore respond to provide comfortable, energy efficient, sustainable accommodation during both the cold wet winters and short hot summers, meeting the expectations of an ever more demanding international market. The government funded research project "Sustainable Construction System and Energy Efficiency for Special Interest Tourist Infrastructure in the Araucanía Andina," FONDEF Regional D10R1003, aims to provide the knowledge needed by the local tourist industry to achieve this goal. This paper presents the methodology and outcomes of the project, including the study of local vernacular architecture, post occupation evaluation of existing infrastructure, bioclimatic analysis, environmental and technical assessment of insulation and construction materials, digital simulation of proposals and the construction of physical test cells. The resulting proposal is a system of timber-framed walls, insulated with sheep's wool, finished externally with a ventilated façade. It is hoped that this prefabricated system, in conjunction with best practice guidelines for construction and management, should enable a sustainable future for the region's tourism. At the same time, the methodology provides a replicable template that has already been applied in other regions of the country.

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1. Introduction

This paper presents the research of the Chilean government funded project "Sustainable Construction System and Energy Efficiency for Special Interest Tourist Infrastructure in the Araucanía Andina," FONDEF Regional D10R1003. The aim of the project was to improve the environmental conditions of the existing tourist accommodation of the micro region Araucanía Andina in Central Southern Chile, often referred to as "the Gateway to Patagonia". This region, rich in natural and cultural heritage, is drawing an ever-increasing number of Special Interest Tourists (SITs). In 2012, official statistics show that 3,554,297 tourists visited Chile [1], with many of these being SITs, that is to say tourism focused around specific activities or interest [2]. In 2011, 78.6% of foreign tourists cited Chile's natural beauty and landscapes as their principal reason for visiting, 40% cited culture and heritage, 30.6% visited Chile's national parks and 15.4% participated in mountaineering activities [3]. In the same year 80% of foreign and 40% of national tourists visiting Chile's Araucanía Region requested information on activities relating to the areas indigenous Mapuche culture [4]. Domestic SIT within Chile is also on the rise due to the emergent middle class, increased access to further education and growing environmental awareness. The importance of SIT as a driver for Chile's economic development has been recognized by the government with three main "destination-products" identified for SIT, these being Arica-Parinacota in the far North of Chile; Patagonia, covering in general the far south; and the Araucanía Andina. The tourist infrastructure of the region must therefore aim to meet the demands of the SIT market. Whilst many do not seek luxury accommodation and may even actively choose rustic or more basic lodgings, in general their expectations in terms of environmental comfort are high, as is the requirement that their accommodation has a minimum negative impact on its surroundings and the environment. The Chilean government is therefore interested in developing efficient, comfortable and sustainable tourist infrastructure.

2. Methodology

The methodology adopted for the project consisted of the following stages:

- Desktop study of context: climate, topography, existing infrastructure and available resources
- Field Study trips to review local vernacular architecture and interview existing tourist accommodation providers
- Post Occupancy Evaluation (POE) of existing infrastructure
- Bioclimatic analysis and recommendations based on desktop studies, field studies and POE
- Design of proposed constructive system based on findings
- Digital simulation of existing infrastructure and proposed constructive system
- Construction of physical test cells
- Diffusion of obtained knowledge through a technical conference

It is hoped that by following this methodology it is possible to draw on the particular characteristics, advantages and requirements of the region, producing a sustainable solution that is specific, local and pertinent to those it intends to benefit. The authors believe that this methodology is applicable beyond this particular project. Elements of this methodology have now been successfully applied by the authors in other areas in Chile such as the Coast of the Atacama Region [5].

3. Context

3.1. The Landscape of the Araucanía Andina

Located in Chile's 9th Region, the Región de la Araucanía, the micro region of Araucanía Andina lies between the latitudes of 38° 12'west and 39° 6' south, extending eastwards from the city of Temuco up to the Andean border with Argentina. Five nationally protected conservation areas are located within its limits. The National Parks Tolhuaca and Conguillío, and the National Reserves Malalcahuello, Alto Bío Bío and China Muerta. The rich biodiversity protected by these parks was recognised by UNESCO with the formation in 1983 of the Araucanía Biosphere, encompassing both Araucanía Andina and the micro-region of Araucania Lacustre that lies directly to the south. Active, snow-capped volcanoes including Tolhuaca, Lonquimay, Sierra Nevada, Llaima and Sollipulli dominate the region. These volcanoes and the surrounding mountain chains provide both downhill and cross-country skiing coinciding with the Northern Hemisphere's summer and peak holiday season. Coupled with the beauty and biodiversity of the lakes, rivers, forests, and the surviving indigenous Mapuche culture the region has an almost year-round influx of tourists. Tourist infrastructure, which previously focused on domestic summer holiday season, must therefore respond to this continual demand.

3.2. Climate

The Chilean Standard NCh1079 of.2008 [6] defines two climatic zones within the micro region of Araucanía Andina. Altitudes below 600m above sea level are classified as "South Interior" a climatic zone defined as "Wet and cold with frequent frosts; short summers of 4-5 months with moderate insolation; numerous lakes and rivers with microclimates; robust vegetation; humid air and ground; winds southerly and calm." [6] Altitudes above 600m are classified as "Andean" a "Zone with dry atmosphere and large diurnal thermal oscillations; blizzards and snow in winter; high altitude vegetation; large component of UV in the solar radiation. Given its large range of latitudes, this zone presents very particular characteristics along its length, being in general of extreme conditions" [6]. The classification of Köppen [7] identifies 3 climatic zones within the region. To the west and in valley bottoms Cfb a temperate climate with no dry season, short hot summers and wet cold winters; on the higher slopes Cfcs a cold wet temperate climate; and on the high peaks ETH cold tundra due to altitude [7]. In those areas where permanent tourism infrastructure is currently located, local weather station data shows winters with an average minimum temperature of 0°C, minimum minimum temperatures of -10°C and an average maximum of 8-10°C. In summer average temperatures range between 5°C and 25°C with extremes of 0°C and 37°C being recorded [8]. With the year-round demand, tourist accommodation must sustainably provide hygrothermal comfort in all these conditions.

3.3. Available resources

In 2012, official statistics of the Ministry of Agriculture showed a total of 2,414,389 hectares of industrial forestry plantations in Chile. 61% of this was Monterey Pine (P*inus radiate*) with 67% being located in the Araucanía Region and bordering regions [9]. Far outweighing all other potential construction materials, timber has historically been the predominant regional construction material.

Thermal insulation is probably the most effective method of reducing heating demands in residential accommodation in a cool temperate climate. Synthetic insulation materials however have a high embodied energy and large environmental footprints. A review of local natural insulation materials was therefore undertaken, including a desktop study of availability and environmental impacts, in conjunction with laboratory guarded hot box testing of thermal conductivity. This concluded that whilst the abundant native bamboo ***quila*** (***Chusquea quila***) has a coefficient of thermal conductivity (❑) of 0.065W/mK in its chipped form, sheep's wool with ❑=0.45W/mK is currently the most viable local natural thermal insulation material [10].

4. Field Study Trips

From the beginning, it was decided that it was essential to visit the region and its existing infrastructure in order to learn from vernacular architecture and the knowledge of the local tourist accommodation providers, drawing on their experiences, both positive and negative. During the first field study trip, a good number of small towns and providers of tourist accommodation were visited. Carefully prepared interviews were conducted to identify their needs, difficulties and achievements. In some cases, preliminary in situ environmental measurements were undertaken. Much useful information about actual microclimate, environmental strategies for buildings, experiences with renewable energy and tourists' expectations, was obtained during this first trip.

Following this trip, four subsequent field study trips were made, maintaining contact with the same accommodation providers initially interviewed, informing them of findings and research progress. This enabled the objective of the project, to not only develop new ideas on construction systems and materials, but to build upon the participants understanding of sustainability and learn together.



Fig. 1. Double door, Curacautín. Fig. 2. Shutters, Curacautín. Fig. 3 Interlocking timber cladding, Casa del Colono, Conguillio

4.1. Local vernacular architecture

The field study trips identified the following bioclimatic strategies in the local vernacular architecture. Double doors form lobbies to reduce ingress of moisture, heat-loss and draughts (Fig.1); projections over doorways provide canopies and rain protection; limited opening windows, favouring airtight fixed-lights; shutters on windows (Fig.2) provide additional insulation at night and control solar gain in summer; low ceilings minimize internal air volume and reduce temperature stratification; interlocking vertical or horizontal timber cladding provide rain-skins(Fig.3).

5. Post Occupancy Evaluation POE of existing tourist infrastructure

Six local tourist establishments were identified to provide a representative sample of the accommodation typologies and geographical locations of existing infrastructure. Semi-structured interviews were conducted with the owners and staff, in conjunction with in situ measurements of hygrothermal conditions, daylight factor, air quality and sound pressure levels. These took place in April 2012 (austral autumn), August 2012 (austral winter) and January 2013 (austral summer). Continual monitoring of internal hygrothermal comfort was also conducted. Further details of this monitoring can be found in the authors previously published paper "The Challenge of Sustainable Tourist Infrastructure in the Araucania Andina, Chile" [11].

These POE concluded that the most common problem encountered was the lack of sufficient thermal insulation, with a complete absence of any kind of insulation in three of the six establishments and a fourth with no roof insulation. This deficiency leads to high heating demands and poor hygrothermal comfort. Even in the best insulated case study, heating was provided by an oil fired boiler. The owner did express interest in investigating the use of a ground sourced heat pump. No problems with air-quality were identified, however high levels of relative humidity were encountered during winter months when tourists were unlikely to open windows. This would suggest that mechanical ventilation with heat recovery could be appropriate. In all but one case there was found to be good natural daylighting. The thermal improvement of the building envelope was therefore identified as the principal pathology to be resolved. [11].

6. Bioclimatic recommendations

Based on the results obtained through the desktop study and especially the field visits and POE, a list of bioclimatic recommendations for tourist accommodation in the Araucanía Andina were prepared. In summary these included, with regards to form; favouring compact forms with reduced external surface area; developing the plan along an east-west axis thereby maximizing north and south facades; orientating habitable spaces towards the north; maintaining low ceilings, especially in bedrooms, to minimize air volume; providing large covered areas and overhanging eaves to provide external spaces protected from the rain. With regards to openings; between 20 and 40% fenestration to prevent excessive heat loss; double glazing with timber frames and triple contact seals; solar protection, horizontal to the north and vertical to the east and west, to avoid overheating in summer; and reducing the use of opening-lights in windows to the minimum required for ventilation. Fixed-lights are more hermetic and also cheaper. With respect to the building envelope, maximum recommended U-values were based on the seldom used Chilean Standard NCh1079 (2008) [6], with the use of those stated for the Andean climatic zone recommended for all areas. These values are presented in Table 1 alongside those required by Chilean Residential Building Regulations.

Table 1. Recommended maximum U-values (W/m^{2}K) according to NCh1079 (2008) [6] and Chilean Building Regulations (OGUC)

	Walls		Roof		Ventilated floors	
Climatic Zone	NCh1079	OGUC	NCh1079	OGUC	NCh1079	OGUC
South Interior	0.5	1.6	0.3	0.33	0.7	0.5
Andean	**0.3**	1.1	**0.25**	0.25	**0.4**	0.39

To avoid overheating during summer months it is necessary that exposed thermal mass is incorporated. This could be in the form of stone floors and gypsum plasterboard partitions. Ventilated roof voids can also aid to reduce overheating. Pitched roofs with an inclination of 28º orientated towards the north were recommended to respond to the high levels of precipitation and provide an ideal surface for solar collectors. Following local advice, gutters are not recommendable due to problems with snow loading and maintenance problems arising from forest locations.

7. Proposed construction system

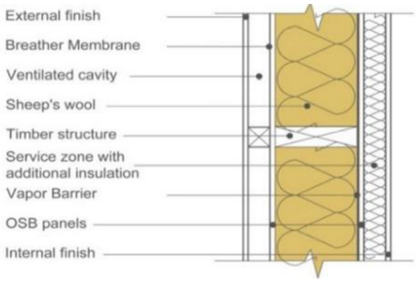
Based on these recommendations and the knowledge of local resources, a constructive system for future new-build tourist accommodation was designed. This consists of a modular prefabricated timber-frame construction with 140mm of sheep's wool and an external rain-screen with ventilated cavity (Fig.4). A 40mm service zone is provided internally to avoid the perforation of the vapour barrier. This service zone is also full-filled with sheep's wool to reduce the thermal bridging of the main structural members. By using horizontal battens, thermal bridging only occurs in the limited area where vertical structure and horizontal batten coincide. External rain-screen cladding can be specified according to location and preferred finish. Options include vertical or horizontal timber weatherboarding, half logs and render on mineral board.

To illustrate the possible application of the proposed constructive system and bioclimatic recommendations, a small two bedroomed cabin was designed (fig.5). Digital simulation with IES Virtual Environment software was then undertaken to compare the performance of this design to the best practice found within the study area. Two models with three scenarios were simulated. Model 1 (M1) was the actual design of the best case study building evaluated in the POE. Model 2 (M2) was the proposed architectural design. The three scenarios were; a) without insulation, b) with the same thermal insulation currently installed in the best POE case study and c) the sheep's wool insulation as proposed in the constructive system. Table 2 presents a summary of the results which clearly demonstrate the effectiveness of the proposed construction system, reducing heating demand by 70% for existing buildings and 76% when used in conjunction with the authors' bioclimatic recommendations.

In addition to these digital simulations, two physical test cells were constructed. Their construction allowed the refinement of construction details through collaboration with local timber-frame prefabricators, in addition to enabling future continual hygrothermal monitoring and perhaps most importantly the creation of didactic elements on public display. These physical test cells have been installed both at the city campus of the Universidad Católica de Temuco in Temuco and in the public entrance of the Nacional Park Malalcahuello, situated within the Araucanía Andina.

Table 2. Summary of IES Virtual Environment Simulation of heating demand KWh/m2/year
Expressed as % with uninsulated models as baseline. (M1 case study, M2 Proposal).

Scenario	M1	M2
Uninsulated	100	100
As insulated	69	51
Proposed constructive system	30	24



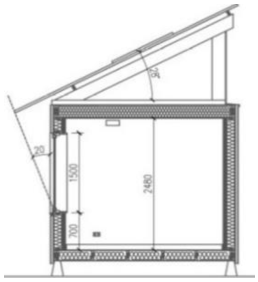


Fig. 4. Sectional detail of construction system. Fig. 5. Architectural application. Fig. 6 Section Physical test cell

8. Public Technical Conference

Finally, to conclude the process, a public technical conference was organized and all those who had participated during the duration of the project were invited to attend. In the first part of the conference, local tourist authorities emphasized the importance of sustainability in tourism accommodation in Chile and especially in Araucanía Andina. The second part took a more technological viewpoint, including the presentation and discussion of this methodology. An animated 3D model of the proposed construction system and small cabin design was projected. In addition, other current constructive systems were presented in detail, including one of the tourist lodges that had been monitored and simulated in this research. Other non-sustainable systems, with outer skins of materials coming from China and synthetic thermal insulation were presented as a counterbalance and received criticism from the attendees because there were situated in a National Park. A number of new tourist accommodation owners asked for advice at the meeting for making improvements to their accommodation.

9. Conclusion

The methodology presented in this paper focuses on the need for designers of the built environment to directly engage with the local reality for which they design. Standard techniques of digital simulation are used alongside the study of local vernacular architecture, local resources, development of new materials, physical testing, Post Occupancy Evaluation, interviews and continuing interchange of information with local inhabitants and entrepreneurs. In this way, the authors believe it is possible to achieve an architecture that is both a product of its context and the most sustainable solution for it.

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