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# Design tools for energy efficiency and thermal comfort in public buildings

## Application to four climatic regions in Chile

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*Abstract*

The main objective is to elaborate tools for incorporating thermal comfort and efficient use of energy in the process of design of public buildings. For this purpose a study is being carried out for the Architecture Division of the Ministry of Public Works. The first stage completed in May 1999 took into account 4 of the 9 building climatic zones of Chile. The tools are aimed at the stage of conceptual design, in order to define minimum requirements and to assess the performance of submissions to design bids. The method was tested in 4 recently built public buildings. The actual comfort and energy efficiency was assessed through a questionnaire applied to users and to building managers. Design achievements and failures were assessed by comparing to the recommended criteria and by software simulation. It was concluded that most deficiencies could have been predicted and avoided through these tools.

### INTRODUCTION

The Architecture Division of this Ministry is responsible of designing or deciding bids of all public buildings, that is, administrative, educational, health and justice buildings. On the other hand, Chile is a country where almost all kinds of climates can be found. For each building type there are standard requirements which have to be fulfilled, thus optimising design towards those goals. However, climatic and regional requirements are less well defined. Also cost advantages of standard design put pressure against diversity. Therefore, poor energy performance and/or inadequate comfort are not uncommon in new public buildings.

A study was requested to elaborate tools in order to incorporate energy and comfort criteria at early stages of design process. These criteria are intended to be taken as terms of reference and to assess performances of buildings at bids.

It is important to point out that, as there is neither an energy saving policy in the country nor enough regulations on the subject, this is an important short-term initiative to improve design and behaviour of new public buildings.

### SCOPE OF THE STUDY

The study is divided into 5 parts. The first one is a reference book of climatic architecture: a general description of qualitative and quantitative methods of analysis used in the study. Details of how and which factors give rise to design recommendations at different stages are found here.

Parts 2 to 5 are devoted to the four climatic regions, involving 6 cities. The climate of each region is summarised, as well as the physical environment. Secondly, regional architecture examples are presented, both from traditional and recent architecture. Design strategies are proposed, ending in specific recommendations. A case study is presented as worked example, including drawings, photographs, performance calculations, energy consumption data and users response.

Finally, the software PASIVA [1] was developed for each region to allow a simulation of the dynamic thermal behaviour of buildings at preliminary stage of design.

### QUALITATIVE TOOLS

After applying a modified version of Mahoney [2] and Givoni [3] methods with the scarce climatic data available, basic design criteria were drawn for each region. Criteria were given as preferred ranges or preferred trends for a number of aspects, ordered as a checklist for assessing preliminary designs.

Recommendations were organised as groups of criteria as follow in Table1.

Table 1. Groups of criteria

| | | |
|---|---|---|
| 1 | FORM | • Orientation<br>• Layout<br>• Open spaces |
| 2 | OPENINGS | • Size<br>• Orientation<br>• Solar protection<br>• Windows<br>• Glazing |
| 3 | WALLS & PARTITIONS | • Wall fabric<br>• Partitions fabric |
| 4 | ROOF | • Roof cavity<br>• Roof fabric<br>• Roof finish |
| 5 | THERMAL INSULATION | • Opaque facade<br>• Ceiling<br>• Floor<br>• Thermal bridges |
| 6 | LIGHTING | • Windows<br>• Control<br>• Skylight<br>• Artificial lighting |
| 7 | VENTILATION | • Natural convection<br>• Moistening<br>• Stack effect<br>• Infiltration |
| 8 | HUMIDITY | • Rain<br>• Vapour<br>• Condensation<br>• Soil |
| 9 | ACTIVE SYSTEMS | • Ventilation<br>• Heating<br>• Cooling |

## QUANTITATIVE TOOLS

As commercially available software is not applicable to preliminary plans, which involve conceptual proposals but no technical specifications, a dedicated software package was required. In addition, few simulators allow for fluctuating, uncontrolled indoor temperature, which represent most actual cases in Chile.

PASIVA takes into account variables of thermal transmittance of fabric, thermal mass, solar radiation in opaque and translucent facades at each orientation, ventilation, schedules of use and internal heat gains. The output is the hourly indoor temperature of a single zone of the building, for both winter and summer periods.

Climatic data are hourly temperature and wind velocity for the second week of January and July, averaged over last 10 years. Radiation data include average cloudiness, but do not include obstructions.

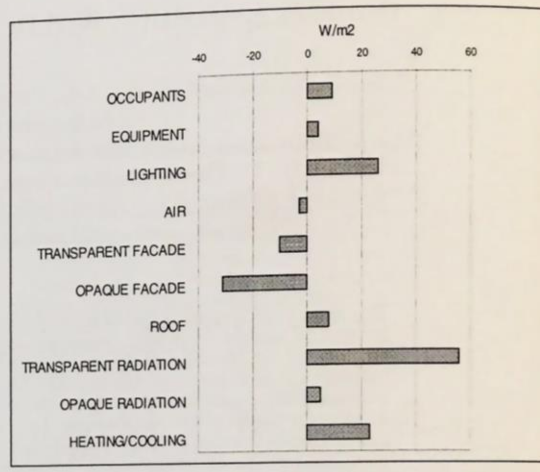
Design data are floor and facade areas, as well as openings percentage for each orientation, including skylight. Fabric data input is a choice from 4 to 5 options of mass and 4 options of insulation. Several options are allowed for roof-attic-ceiling configurations.

Several options for shadow on transparent facades as well as options for colour on opaque facades are allowed.

Operational data include time of windows opening, occupancy and equipment use. Lighting input is based on floor area and type of activity, considering a fixed rate of efficiency.

Output of results includes curves of both indoor and outdoor temperature, as well as the estimated comfort range.

Partial heat gains or losses are presented for each hour, as shown for one of the worked examples at an office building in Santiago. (Figure 1)




## ACTUAL COMFORT RATING

The method was tested in 4 recently built public buildings: police headquarters, civil registry, courts building and elementary school.

Figure 1. Building gains and losses at 10am during winter

The actual comfort and energy efficiency was assessed through a questionnaire applied to users and to building managers.

Building managers are a good source of information: about the thermal sensation and complaints of users at every time of day, about peak hours and total energy consumption, about differences of temperature within areas of the building,

Questionnaires were applied to know about some specific working place of users. Questions were about thermal and lighting comfort, annoying noise and droughts, need of fresh air, opening windows frequency and modifications of the working place to minimise environmental annoyance.

Design achievements and failures were assessed by comparison with recommendations and by software simulation. It was concluded that most deficiencies could have been predicted and avoided through these tools.

## REFERENCES

1. E. Collados, *'PASIVA: Programa de Arquitectura y Simulación de Variables Ambientales'*, (Ambiente Consultores, Santiago, Chile, 1999)
2. G. Mahoney, *"Climate and house design"* (United Nations Centre for housing, building and planning, 1973)
2. B. Givoni *" Comfort, climate analysis and building design guidelines"* (Energy and Buildings, 18, pp11-23, 1992)