Building Simulation in Practice
The Portuguese Experience

Helder Gonçalves
INETI-DER
Estrada do Paço do Lumiar 1699 Lisboa Codex Portugal

The use of simulation as a tool for assessing building thermal performance is a powerful technique but contains certain difficulties, which limit very much its application and even its dissemination. In this paper, some of the Portuguese experiences of building simulation are presented and discussed, focusing on a large simulation exercise. The different strategies and decisions taken by the modeller during the process and their consequences, are discussed for this particular case. A more general discussion on the simplification of the simulation process is put forward having in mind the issues facing the application of simulation in practice, and the need to retain the quality in the results.

INTRODUCTION

Many simulation programs have been created and developed during the last two decades. Some of these programs have been over the years extensively checked and their results are now quite consistent and reliable, compared with extensive measurements made all over the world.
Nevertheless, these programs have been used much more by the research community, in issues regarding building research (Wouters and Vandaele 1990), than by those who are deeply involved in building design and construction, mainly the design community, architects and engineers.

The reasons for the difficulties of the design professionals in the adoption of these techniques are quite well known and can be classified in different levels.
The first, is related to the poor *technical background*, in general, of these designers, who do not have enough knowledge of these techniques and their potentialities. Sometimes they do not know what can be achieved with the building performance assessment.
The second, is related to *technical information* they may heard about. They do not understand the advantages of using this approach so, they need much more information and above all they need training and a support center which could assist them.
These two issues, nevertheless, have nothing to do with the simulation process and the methodology itself. It is more an educational problem where, of course, the research community involved in this process can do a lot regarding this issues, namely in organizing courses and seminars for the design community and also for University students.
A good example of this approach is the experience in U.K where a training and information program have been carried out in the last few years (Hand, 1991).

THE METHODOLOGY

The application of simulation tools to the design process and performance assessment in building is, in fact, a technique which needs minimum background requirements of building physics, heat transfer phenomena, and a lot of common sense.
The main issue in all simulation processes is related to the way the building is (or will be) and the way the designer built its model. This crucial issue is the so called *"problem* or *descriptive abstraction"* (Clarke 1992). In this transfer process, the modeller has to understand, quite well, the overall heat transfer process in the building, and analyze which are the driven phenomena present in each particular case, e.g. solar gains, internal gains, heat losses, infiltrations etc). With this information, and above everything else knowing quite well or exactly what is wanted as a final result, the necessary decisions can be taken regarding all the implicit simplifications

National Institute of Engineering and Industrial Technology, Renewable Energies Dep.(INETI-DER)
Tel.351-1 7165141 Fax.:351-1 7160901
email:helder@donald.lneti.pt

which need to be done to the building, in order to obtain a consistent model with the reality, in physical and heat transfer process terms. In those simplifications it is necessary to have in mind the limitations of the simulation program itself and the hardware environment.
In figure 1 the several phases of all the simulation process are presented.

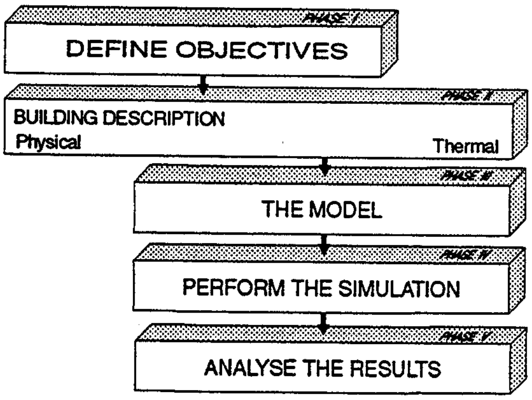

Figure 1: The Simulation Process

Objectives

In general terms, the simulation techniques can be used to assess the building performance, in a certain phase of the design process (a new building) or for an existent building (the usual case of a retrofit). In both cases, the objectives could be the same or different so the definition of these **objectives,** in the context of the simulation process, is quite important because is deeply related with phase II and III. In fact, the information required in these phases is dependent on the goals of the exercise. In any case, the performance assessment of a *part* or the *overall* of the building, or even a *detail*, is the final goal. Several items could be addressed in the simulation which have a major influence in performance, namely those related to;

geometry (site, orientation, opening areas, monozone, multizone, obstructions etc),
construction (type of envelope: walls, glazings, insulation, colour, shading devices etc),
occupation (people, equipment, lighting and ventilation strategies, etc),

Heating/Cooling (with or without, how much when and where, etc).

All, or a part, of these issues can be treated in the simulation process, depend very much on each case. If for instance, we are dealing with a design process, some of those issues are treated in the different phases of the design. In the early stage, probably only issues related with geometry, site and orientation should be addressed, then will follow decisions related to construction elements and finally in an more advanced stage, those related with energy consumption, mechanical systems and control.

Building Description

Having decided what are the objectives, it is time to move to phase II, the **building description.** This includes a detailed analysis of the geometry (quantification of areas), and the construction elements (type, thickness, physical properties). In this phase is also very important to define all thermal processes present in the building, such as major solar gains and its interaction with shading devices (if any), internal gains, their location and profile. In figure 2 an example of a possible case is presented.

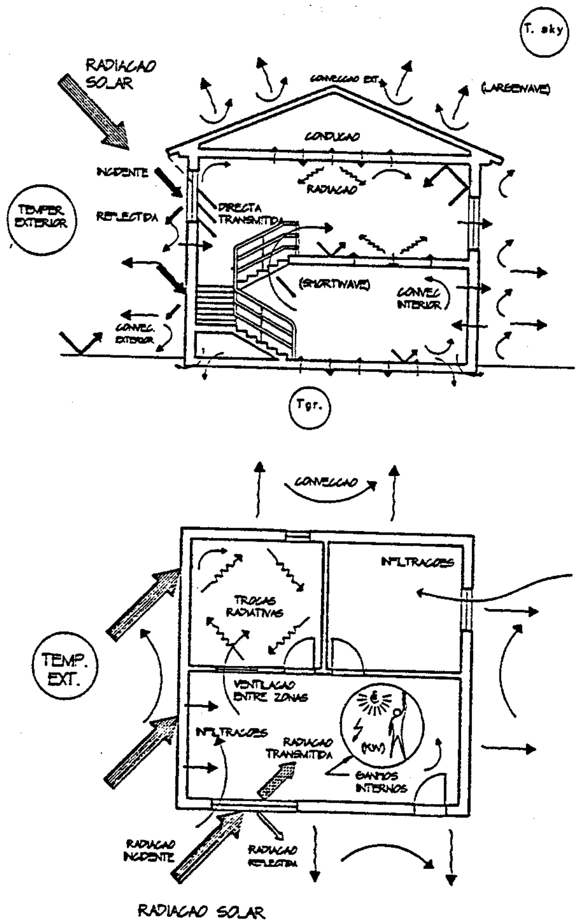

Figure 2: Thermal Process Characterization

The detail description in this phase depends very much, as said before, on the building itself and the objectives. As an example an exhaustive definition is not necessary, if for instance, we are in the early stage of the design process, were the main questions are related with the major forms of the building. On the contrary we will need a detailed definition if we are studying a Trombe Wall for example, where the thermal processes present are complex.

Model Definition

With these elements, it is time to move to the **model definition**, which corresponds to the *"problem abstraction"* and answers questions like;

-how many zones could realistically represent the building ?
-could a particular zone represent the overall thermal behaviour of that part of the building ?
-should we do a detailed definition and calculation of the view factor?
-how deep, should we model the air flow between zones ?
-how many layers should we consider in the exterior and interior envelope ?

The correct answer to these questions, is the key to the success of the simulation process, as sometimes there are several answers for the same question. The expertise and the experience of the modeller and a good knowledge of the capabilities of the program, which is being used, are fundamental issues in this phase.
In this paper we will not address any problems regarding the simulation program itself, because we are only dealing with simulation practice, we assume that we are using a proper and a well tested program where a validation methodology as been applied (Jensen and Perre 1991). If it is not the case, several other issues must be addressed prior to this discussion.

Perform Simulation

After the definition of the model, we are ready to perform the simulation. Several aspects must be addressed at this stage, related to the climate data, the period of simulation, the time steps, the controls errors and the global strategy.
The climate data, are a main constraint in the use of these programs as they need usually hourly data, which are not easily available. The period of the simulation varies widely depending on the objectives, e.g. do we wish to study a whole year or a particular period, summer cooling, winter heating or both ?
The time step is directly related to the quality of the results, but do we need more than one time step per hour ? It depends, on the real need of improving the performance.

Two main strategies are usually applied in the simulation process, the so called *free floating* and the *thermostatic* mode. Both can be used for the same situation, the answers obtained in both cases give us different information. For example, a building simulated for a winter situation in free floating mode give us information related to the dynamic response of the building itself, environmental discomfort, minimum and maximum air and mass temperatures. In the thermostatic situation the information is much more related with the energy issues.

The **analysis of the results**, is the last phase of the process, and involves the exploration and the interpretation of the information for the bad or good results. The first analysis of the obtained results must be a "mental" comparison with the expected prediction of the modeller during the process. It is at the first look where the main errors, if any, are discovered. Then it is time to explore the meaning of some particular results, having in mind our goals. Some crucial questions must be addressed at this stage, are we satisfied with the results ?, should we return to phase III and refine the model ?, when should we stop ?. The answer to these questions again depends very much, on the building case, the objectives, the goals and the modeller. There are no defined rules, except the ones related to good common sense.

CASE STUDY

The case we present in this paper will try to focus his attention in the model definition (Phase III), and also present the potentialities of using these tools.
The simulation program used in this exercise, is the European Reference Building Simulation Program ESP_r (Clarke 1985), which has been used in our Department since for a number of years.

The building in this case, is a ten year apartment building (figure 3) which is being used for research purposes and also as an example for the design community of the potentialities of the use of building performance assessment on a large scale.

The main goals in this case where:

* compare the relative position of the apartments
* quantify the influence of several types of construction.
* study the influence of internal gains and infiltration.
* compare several heating strategies.
* analyze how many zones can represent the total building.

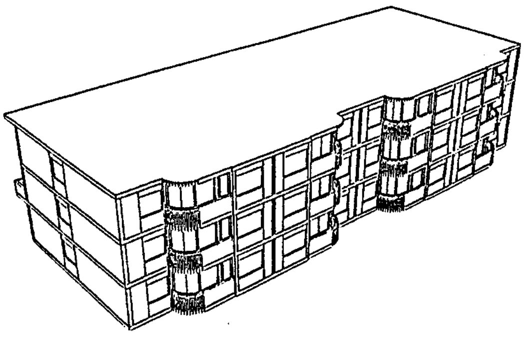

Figure 3: Building Apartment (West view)

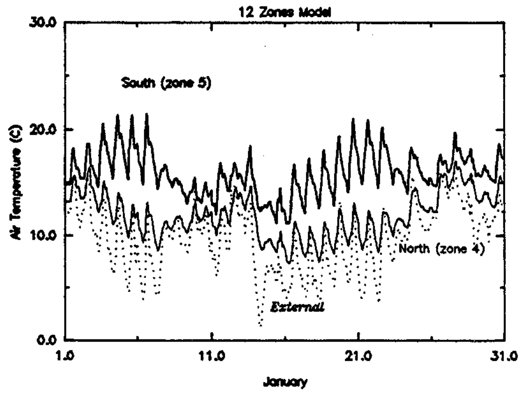

Figure 5: Free floating mode

12 Zone Model

The building is built with single brick walls (20 cm thick) without any insulation at all, single glazed, with the main glazing areas facing west.
The first strategy used in the model definition, was to consider each apartment as a zone. According to this concept a 12 zone model was created (figure 4 is a representation of the model).

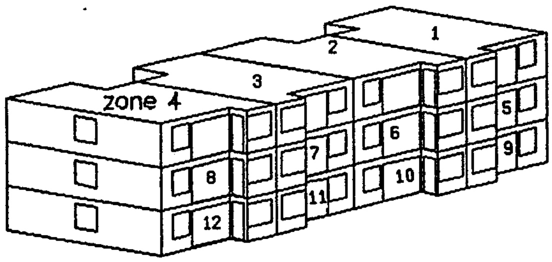

Figure 4: 12 Zone Model

This option, which corresponds to a large simulation exercise, will lead us to global results for the all building where relative comparisons between zones are possible. Nevertheless, this could not be the best option if we need to study, in detail, a particular apartment (see 7 zone model below).

The first simulation carried out for the 12 zone model was for a winter period, using the Test Reference Year for Lisbon (Lisboa.try), in a *free floating* strategy. Figure 5 represent the air and ambient temperature in two particular zones, 5 and 4, south and north zone respectively. Throughout this strategy, it is possible to analyze the dynamic of the building and compare, quite well, the performance of each zone. In this case it shows how bad the building is, even for the south zone.
In the next step simulations have been carried out, for the same model, heating all the zones to a thermostatic set point of 20°C.

In figure 6 the energy consumption for all the zones is presented, and several zones can be compared.

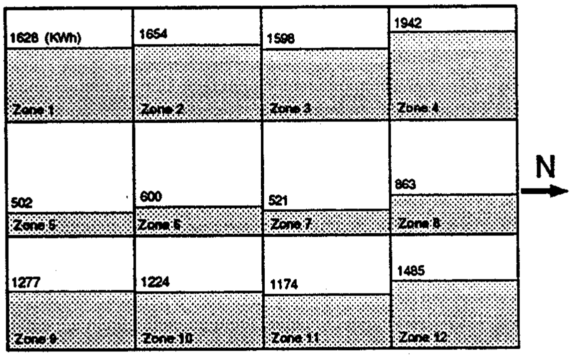

Figure 6: Heat energy (12 zones).

Several other simulations have been carried out in order to compare different types of construction, heating and operative strategies. Three cases were studied in terms of construction:

Case A: Single brick walls, 20 cm thick.
Case B: Single brick walls, 20 cm thick, + 5 cm external insulation.
Case C: Double brick wall with air gap, (11cm+4cm+11cm)

Three operative conditions, have been created, and are represented in figure 7.

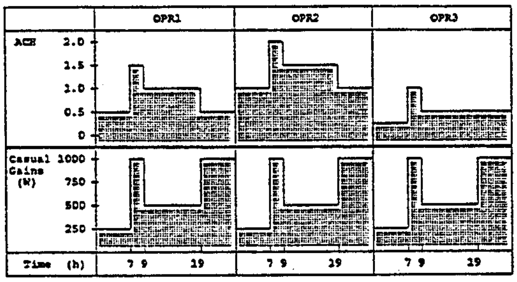

Figure 7: Operative conditions.

The heat energy for the total building, for these cases and several heating strategies are presented in figure 8 and 9.

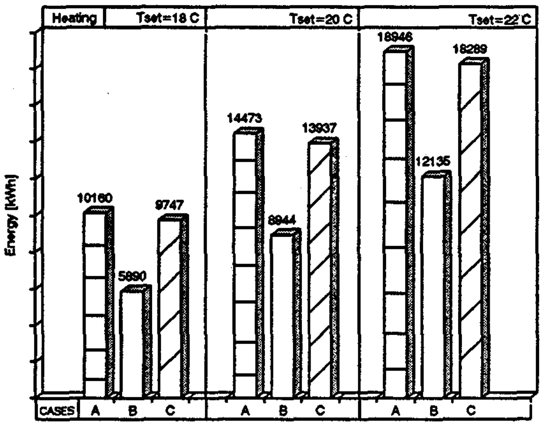

Figure 8: Heating Energy
(Cases A,B,C with Opr1)

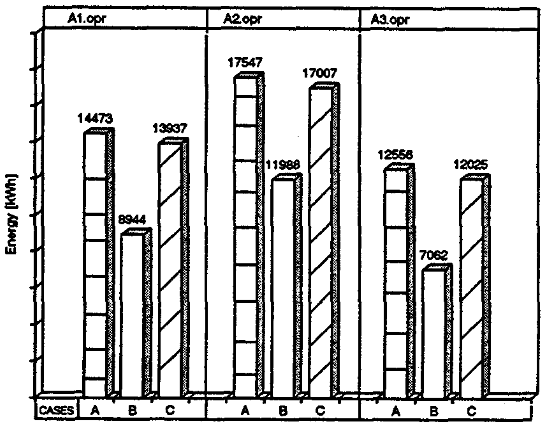

Figure 9: Heating Energy
(Tset=20 C)

1 Zone Model

The previous simulations are quite time consuming, in man and computer power, especially when the goal is a sensitivity study of different types of construction.
The next approach, in this exercise, was to explore the possibility of simplifying the model, in such a way that each zone could be studied in isolation. Therefore, by replication, the behaviour of all the building was successfully achieved.

A one zone model was created in order to represent a particular northerly apartment, (zone 4 in the 12 zone model), represented in figure 10. The assumption made was that the connections between existent zones were adiabatic. The simulations were carried out for constrution Case A and operation strategy opr1.

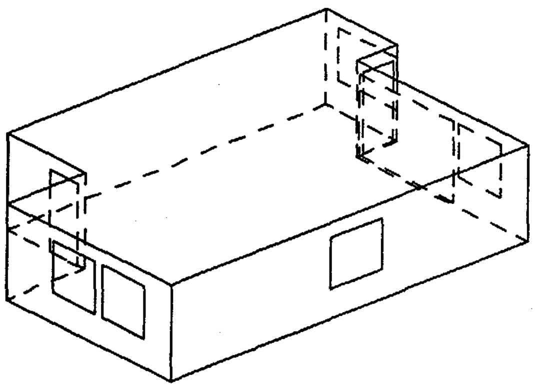

Figure 10: 1 Zone Model

In figure 11 the air temperatures for the two models are plotted, for the free floating situation, and no significant differences can be observed.

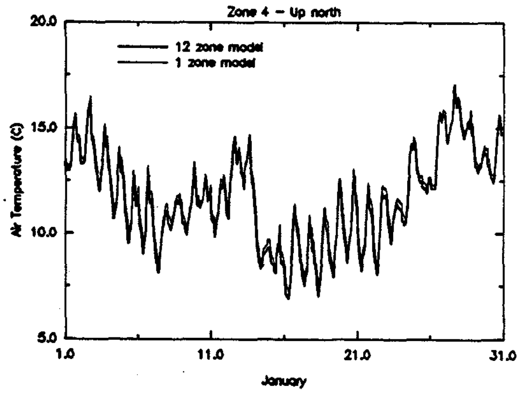

Figure 11: Models comparison (12/1 zones)

The same conclusion can be derived, for a heating situation (Tset=20°C) as the energy consumption for both models are very similar:

12 Zone Model- Qaux=1942 KWh
1 Zone Model- Qaux=1957 KWh

The obvious conclusion is that the one zone model can represent quite well a particular zone of the building.

7 Zones Model

A question must be raised by the modeller at this stage of the process. Is the option of representing a particular zone as a one zone model the best one ? In order to answer this question a 7 zone model has been created (figure 12), based on zone 4 in the 12 zone model.

In order to compare the three models (12,1,7 zones) it was necessary to have similar operative conditions. A new operative condition was created for all three, which assumes no ACH and casual gains.

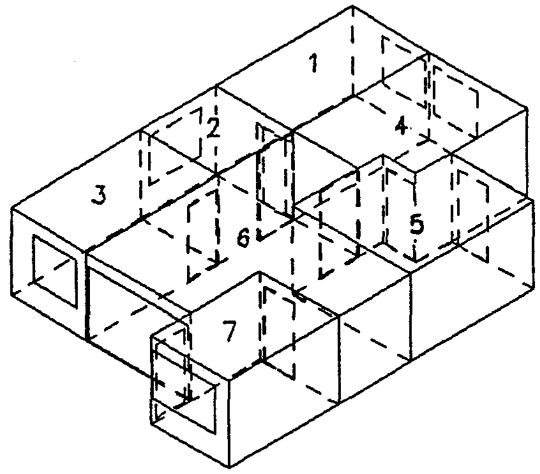

Figure 12: 7 Zones Model

In the first simulation carried out, with free floating strategy, the objective was to check the differences between the seven zones. In figure 13, the air temperatures for these zone are plotted, and the relatives differences are relatively insignificant.

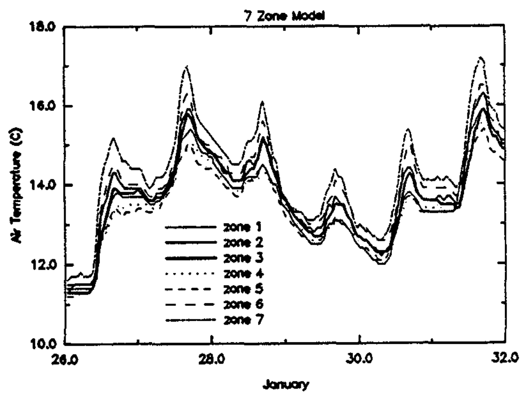

Figure 13: 7 Zone Model-Air Temperatures

Finally the results for the three models are compared, for free-floating and heating strategies.
In the first case, the results are presented in figure 14, the air temperatures for the models are compared over a six day period, for better visualisation.

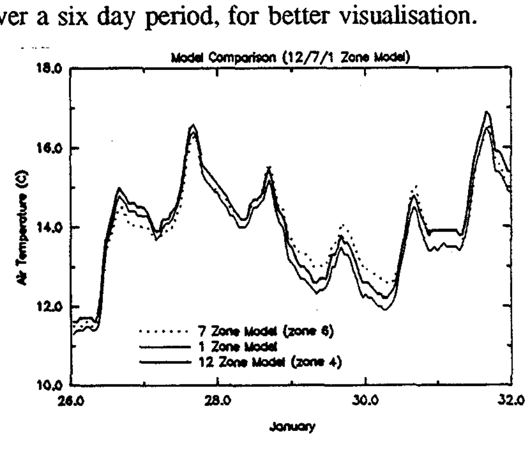

Figure 14: Model comparison (12/7/1 zones)

For the heating strategies (Tset=20°C) the heating energy for the three model is presented in table 1. The results are very similar, and the differences regarding heating energy are not significant.

Model	12	7	1
Qaux(KWh)	1732	1694	1738

Table 1: Heating Energy

CONCLUSIONS

The case presented in this paper has tried to focus on the main issues faced by the modeller in building simulation practices.
The several phases of the simulation process were presented, and the model definition phase was discussed with a particular case as an example.
The main issue in the example was related to the issue of "*problem abstraction*". In the early stage of the exercise a 12 zone model was created and several possibilities of thermal analysis presented. Then the goal was to simplify the models and compare the results with the large one (12 zones) as a reference. Two models of 1 and 7 zones were created. The analysis of the results lead us to the following conclusions:

* large simulations models, are quite difficult to built, and very time consuming.

* the one zone model, with replication of zones, can represent the total building very well. Consequently it is quite easy to perform sensitivity and parametric studies, without the disadvantages of the large model.

* the seven zone model, describing a particular zone, is a very good option if the goal is to study in detail that particular part of the building.

ACKNOWLEDGEMENTS

I would like to thank Luis Carvalhal and Susana Camelo for their help in the simulation exercises.

REFERENCES

Clarke, J.A. 1985. *Energy Simulation in Building Design*, Adam Hilger Ltd, Bristol and Boston.

Clarke, J.A. 1992. "Building Performance Prediction", *Proc.2nd World Renewable Energy Congress*,(Reading, U.K,Sep.13-18).

Hand J. "The Application of Building Performance Assessment Tools in Professional Pratice", *Proc.IBPSA 91 Conf.(Nice-France,Aug.20-22).*

Wouters P and Vandaele L (eds)(1990)."The PASSYS Test Cells PASSYS" *Document:114-89-PASSYS-INS-033 CEC,DGXII.*

Jensen,S.O.,Perre,R.V. "Tools for Whole Model Validation of Building Simulation Programs Experience from the CEC Concerted Action PASSYS",*Proc.IBPSA 91 Conference,(Nice-France,Aug.20-22).*