SIMULATION TOOLS FOR BUILDING ENERGY DESIGN

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ABSTRACT
This research aims to investigate how building energy simulation tools are used in the first design stages, focusing on the design practice of architects willing to obtain the optimal energy performance in order to create sustainable architecture. We survey in which measure the simulation tools could guide the choices of the designer, if they are used by consultants or by the designers themselves, and which are the main reasons that prevent their use in the common design practice. The research is conduct through these instruments: literature research, research by professional figures -questionnaires-, research through a case study.

INTRODUCTION
In the last 40 years two events pointed out the problem of environment pollution and the necessity of a better energy use. First is the oil embargo in the 1973: the shortage of the most used energy source warned the society of the exhaustibility of the not renewable ones. Second are the global warming and the ozone depletion: the Kyoto Protocol in the 1997 represents the agreement of the industrialized countries to reduce the emission of pollution in the atmosphere, to increase the energy efficiency in the principal economical sectors and to promote research and development projects in the use of renewable energy.

In this general outline the issues of energy efficiency and saving become fundamental at the scale of the building, given that they are responsible for 30%-40% of the primary energy consumption. The challenge is to introduce an energy conscious approach in the normal building design process in order to reduce the environmental impact.

As Figure 1 shows, the scheme of an energy efficient design is characterized by:

- a previous establishment of the targets to be achieved (in a pre-design stage)
- a cycle structure based on hypothesis/verification and hypothesis/choices
- an interdisciplinary work among the actors with an addition of expertise in energy design and sustainability.

In each design stage the decisions taken have their influence in the energy savings, but it is in the early design stage where the most important ones are allocated; the latter have the largest impact on the final result of the building design, considering also the greater opportunities and the less expenditure in design changes (see Figure 2).
The building is an extremely complex environment, where the envelope, the HVAC (Heating, Ventilation and Air Conditioned) and lighting system are the principal responsible of the energy consumption and, working as an integrated system, define the energy requirement and behaviour. Therefore it is important that the energy performance is understood like a result of all the aspects of the building design process and, given the strong complexity of the problem, that it is backed by adequate analysis and modelling tools [Hong et al. 2000]. Among the support tools that are available to the expertise involved in the design process, architects and engineers, the most efficient in evaluation of the energy behaviour are the energy simulation tools. These software create a virtual building and environment, allowing a performance prediction closer as much as possible to the reality. This approach gives the possibility to the designers to improve and to optimize the design and to introduce new technologies for energy efficiency and saving. The effect of the simulation in the design process can be maximized if the energy performance analysis is realized in the first stage of the design (see Figure 2).

STRUCTURE OF THE RESEARCH

After a brief introduction about the energy problem in building design, the research is carried out through three investigation tools:

- **LITERATURE**: it represents the first step in understanding the simulation tools and their application in the design practice, starting point for the comparison and the selection of the parameters for the evaluation.

- **SURVEY TO PROFESSIONALS**: after the general overview obtained by the literature, the surveys allow to investigate on the design practice from a closer point of view and to get, directly from professionals, an evaluation of the simulation software.

- **CASE STUDY**: it is a simple design tested in the first stage to approach directly the energy simulation software.

The next sections analyse deeply the aim, the methodology, the boundary conditions and the results of the used investigation tools.

LITERATURE RESEARCH

Given the constant evolution and the relative newness of this field, literature about this subject mainly means proceedings of conferences, PhD researches, papers about developments and implementations of existing tools, applications, discussions on internet sites, magazines, informative advertisings.

Some programs have been chosen for a more detailed analysis. Among them there are well known energy simulation programs, tools developed in The Netherlands, that we knew during the Building Simulation Conference 2003 in Eindhoven and tools we wanted to investigate more in.
The survey includes three answer types: multiple selections of specific categories, a single selection of a specific category and free answer.

**Discussion of results**

The results are discussed on a sample of 44 architects and 50 engineers, who answered the survey. Figure 3 shows that the decisions taken by architects about energy and environment are still mostly guided by experience, while a consistent percentage of them uses the energy simulation software, comparing to those who turn to consultants for advices.

![Graph showing what guides architects' choices about energy and environment in the design process.](image)

**Figure 3**

Figure 4 shows the different approach of architects and engineers to the use of energy simulation tools in the different design stages. It is possible to assume that in the late design stages, being required a higher level of expertise both in modelling and in building physics, the architects turn to consultancy firms.

![Graph showing in which design stage is the simulation tool used.](image)

**Figure 4**
The participants were also requested to point which energy simulation tool they use the most. The legend of Figure 5 shows the list of tools that were investigated in the literature research and which of them are used by the professionals. The most considerable differences between the two groups are the use of ECOTECT, meant for architects and in the common practice used only by them and that, in both graphics, the answer “other” has a prominent position, because of the not exhaustiveness of the list of considered tools, not comprehensive of the one feature tools, the in-house developed tools, less know ones, etc.

**Figure 5**

**CASE STUDY**

It represents the conclusive element of this research. To go in deep in the use of the simulation tools was necessary to analyse, from the point of view of a designer, the use of some energy simulation software. The testing process is carried out as if a designer has to start a new project, approaching to the previously unknown world of the simulation tools, with the aim to be helped and advised on the design choices by the simulation tool itself. As already pointed out, the objective of this kind of investigation is to survey how simulation tools could guide the choices, especially in the first stages, when are taken important decisions that influence the energy efficiency of the building: orientation, floor plan distribution, space usage, material, glazing area (approximately), wall system (approximately) and heating and cooling strategy.

Therefore are analysed the tools that evaluate the building thermal behaviour and at the same time claim that they are suitable for the early phases of the design process. They are: B.D.A., ECOTECT, Energy-10, eQuest, h.e.n.k., IES, M.I.T. Design advisors, ORCA, Tas.

**Design**

To simplify as much as possible the decision making process and to arrive to a stage where it is possible to intervene in the energy choices, the design has been defined by:

- Decided shape: a BASE CASE that has a simple plan, a predefined surface area, function and occupancy;
- Lack of constraints: physical (site, location, orientation, etc.), economical (material cost, time, etc.), regulations, aesthetical, distributive and resulting from involvement of any third parties;
- The choices are taken only to evaluate and optimise the building energy design.

To better test out the simulation capabilities and versatility of the software, two different base cases were realized:
1. THE OFFICE: a three storied building with a rectangular floor plan of 400m² (each floor). The windows are continuous at every floor and the roof is flat. The internal distribution is characterized by a central staircase that is the vertical distribution and a corridor around it. The office rooms are distributed along the sides.

![Figure 6: floor plans and a three-dimensional view of the office base case](image)

2. THE DETACHED HOUSE: house with pitched roof, the floor plan has an “L” shape organized in two storeys for a total floor area of 200 m².

![Figure 7: floor plans and a three-dimensional section of the detached house base case](image)

**Evaluation method in the design process**

A very important issue was the insertion of the evaluation method in the case study design process, especially how to analyse the results and assess the choices, considering the multiplicity of the tools used.

![Figure 8: evaluation method in the design process](image)

As it is shown in the Figure 8, the design choice is evaluated in the same time with all he simulation software and from the analysis of the results the decision will be taken and that trough the various design stages.

Zooming in on the early design stage, the decision-making process becomes more complex (see Figure 9):

- The base case is evaluated with the “tool A”;
- The designer reads and analyses the results;
- More solution options are created and simulated with the “tool A”;
- Those results and the previous ones obtained are compared;
• The designer evaluates the options and makes the decision;
• To assess the next design decision the process restarts.

*Figure 9: evaluation method in the early design stage*

The same process will be applied on the other energy simulation tools.

The final results will consist in applying a methodology of the use of energy simulation tools in the first stages of the design process and in the evaluation of the selected software.

**CONCLUSIONS**

The research is still in progress and the results have to be finalized.

As regards the literature research new papers are constantly added to the references, broadening the information about the available tools and the developments in the sector, following the debate about the use of energy simulation tools in the design process.

The surveys are on line since January 2004 and at the end of April a reminder will be sent to the same professionals and mailing-lists. Anyway has been reached a sample numerous enough to draw some conclusions, that need to be more elaborated through the connection of related variables, such us the dimension of the studio or the working experience with the way of evaluating the building energy behaviour or the simulation tool used.

The evaluation method through the case studies has been applied to the half of the chosen programs and in the end the comparison of the tools will be elaborated on the basis of different parameters: kind of interface, type, number and specification of the input, level of needed simplification, kind of technologies that can be verified, readability of the output, etc.

**REFERENCES**


