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SIMULATION TOOLS FOR ENERGY AND ENVIRONMENTAL DESIGN PRACTICE OF ARCHITECTURE

A CRITICAL AND COMPARATIVE ANALYSIS

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EXTENDED ABSTRACT

ARCHITECTURE

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INTRODUCTION

In Architecture nowadays there is a growing need for the use of softwares in order to perform a more prompt analysis of some essential variables (environmental issues such as comfort, light, sustainable performance and costs among other things) which, otherwise, would be slowly carried out. Consequently, the existence of some software support is almost mandatory because its use allows determining the effects that the variables have on the building's performance in a swift and accurate way. However, if the software doesn't satisfy the needs of the user it will become of little use for the task to be fulfilled. And so the comparative studies of this kind of software arise. But from the studies made so far, few are those which take the user into greater account and those that do so, even harder it is to find any in which the architect is considered the main user. Besides, none of these studies was made in Portugal. Having these facts been taken into account, this dissertation's theme focuses on the comparison between several environmental and energy simulation softwares available for use, setting out to understand which one is more accessible for an architect. This study is of great importance because it allows, according to the intended use, to know which software is more adequate to a specific problem, allowing for a swifter and more precise processing and interpretation of the obtained results.

The following goals were considered foremost to the development of this dissertation:

1. Acquire the environmental and energy simulation softwares available in the market;
2. Analyze the different characteristics of the softwares from the perspective of an architect such as the outputs, the usability and the result's rigor among others, as well as it's adequacy to different purposes, with the aid of a case study;
3. Make recommendations for the different kinds of use, such as the adequacy to professional practice and to architecture teaching.

In order to reach the proposed objectives, it was necessary to create a methodology based on the initial theoretic investigation followed by a practical investigation based on a case study.

A bibliographic consultation was made as to understand the programs, its theoretic concepts and the principles underlying their different tools. This consultation is based on the web pages of the corporations that created the programs under scrutiny (like the *Autodesk®* site referring to *Autodesk® Ecotect® Analysis* or the *DesignBuilder®* site), on some articles referring to comparative analysis of this kind which were already made and also in books that explain the concepts concerning the programs.

The practical investigation was based on the application of environmental and energy simulation softwares such as *Autodesk® Ecotect® Analysis, DesignBuilder®*, *eQUEST®*, *LT Portugal®* and *VE-Gaia®* (with some of these programs being available in the LAB), and on a critical review made for each one of them in terms of quality and quantity. This analysis was also made based on a case study – The Civil Engineering Building of the IST, for a more complete comparison. Regarding the quantitative analysis, there is only a comparison with the results of the case study in terms of energy consumption and CO_2 emissions, for it was the only data obtained. However, regarding other simulations, it was only established a comparison between the various softwares.

In order to better evaluate and objectify the chosen parameters for the qualitative analysis, a questionnaire was made for the 4th year Architecture students who attend the Environmental Design I class (academic year of 2010/2011). This questionnaire also served for a better understanding of the user's perspective, specifically architecture students, on the softwares used in class (*Autodesk® Ecotect® Analysis*, *DesignBuilder®*, *LT-Portugal®*, *AutoCAD®* e *ArchiCAD®/Artlantis®*).

After the analysis and comparison of the different softwares, it was possible to establish which one or which ones were more accessible for architecture practice, that is, easily maneuverable, intuitive and graphically representative, more "user friendly" and those that set themselves to perform deeper analysis within the scope of investigative research.

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THE SOFTWARE'S BACKGROUND IN ARCHITECTURE

For a better knowledge of the Environmental and Energy Simulation computer programs' importance and impact on architecture, it is important to determine the concept of Environmental and Energy Simulation. *The American Institute of Architects* defines it as being the practice of using computer programs to model and simulate the energetic performance of an entire building or the systems inside it. This complete modeling of the building provides valuable information about the building and the use of energy systems as well as the running costs. An important aspect of this kind of modeling/ simulation is the fact that it considers the interaction between the different elements of the building such as the impact of lighting on the conditioned space gains or the impact of natural light on the electrical lighting gains. The impact of the different uses of the building and its occupation patterns are also considered.

According to Mills (2004), the origins of the energy simulation softwares began in the 70's. Before that time, the energy audits were handmade and at a significant cost. In the 80's, the first Analysis and Design softwares based on 1st generation simulation started to be used by researchers and consultants. The 90's were marked by the improvement and fast proliferation of tools meant to a wider spectrum of users, including commercial and residential consumers, and also by internet based tools. This influx of users and the development of softwares caused the audits' costs to drastically drop. He also mentions the fact that despite the enhancements shown throughout time, the residential energy softwares have revealed very little market penetration. This is essentially caused by the variety of existing softwares which are developed by different teams and lack a sense of unification.

Nowadays there are still many architects that don't use these kind of tools in their daily practice for most of them, while designing a building, must have into account a great variety of factors of which the energy and environmental efficiency is only one and sometimes it isn't even considered as having the slightest influence on the final outcome due to lack of proper knowledge. Also, when this aspect is looked upon, usually the simulations only take place when the building is already completely set out. This kind of attitude leads to a situation in which if there is a need to change something, it will be a lot harder and costlier to do so because it wasn't thought of from the beginning. Another reason that makes architects a bit reluctant in using these kinds of softwares is the fact that, many times, there is a need for a deep understanding of numerical and thermal analysis, which isn't a very common feature among architects. Altogether, there are few types of software that make recommendations for an energy and environmental improvement of the buildings, most of the times leaving the user to test the various solutions for himself, which becomes quite difficult in an advanced phase of design.

Despite the fact that these tools haven't been very popular in the last decades, currently these values are beginning to augment and it is predictable that, in the future, they will be part of the architecture studios' day-to-day. This is due not only to the existence of legislation, which is becoming more constraining, but also to the fact that technology evolves vertiginously, leading to the perfecting of the softwares' calculations combined with an appealing and easy to use interface. Notwithstanding that it isn't yet a reality for every type of software, it is predictable that the development of these kind of tools will evolve to the point in which it will analyze a building and indicate what are the best solutions for an optimization of comfort and consumption, allowing the architect to choose the solution that most pleases him/her. This would increase the number of users of these kinds of tools at a large scale.

Currently on the USA Department of Energy's webpage there are more than 400 types of software focusing on energy and environmental simulation. Each one of these has a small description, the target audience, the kind of inputs it needs, the kind of outputs it generates, the necessary knowledge, the weaknesses and strengths. These parameters serve for a brief introduction to the type of software being dealt with.

Throughout the years and in order to better develop these tools, the need came up to compare them and realize what would be needed to improve in each one of them.

Presently there are various studies carried out in this field. On the other hand, and considering that only recently did architects started to explore these kind of tools, the comparative studies already made have a very technical speech and few take the user into account. Also, none of these studies was made in Portugal hence the necessity for the execution of this study.

Comparative Analysis: *Software* Performance

Through the case study chosen, there was a qualitative and quantitative analysis of the software, taking into account various relevant parameters.

Regarding the qualitative analysis, the parameters defined were: System, Features, Modeling, Outputs and User. Within each parameter, specific criteria were defined for a more rigorous analysis. Subsequently scores were given within the criteria for each parameter in ordinal scale, in order to assess the satisfaction of this criterion in the software concerned, following the principles established by Roy (2000) and Bryan (2002), using a scale of zero to three, where **zero** refers to the absence of the criterion, **one** equals a reduced satisfaction of the criterion, **two** a moderate satisfaction and **three** is the overall satisfaction with the criteria. This evaluation of the parameter is obtained by the sum of the values assigned to each criterion, making it simpler to make a general assessment of all parameters in the following chapter, discussion of results.

In the **system** parameter very important criteria are considered that are required knowledge at the start of a project for each of the softwares analyzed. Six criteria were chosen for this parameter: *Operating System*, *System Units*, *Embedded Library*, Software Stability, *Climate File* and *Control of History*.

In the **features** parameter, regarding calculations and technical approaches of each program which are essential to understand to what end each software should be used, three criteria were chosen: *Technical Approach*, *Calculation Type* and *Cost Estimates*.

The **modeling** parameter is divided into three sub-parameters: **Extension**, **Building Modeling** and **HVAC Modeling**. Regarding the **Extension** sub-parameter, which refers to the ability of software to extend to other programs, such as modeling or energy simulation programs, two criteria were highlighted: *Interoperability* and *Design Data Input*. **Building Modeling**, which refers to the entire process of modeling the building and set all parameters (except for HVAC) concerning the operation of the building before any simulation, is divided in seven criteria: *Project Information*, *Geometry*, *Building Construction*, *Renewable Energy Systems*, *Internal Gains*, *Infiltration* and *Lighting Factors*. In **HVAC Modeling**, a parameter that encompasses all the relevant criteria for a good characterization of the modeling, three criteria were approached: *Thermostat Set Point*, *HVAC System* and *Design of Systems*.

In the parameter **outputs / results**, which is one of the most important for this thesis development due to the fact that it is through these that conclusions at quantity level can be drawn and it is through these that the analysis and interpretation to improve the performance of the building can be made. Here seven criteria stand out: *Export Outputs*, *Outputs Formats*, *Types of Outputs*, *Content of Outputs*, *Optimization Recommendations*, *Other Simulations*, *Analysis Duration* / *Simulation and Interpretation Easiness*.

Finally, the **user** parameter, which relates to all the criteria that regard the interpretation and interaction with the user, seven criteria were chosen: *Help*, *Clarity of Menus and Toolbars*, *Model View*, *Presentation of the 3D model*, *Required Knowledge*, *Flexibility of Inputs* and *Ease of Use*.

The following table presents a summary of the ratings for the softwares analyzed regarding all parameters.

	Autodesk® Ecotect® Analysis	*DesignBuilder®*	*eQUEST®*	*LT-Portugal®*	*VE-Gaia®*
I. System	13	14	11	12	13
II. Features	6	6	8	3	5
III. Modeling	24	26	24	12	26
IV. Outputs/Results	17	17	14	13	19
V. User	17	17	12	12	15
Total	77	80	69	52	78

In quantitative analysis, several simulations were performed on the case study in the different software. The comparison is performed at the energy simulation, CO2 emissions, thermal comfort and daylight levels. This comparison is achieved through the simulation results of the case study, which are then compared as a curiosity with real data. These data are only for the total energy consumption, both monthly and yearly. The comparison performed at the level of CO2 emissions is based on a study for a rehabilitation project for the case study building, conducted by members of the Instituto Superior Técnico and ADENE in 2003. The comparison made in terms of thermal comfort and luminance is performed only between the results obtained by the software, because, although there is no real data for a more reliable comparison, it is interesting to see and analyze discrepancies in the results obtained. Besides, these values are very important for an architect to develop a good building; it lets one know if the building is sustainable or not and have a performance that is comfortable both thermal and luminous for users who will enjoy it.

CONCLUSION

This work aimed to compare, both at critical and analytical levels, the environmental and energy simulation tools for the practice of architecture design, taking into account a careful and complete analysis, regarding the perspective of the architect. The theme of this dissertation includes some of the very current research at performance and sustainable energy levels, which will become increasingly important over the years. Being such a tool a very useful one for a design practice of Architecture, it is important to know what types of software are more suitable for the intended purpose. Although there are already some studies in this area, there are a few that have the user into account and it is rare to find these regarding an architect as a user. This, probably, due to the fact that only recently architects began to express a greater interest in this area. Moreover, none of the studies found was carried out at national level, which confers to this study utmost importance.

For the qualitative and quantitative analysis the Civil Engineering Building was used as a case study, which is described in terms of space, materials and occupations, to standardize the inputs required for each software and obtain outputs with less margin for error.

A qualitative analysis was conducted, taking into account as the main matrix the study by Lam et al (2004), the main parameters of the selected papers and some aspects of the questionnaire answers. After this analysis, for each group of parameters, a rating is made, in ordinal scale 0-3, depending on whether or not the parameters considered are satisfied. Taking this classification into account, the software with the highest score is the *DesignBuilder ®,* followed by *Autodesk ® Ecotect ® Analysis* and *VE-Gaia*. The quantitative analysis, performed at the level of energy consumption, CO2 emissions, thermal comfort and daylight levels, presents results not quite consistent among themselves softwares and the actual values. However, the amount of factors that alter the results do not allow an exact comparison of the results, and is considered more relevant to know if all follow the same trend and are in the same order of magnitude, what happens, apart from some exceptions.

After analysis, it is understood that the best software at the simulation energy level must be set according to the type of user and the intended purpose. Taking these factors into consideration and all the qualitative and quantitative analysis, the software most appropriate for each situation is recommended.

Note that almost all the software studied perform more detailed analyzes examined throughout the project to an optimization the project, while the *LT-Portugal ®* is designed for the early stages of the project, so that in the initial decisions gross errors at the level of building energy performance can be avoided. This difference of purpose does not allow a rigorous analysis the software, because they have different characteristics. However attempts are made to reach a more objective evaluation as possible through a detailed analysis, both qualitatively and quantitatively.

Here we arrive to the conclusion that the best software for a user with basic or null knowledge regarding the building analysis mentioned above, seeking a quick and easy modeling, capable of comparison, is the *LT ®-Portugal.* For a user who has some more advanced notions of concepts of energy consumption and seeking relatively quick results, no need to be very strict, as an architect who works in an office where you do not have time for a complex analysis, or even a student architecture, the recommended software is *Autodesk ® Ecotect Analysis ®* or ® *VE-Gaia.* For more experienced users who want to conduct a further study, such as architects who already have some experience and knowledge of concepts related to building energy performance, or architects who are performing some sort of research (at post-graduate or doctoral), the recommended software is *DesignBuilder ®.*

This study is extremely important and it would be interesting to see more papers written about this subject because there are constantly emerging new software with features more advanced and it would be important to pursue this type of analysis in order to inform the community of architects at national level and also international level, regarding the type of existing software and which are best suited to each type of user. In addition it is hoped that this study serves as a basis for future deeper investigations in this area. For example, to create an interface in *AutoCAD ®* enabling the calculation of the main environmental parameters that an architect needs to know to create more sustainable projects, without the need to export the information to other software, and at the same time suggest more sustainable solutions taking into account the analysis made of the project. Another example for a future investigation is to analyze the same softwares, more deeply at the usage level, by using different case studies with different types of uses, to check the impact of the variations of usage in the results and if these are very different from the results obtained in this study.