REFLECTION

A computational method to guide sustainable energy upgrading of school buildings in Greece

through passive design interventions

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1.0 Introduction

This document aims at presenting a reflection on the process followed and the final outcome of the conducted thesis. More specifically, the question of whether or not, and to what extend, the developed workflow managed to achieve its initial goal, will be addressed.

1.1 Product, process and planning

The objective of this thesis was to develop a computational method in order to guide the renovation of typical school buildings built between 60s and 80s in Greece, using passive design measurements. More specifically, this is done through the combination of simulation and optimization tools aiming to identify optimal designs for different renovation cases.The method seeks not only to identify the most impactful passive interventions in terms of the schools' thermal and daylight comfort, but also those with the highest effect in lowering their energy demands. A generic geometric model of a classroom-corridor layout is taken as case study, exploring the applicability of the developed workflow for two climate zones in Greece.

The final product of the thesis is the developed method itself along with the conclusions drawn from the analysis of the optimization results for the three different climate zones, which indicated useful correlations between the various passive design measurements and the defined objectives. Moreover, knowledge gained throughout the process regarding the possibilities, risks and limitations of the developed workflow, can be used for further improvements and as recommendations in similar case studies.

Last but not least, main focus of this thesis was to gain more knowledge about the different aspects that are, or might be, involved in an architectural design problem such as the renovation of school buildings. In this case, these are building physics aspects such as thermal comfort, natural ventilation and daylight, and computational aspects, by means of the available computational tools. Handling both these topics, with which i previously had very little experience, proved to be quite a challenging task but it also broadened my perspectives on why and how these aspects can become more integrated parts of the architectural processes.

The process of the thesis evolved several steps, from the definition of the research framework, to the first conceptual ideas for the creation of a computational design tool and finally the development of the final computational model. While the time planning was in general aligned with the P1,P2,P3 and P4 phases, the process was partially interrupted between P2 and P4 due to my dedication to the Solar Decathlon competition which demanded large amount of my time, ultimately decreasing the amount of time spent for the thesis.This led to a very limited time planning for the completion of the thesis, partly limiting its initial goals

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1.2 Method

1.2.1 Literature review

As a first step, an extensive literature review was conducted. The main aim of this step was to provide valuable insight about the current condition of existing school buildings in Greece, identifying their most problematic aspects as well as defining the parameters that influence their energy, daylight and thermal performance the most. In addition to that, research was done to investigate the current regulations and guidelines for school building designs in Greece. Moreover, review of various research papers regarding energy upgrade of existing schools was conducted, to compare different approaches and provide an overview of different assessment tools and metrics for daylight and thermal comfort. Finally, optimization techniques for building scale problems related mainly to energy performance were explored, in order to better understand and validate their importance, as well identify possible challenges and limitations of their application.

1.2.2 BESO

The applied method follows the Building Energy Simulation and Optimization (BESO) workflow.

Preprocessing

This step involved the creation of the parametric design model for the case study, as well as the development of the simulation workflow. For that purpose Rhino, along with Grasshopper and its plugins Ladybug and Honeybee were used. Preliminary analysis, provided annual results regarding daylight comfort, thermal comfort and energy consumption for the case study model in the 3 main climate zones of Greece. Once the preliminary analysis of the existing situation was done, the insertion of possible passive measurements takes place in the form of parametric variables. More specifically these variables consist of various window-to-wall ratios, shading options, corridor types, wall types, glazing and shading material and orientations. The initial selection of variables along with their ranges was re-evaluated in preliminary manual simulation processes. The main challenge in this step was to address the complexity of parametric model simulations. For this, a good balance had to be found in how abstract and simplified the parametric model and the simulation settings had to be, so as allow for a good control of the included variables, while at the same time generating accurate results.

Optimization

In order for the optimization model to be developed, variables, objectives and possibly constraints, had be defined and the proper algorithm and number of designs had to be selected. Optimizations were run on modeFRONTIER software, which integrates with Grasshopper for running the simulations. The process of running the optimization was proven to be quite challenging in regards to technical issues. More specifically, the fact that an experiment could run for up to 72 hours, grew the -necessary for refining the process- feedback loop significantly. Moreover, an interruption of the process, due to network issues, sometimes caused the software to fail license validation thus terminating it. The process then had to be restarted. Lastly, access to hardware provided by TU Delft, although very helpful, was also limited, as the infrastructure had to be shared with other university members.

The results from the successful optimizations were further analyze, exploring their distribution in the design space, the correlations between variables and objective and the impact of the variable ranges towards the objective and finally the selection of the best performing results. The formed guidelines regarding both the results and the process will ultimately help architects and engineers, responsible for the renovation projects of such school buildings in Greece, to select among various passive interventions depending on the climate zone the building is located by integrating the proposed method as part of their early design process.

1.3 Relation to the scientific and social framework

1.3.1 Scientific relevance

The process of converting an existing school building into a modern sustainable, energy efficient one is a demanding task. Trade-offs are introduced between energy efficiency, comfort, feasibility and educational impact. The aim of this research was to make the correlations between the first two clearer, in terms of the parameters that define them, and provide more knowledge regarding the possible passive design measurements that can be applied. Understanding the possibilities, risks and challenges of the proposed method ultimately provides valuable insight regarding the future development of such renovation processes. The research carried out, also aims to create a more clear and better defined path towards achieving energy efficient school buildings using computational tools.

As part of the research conducted important knowledge has been gained not only concerning the parameters affecting these two objectives, but also the useful guidelines that can be extracted from the optimization results themselves. These guidelines can in turn prove extremely valuable during the early design phase of the retrofitting process, as the effect of their application will become clearer, leading to a future where:

“A school building designer has access to a database of conducted BESO studies and their results and is able to address his design decision guided by the knowledge and guidelines the collected data can offer him, based on his/her specific case study and its constants.”

This thesis ultimately served the aforementioned vision by:

- Establishing the foundation for consequent BESO studies
- Justifying its importance by highlighting the relevance of its results
- Constitute an example of proposed guidelines, under its specific context
- Explore and define the most appropriate data visualization methods

Therefore, this research can only be seen as a very first step towards the further development of a design tool that could potentially constitute a necessary asset in the hands of the School Building Organization of Greece, during retrofitting processes.

This process could save the designer a lot of time and effort. The increased complexity of satisfying contradicting design objectives is addressed by the optimization processes. This way, the designer can then focus his efforts in integrating the proposed design solution in a real life scenario and address the gap introduced due to the abstractions present in the simulation classroom-corridor model.

1.3.4 Societal relevance

Students spend significant amount of hours in school buildings, which are often described as the “third teacher” as they have the ability to shape behaviors. It is thus crucial to ensure that school buildings provide students with healthy comfortable environments, improving the conditions for learning. Furthermore, by implementing sustainable strategies such as reducing dependency on fossil fuels for heating and lighting, school environments can raise environmental awareness to future generations and guide sustainable lifestyles. As described by the ISO-15392 standard sustainability involves three primary aspects which are mutually interdependent and interrelated:

- the *environmental* aspect
- the *economic* aspect
- the *social* aspect

This research eventually tackles all three aspects in a direct or indirect way.The environmental aspect is tackled through one of the main research objectives which is to minimize the energy demand in school buildings. The economic aspect lies on the energy and time efficiency that may be achieved by developing such a renovation process while the social aspect,as it was initially mentioned, relies on the improvement of the students well being and enhancement of their learning ability.