Implementation of Sensitivity analysis in sustainable building design

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Abstract

Very low energy buildings and passive houses need to be planned in an integrated manner. Integrated energy design (IED) process is based on the well-proven observation that changes and improvements in the design process are relatively easy to make at the beginning of the process, but become increasingly difficult and disruptive as the process unfolds.
IED is based on the trias energetica approach and typically requires the development of building models that support the design process. Furthermore, an integrated energy design process involves the integration of the following primary design concerns (based on Steemers 2006).
A new tool that can be used to run simulations during the design phase to produce building performance information on energy use and thermal comfortwas developed further to maximise the design information output. It was also coupled with cost data in order to be able to do total cost evaluations as required by EPBD. It can handle input parameter and run them in a parametric study on energy performance and cost optimality. This can be performance vs. costs, performance vs. comfort, and costs vs. comfort and can be used to support the IED. A sensitivity analysis makes it possible to identify the most important parameters in relation to building performance and to focus design and optimization of sustainable buildings on these fewer, but most important parameters. The sensitivity analyses will typically be performed at a reasonably early stage of the building design process, where it is still possible to influence the important parameters. The methodology is presented and an application example is given for design of an apartment building in Norway. Thus it helps to make design decisions that are on the core line of sustainable building design.In the design of sustainable buildings it is beneficial to identify the most important design parameters in order to develop more efficiently alternative design solutions or reach optimized design solutions.

Sustainable building design; sensitivity analysis; multi-objective optimization

1. Introduction

Building performance can be expressed by different indicators as delivered energy use, environmental load and/or the indoor environmental quality and a building performance simulation can provide the decision maker with a quantitative measure of the extent to which an integrated design solution satisfies the design requirements and objectives(Augenbroe and Hensen 2004).

In order to achieve such reductions of the energy use in new buildings it will require development of new construction solutions, new types of building envelopes, and development of new building materials. It will also require the development of more holistic building concepts, sustainable buildings where an integrated design approach is needed to ensure a system optimization and to enable the designer(s) to control the many design parameters that must be considered and integrated(Heiselberg et al. 2006).

In the design of sustainable Buildings it is beneficial to identify the most important design parameters in order to develop more efficiently alternative design solutions or reach optimized design solutions. In the re-cast Energy Performance of Buildings Directive (EPBD) adopted in May 2010, a benchmarking mechanism for national energy performance requirements was introduced. The revised Energy Performance in Buildings Directive (EPBD) 2008/0223 calls for a calculation of the cost optimal energy standards and renovation standards. Cost optimal calculations may often be too short-sighted to deal with the urgent need for societal answers to the climate change challenge and may risk underestimating the potential for energy renovations in the building sector. The calculation should be informed by a long term cost effective figure of reaching a certain energy efficiency target which sufficiently contributes to mitigate climate change (EEB, 2010). Life-cycle costing based on net present values provides a sound basis for the development of a common methodology for calculating cost-optimal levels of renovation.

2. Methodology

Sensitivity analysis

First, a local OAT sensitivity analysis was used as a screening method in order to evaluate which design parameter is significantly sensitive to building energy performance and global costs(Haase et al. 2008).

Then, a global sensitivity analysis method was performed to identify the important design parameters to change in order to reduce the energy use in the reference building (Saltelli et al. 2000). With this method output variability due to one design parameter is evaluated by varying all other design parameters as well, and the effect of range and shape of their probability density function is incorporated. In the analysis a series of parameters were changed and the effect of the changes on the demand for heating, cooling and total energy were evaluated by a dynamic building simulation software package which needs about 10 sec per run. When applying the Morris method (Saltelli et al. 2000), about 220 calculations of output variables were needed for an investigation of 20 variable design parameters.

The sensitivity analysis shows which design parameters are the most important ones to change in order to reduce the energy consumption. The results show that lighting control and the amount of ventilation during winter are the two most important parameters that will have the largest effect on the energy use. This means that introduction of lighting control according to daylight levels and demand controlled ventilation in the heating season are two technologies that should be considered in the next design step.

Multi-objective optimization

The simulation software IDA-ice was coupled with MOBO (equa, Palonen et al. 2013). MOBO is a generic freeware able to handle single and multi-objective optimization problems with continuous and discrete variables and constraint functions and can be coupled to many external (simulation) programs such as IDA-ice.

It has a an extendable library of different types of algorithms (evolutionary, deterministic, hybrid, exhaustive and random), is able to handle multi-modal functions and has automatic constraint handling.

Theproblem here is optimized using three algorithms: the Brute-Force algorithm, Random-Search algorithm and Pareto-Archive NSGA-II algorithm. The Brute-Force algorithm used a step of 0.05 m for continuous variables (insulation thickness, thermal mass, window type, shading device). This resulted in 32000 simulations. The Random-Search algorithm applied 600 simulations. The Binary aNSGA-II was run twice.

3. Results and conclusions

The methodology presented helps to make design decisions that are on the core line of sustainable building design. In the design of sustainable buildings it is beneficial to identify the most important design parameters in order to develop more efficiently alternative design solutions or reach optimized design solutions.

4. References

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