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# Method and simulation program informed decisions in the early stages of building design

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ABSTRACT

The early stages of building design include a number of decisions which have a strong influence on the performance of the building throughout the rest of the process. It is therefore important that designers are aware of the consequences of these design decisions. This paper presents a method for making informed decisions in the early stages of building design to fulfil performance requirements with regard to energy consumption and indoor environment. The method is operationalised in a program that utilises a simple simulation program to make performance predictions of user-defined parameter variations. The program then presents the output in a way that enables designers to make informed decisions. The method and the program reduce the need for design iterations, reducing time consumption and construction costs, to obtain the intended energy performance and indoor environment.



## 1. Introduction

A rapidly growing demand for better energy performance in buildings is leading to an ongoing development of strategies and technologies to improve energy efficiency in construction without compromising on comfort, cost, aesthetics and other performance considerations. The European Performance Building Directive (EPBD) [1] reflects this need with a paradigm shift in regulations from individual component and system requirements to a framework for the total energy performance of the building. Choosing an appropriate combination of design options is thus a task of increasing complexity and cost. Creating an overview of possible design options and their performance is a critical task for building designers. There is a distinct risk of missing design opportunities which would have led to a better performance or obtaining undesirable effects if the design process is not properly informed. Making informed design decisions requires the management of a large amount of information on the detailed properties of design options and the simulation of their performance. Computer-based building simulation tools are ideal for this. However, Radfort and Gero [2] noted that the information provided by simulation tools is often evaluative rather than prescriptive. They argued that such tools are inefficient for the investigation of alternatives in the early stages of design, and they suggested a certain type and application of trade-off diagrams as a way of applying computer assistance in the design process. There has been an undeniably rapid development in computer technology and an increase in the number of available building simulation tools in the decades since the realisations provided by Radfort and Gero, but even so their realisations are still remarkably relevant today. A study by Crawley et al. [3] summarises the development by describing 20 major building simulation programs. The study indicates, with a few exceptions like Energy-10 [4], a focus on the development and sophistication of detailed evaluative tools rather than prescriptive tools. The reason is that building simulation tools often are a product of research activities. Many available tools are developed by researchers, for research purposes. As a result, the tools are not easy to use, as they require a significant level of expert knowledge. But as performance issues like comfort and energy become increasingly important, the capabilities of building simulation are increasingly in demand to provide information for decision-making during the building design process. This need has started the development of design advice tools where the common objective is to facilitate the use of building simulation in the design process. The research in detailed evaluative tools is an important prerequisite for this development. For instance, some design advice tools, like the Building Design Advisor [5,6] and COMFEN [7], are developed to work as data managers and process controllers which utilise external detailed evaluative tools to provide design advice. Some existing detailed tools like Energy Plus [8] and TRNSYS [9] have an inbuilt feature to facilitate parametric runs which could be used for generating design advice. Other strategies adopted in the development of design advice tools include the integration of simple simulation models, e.g. the MIT

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Design Advisor [10], and the utilisation of expert and rules-based systems, e.g. NewFacades [11].

The currently available design advice tools tend to focus on the development of a platform for the evaluation of alternative designs rather than giving actual design advice. Just like conventional building simulation tools, they provide building designers with a predicted performance of certain designs but provide no constructive feedback in the event of undesirable performance. This forces the designer to perform design iterations until a satisfactory performance is reached. Reductions in the number of these time-consuming design iterations (reducing building design cost) could be achieved if building simulation was used more actively in the development of the design rather than for merely passive performance prediction. However, the successful integration of building simulation as an active design advisor requires in-depth understanding of the design process.

This paper is about the design theories and strategies used for the development of a method and an appurtenant building simulation program that can be used as an active design advisor in the early stages of design. The idea is to make use of a differential sensitivity analysis to illustrate how design parameters will affect the energy performance and the quality of the indoor environment prior to any actual design decision. This helps designers to pass from abstract design stages to more concrete ones with a conceptual solution which is aligned with the design intentions.

## 2. Method

The research in methods for structuring and managing the design process has been a field of interest since the 1960s. The body of research in this field is therefore vast. An overview of the development in design methods can be found in Ref. [12]. The general approach when it comes to the research in building design process is to divide the process into phases. The suggested amount, scope and naming of phases may vary, but in general the division can be summarised in three main phases with the following design tasks [13]:

1. *Conceptual design*—The initial problem-setting and creative phase.
2. *Main design*—More systematic analyses and tests, ending in a formal presentation of the design.
3. *Detail design*—Detailed documentation of the design.

This subdivision of the design process into phases is an attempt to ensure a certain progression in the development of the design. The output of a phase constitutes a number of constraints on the design tasks in the following phase. This subdivision of the design process might be convenient to ensure progression in the development of design at the project management level, but it does not provide designers with any explicit support in making better decisions in the actual design situation. A lot of design research is devoted to improving the ability of the designer. This research utilises various kinds of research methods, and investigations range from the more abstract to the more concrete [14]. One of the more recent and pragmatic outcomes is a paradigm called ‘performance-based design’ formulated by Kalay [15]. Kalay states that building design is an iterative process of exploration, in which alternative shapes for fulfilling certain functional traits are suggested and evaluated in a given context. Making an actual design decision relies on the designer’s ability to explicitly represent, and then reflect upon, the desirability of the performance of a certain constellation of form, function and context. A major advantage of the performance-based design paradigm is that it is relatively easy to formalise as a practical workflow, see Fig. 1.

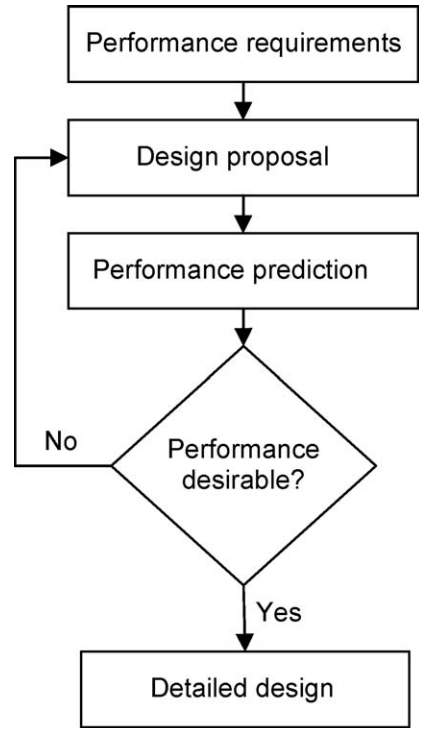


**Fig. 1.** The workflow and subtasks in performance-based design as described by Kalay [15].

The first task is to establish the performance requirements. The explicit definition of quantifiable performance requirements is the backbone of the performance-based design paradigm. Despite its importance the subject is not investigated further in this paper. Methods and experiences related to the translation of client and user requirements into assessable performance specifications can be found in Ref. [16]. The subtasks *design proposal*, *performance prediction* and *performance evaluation* constitute a loop of actions which ends the instant a desirable performance is reached. The whole process of going through the loop is called ‘design iteration’. The presence of design iterations is not unusual in design processes. Steward [17] considered design iterations and defined the possible relationships between a pair of design tasks as independent (parallel or concurrent), dependent (serial or sequential) and interdependent (coupled). The need for design iterations emerges when design tasks are identified as dependent or interdependent. The design process contains different types of design iterations varying in scope, number and level in planning. The types of iterations can be categorised as intraphase or interphase [18]. Intraphase iterations are several rounds of dependent or interdependent design tasks within the same design phase. Interphase iterations are cross-phase, cycling around a range of design phases. The workflow in Fig. 1 is an attempt to improve the ability of the designer to facilitate the design activities in the conceptual design phase. The design iteration within the workflow is therefore an intraphase iteration.

The workflow in Fig. 1 is ideal for the integration of building simulation tools to predict the energy performance and the quality of the indoor environment of a design proposal. But while using simulation tools for performance prediction may provide information needed to decide whether the performance of a certain design proposal is desirable or not, it does not provide any design advice in the case of undesirable performance. The workflow therefore does not utilise the full potential of building simulation tools. With minor adjustments to the workflow of the performance-based design paradigm, building simulation tools could become an active