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THE NEED FOR COMPUTATIONAL SUPPORT IN ENERGY-EFFICIENT DESIGN PROJECTS IN THE NETHERLANDS

P. de Wilde[1], M. van der Voorden[1], J. Brouwer[1], G. Augenbroe[2] and H. Kaan[3]

1. Delft University of Technology, Faculty of Architecture, Building Physics Group
Delft, 2600GA - The Netherlands
2. Georgia Institute of Technology, College of Architecture, Doctoral Program
Atlanta, GA 30332-0155 - U.S.A.
3. ECN, Unit Renewable Energy in the Built Environment
Petten, 1755ZG - The Netherlands

ABSTRACT

This paper reports on a research project that investigates the need for computational support for a specific stage of the building design process: the selection of energy saving components. The approach consists of a survey amongst architects and consultants who were involved in the design of recent energy-efficient building projects. The results reveal that computational tools only play a limited role in the selection of energy saving components, mainly due to the design decision process currently in use. The conclusion is that future developments in the field of 'design tools' should include the development of procedures ('process templates') for specific stages of the building design process in which the use of appropriate computational tools can be embedded.

KEYWORDS

building design, computational tools, energy saving components, selection process, survey

1. INTRODUCTION

In building research, the use of computational tools for building performance simulation is widely accepted. These tools allow the comparison of various design options under identical conditions, making them the ideal means for evaluation and optimization. Because of this one would expect these tools to play a substantial role in complex design decisions too: as support instrument to assess the performance of various design variants under consideration. This should apply for energy-efficient building design in particular: this is a field where many computational tools are available (DOE) and where most design decisions have multiple consequences on many performance aspects. However, building design involves several professions. And whereas the engineering consultants are regular users of computational tools, the uptake of these tools by architects appears to be very limited. As the architect is usually the pivot of the design team, bringing in and directing the consultants, there clearly is a need to better understand the decisions that occur in the design process of energy-efficient buildings. The main purpose would be to analyze the impact of computational tools on energy-related design decisions. This research will reveal actual advantages and shortcomings of both the design process and computational tools, and can be used to direct further developments in the field.

For the research presented in this paper the field of energy-efficient building design will be narrowed down to one specific part of the design process: the selection of energy saving components. Energy saving components can be defined as integrated building components that are designed to contribute to lower energy demands. Examples of energy saving components are sun spaces, solar walls, advanced glazing systems or photo-voltaic arrays, but also traditional design options like extra thermal insulation.

2. EARLIER WORK

Previous research at Delft University of Technology has explored the integration of energy saving components and use of computational tools in real-life building design scenarios. This work consists of in-depth analysis of the design process of three cases (large office buildings with a high energy saving profile) by means of interviews with architects and consultants, the development of formal process models, and feedback interaction with architects and consultants to verify these process models. The overall conclusion from this research is that there is a general misconception that the present computational tools respond to a well-defined need of building design teams. Results show that energy saving components are mainly selected during the phase of conceptual design; computational tools are only used in later phases. Computational tools are used for optimization and verification; there is no evidence of tools being used to support design decisions concerning the selection of energy saving components. The selection of energy saving components is based on experience and reference projects instead (de Wilde et. al. 1999a, de Wilde et. al. 1999b).

3. GOAL

Goal of the research project described in this paper is to verify whether or not the results of the before-mentioned case studies hold for a larger sample, and to gain further understanding of how energy saving components are selected in current practice and how computational tools are used to support this selection. In this project the research method consists of a survey. Specifically the following research questions are to be answered:

- In which phase(s) of the design process are energy saving components being selected, and what is the distribution over these phases? Are most energy saving components selected during the phase of conceptual design, as indicated by the case-studies?
- Which reasons are used to motivate the selection of energy saving components? Are most energy saving components selected based on experience and demonstration projects, as indicated by the case-studies?
- In which phases of the design process are computational tools being used? Do the results confirm that computational tools are mostly used after selection of energy saving components has taken place?
- What are the reasons to use computational tools? Are the main reasons optimization and verification of earlier design decisions, as indicated by the case-studies?

4. APPROACH

The survey is carried out amongst the architects and consultants who were involved in the design of recent energy-efficient building projects in The Netherlands.

First step is the selection of appropriate projects; 70 buildings are selected from literature on energy-efficient architecture. This list includes the 3 cases studied before; these projects are used for a test of the survey. For each project a list of energy saving components is compiled. Based on this information, project-specific questionnaires are developed for the architects and consultants who designed these buildings. The questionnaires for architects differ from those for consultants; both are tuned to the specific knowledge of the interviewees. The majority of the questions are multiple-choice questions; this allows for statistical analysis of the results. Open questions are used to gather background information and to gain further insights.

Some questions in the questionnaire ask to position specific design activities or computational activities in the design process. For equivalence of the results the use of a consistent classification of process phases is important; therefore a standard classification using five main phases is prescribed. These five phases are: feasibility study, conceptual design, preliminary design, final design, and preparation of building specifications and construction drawings. This phasing is in general use in the Netherlands; it is based on recognizable end products for each phase.

After a test of the survey by the architects and consultants of the three cases, questionnaires have been sent to the architects and consultants of the remaining 67 energy-efficient building projects. For some of these projects the architect did not employ a consultant; in those cases the architect received a combined / extended questionnaire.

The results consist of the data of 70 energy-efficient building projects and all returned questionnaires. Project data is analyzed to find out which energy saving components are being used, to determine the minimum, maximum and average number of energy saving components in one project, and to examine whether or not the energy saving components have different fields of action (impact on cooling, heating, transmission, ventilation / infiltration, energy storage, efficient use of fossil fuel, use of renewable energy, lighting).

Results from the survey are subjected to a statistical analysis using the software package SPSS for Windows, release 7.5.2 (SPSS). Results are analyzed in groups: questionnaires returned by architects are compared with each other, just as are questionnaires returned by consultants. The analysis consists of computation of frequency distributions of answers, representation of these answers in tables and diagrams, and determination of tendencies in these answers. Wherever percentages are used the total amount of answers (N) is given in order to assess the sensitivity of these percentages. Confrontation of answers from architects with answers from consultants only takes place for those building projects for which both architect and consultant have returned the questionnaire. Due to space restrictions only a selection of all results is presented in this paper.

Finally the results of the survey are compared with the results of the case studies. As most data from both research activities is not numerical but qualitative, this comparison is executed by hand. Differences are discussed and (whenever possible) explained. Based on the conclusions from this research recommendations for further developments in the field of 'design tools' will be made.

5. RESULTS

5.1. Project Data

A total of 303 energy saving components have been integrated into the 70 energy-efficient building projects. This means that on average these buildings have four energy saving components. The minimum is only one component, the maximum is nine energy saving components per project. In 26 buildings all energy saving components have completely different fields of action; in 37 buildings some overlaps are found. Seven buildings have a number of energy saving components that seem to be redundant, i.e. that seem to overlap substantially with other components.

5.2. Survey - Response

Questionnaires were sent to 54 architects, 54 consultants and 13 architects who did not employ a consultant. The response was as follows:

- 29 architects (54%)
- 18 consultants (33%)
- 5 architects without consultant (38%)

completed and returned the questionnaire.

This combines to partial data sets (response from either architect or consultant) for 42 projects (63%) and full data sets for 10 projects (19%).

5.3. Survey - Partial Data Sets

The responses of the architects (including those that did not employ a consultant) can be combined into the following results:

- According to architects most energy saving components are selected during the phase of conceptual design. The relative shares for the other process phases are shown in table 1.
- Architects mostly motivate selection of energy saving components by experience and/or demonstration projects. For other motivations and the frequency distribution, see table 2.
- Most architects do not use any tool at all to support the selection of energy saving components. If architects use tools, they use checklists, handbooks, other means (like scale models) or a combinations of these three, but no computational tools. See table 3.

Table 1: percentage of energy saving components selected per design phase

phase:	percentage:	
feasibility study	16%	
conceptual design	57%	
preliminary design	13%	
final design	10%	
construction drawings and building specification	4%	N = 204

Table 2: motivations for selection of energy saving components

motive:	percentage:	
experience and/or demonstration projects	41%	
maximal energy savings	27%	
cost-benefit tradeoff	12%	
other reasons (for instance: thermal comfort, experimentation, architectural expression)	20%	N = 204

Table 3: tools used by architects for the selection of energy saving components

tool:	percentage:	
checklist	15%	
handbook	6%	
other means	3%	
checklist and handbook	6%	
checklist and other means	3%	N = 34
no tool at all	67%	

- Architects can name 23 specific alternatives for the 204 energy saving components that they selected; this means that for only 11% of all energy saving components there was a real design decision between (at least) two options.
- Only 7 out of the 34 architects optimize the interaction between energy saving component and the building themselves using these checklists, handbooks and other means.

The responses of the consultants can be combined into the following results:

- According to consultants most energy saving components are selected during the phase of feasibility study. The relative shares for the other process phases are shown in table 4.
- Consultants mostly motivate selection of energy saving components by experience and/or demonstration projects, too. For other motivations and the distribution, see table 5.
- Consultants can name 21 specific alternatives for 111 energy saving components that were selected in the design projects in which they participated; this means that for only 19% of all energy saving components there was a real design decision between (at least) two options.
- According to the consultants, for a total number of 111 energy saving components:
    - 33 components were selected without any computation at all (30%);
    - 32 components were selected after computational assessment of their efficiency (29%);
    - 57 components were checked for their impact on energy efficiency after they had been selected (51%);
    - 50 components were optimized using computational tools (45%).
- The 18 consultants that returned the questionnaire used a total of 42 computational tools; this means an average of two tools per building design project. These 42 tools were used for several purposes; 95 specific usages of computational tools were listed. These usages were ordered in groups; for an overview, see table 6.

Table 4: percentage of energy saving components selected per design phase

phase:	percentage:	
feasibility study	44%	
conceptual design	28%	
preliminary design	21%	
final design	4%	
construction drawings and building specification	3%	N = 105

Table 5: motivations for selection of energy saving components

motive:	percentage:	
experience and/or demonstration projects	37%	
maximal energy savings	29%	
cost-benefit tradeoff	11%	
other reasons (for instance: thermal comfort, experimentation, architectural expression)	23%	N = 105

Table 6: usages of computational tools

usage:	percentage:	
assesment of energy consumption (whole building)	24%	
evaluation of all design options (not only related to energy saving components)	30%	
optimization of parameters	33%	
other usages (study of thermal bridges, daylighting, …)	13%	N = 95

5.4. Survey - Full Data Sets

For 10 building projects both architect and consultant returned the questionnaire; for these projects answers from both groups can be compared.

The percentages of energy saving components selected per building design phase according to architects and consultants are plotted in figure 1.

Clearly the results from the partial data sets are repeated: architects state that most energy saving components are selected during conceptual design, whereas consultants state that most energy saving components are selected during the feasibility study. See figure 1.

As a follow-up of these general results individual projects have been studied. This reveals that in 6 out of 10 projects there is a phase 'gap' which seems to be consistent across projects. The gap indicates that the consultant perceives decisions to be taken one or two phases ahead of what the architect perceives. In one project the architect is ahead of the consultant; and in 3 projects there is no phase gap.

Another important aspect is the phases in which computational tools are being used. These tools are used for several reasons (assessment of energy consumption of whole buildings, support of design decisions, optimization, other reasons). For one of those usages (others show the same trend), the assessment of energy consumption of whole buildings, the phases of use are shown in figure 2. Architects were asked to indicate in which phases tools were used, resulting in one distribution; for consultants the question was divided into an indication of the phase in which computations started and an indication of the phase in which they ended. See figure 2.

Clearly many computational efforts start early in the design process, but take quite some time to be completed. For instance, at the beginning of the preliminary design 7 computational analyses have been started, but only one is completed.

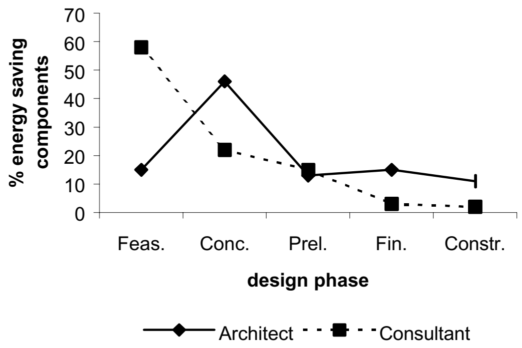

Figure 1: *energy saving components selected per building design phase*

N (architects) = 54
N (consultants) = 59

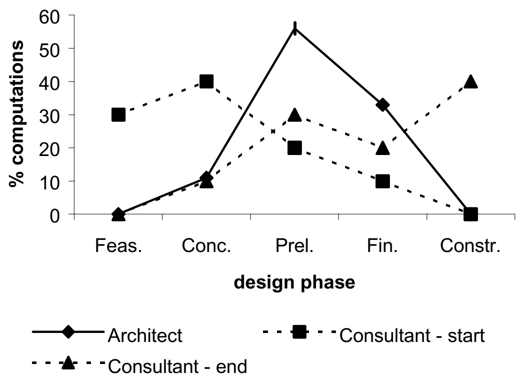

Figure 2: *phases in which computational tools are used for assessment of energy consumption of whole buildings*

N = 7
(computations for assessment of energy consumption of whole buildings)

6. CONCLUSIONS AND DISCUSSION

1. The trends in the partial data sets, the full data sets as well as the results for individual building design projects all show that architects and consultants have different perceptions concerning the phases in which energy saving components have been selected. Therefore it is not possible to determine one common distribution of the selection moments of energy saving components over the phases of the building design process. However, the general finding is that almost three quarters of all energy saving components have been selected at the end of the conceptual design phase.
2. The most important motivation for the selection of energy saving components is experience, or knowledge of use of energy saving components in demonstration projects; both architects and consultants base approximately two fifth of their choices on this argument. Other important arguments are maximization of energy savings, and selection based on a cost-benefit tradeoffs. Many more motives were found; some of these are thermal comfort, architectural expression, use

of energy saving components to gain experience, or selection based on available subsidy.
In this context it is important to note that two thirds of the architects do not use any tool at all to support their choice. Consultants support the choice of only one third of all energy saving components with computational tools.
3. The results obtained from consultants clearly show that most computational tools are used during several phases of the design process; the implication of this is that it takes some time for results to materialize, even if calculations start in an early phase. This is confirmed by the view of the architects, who experience that most computational results are obtained during the phase of preliminary design or later, and consequently after selection of energy saving components has taken place.
4. The main reasons to use computational tools are optimization of parameters, verification of earlier design decisions, and support of all kind of design decisions still to be made (including some decisions concerning energy saving components). Differences between the three are small; each accounts for approximately one third of al computations. It must be strained, however, that in spite of these results about 70 percent of all energy saving components is selected without computational support.

The overall conclusion from this research is that most energy saving components are selected without proper underpinning; instead, the selection of these components seems to be mainly based on experience and analogy. Approximately 80% of all energy saving components are selected without considering alternatives, which demonstrates that the decision to select a specific component is highly intuitive. However, as observed by Suh, 'intuition and experience are not absolute or objective; moreover, even good intuition and experience cannot be transmitted to succeeding generations' (Suh 1990). For energy saving components an intuitive selection appears to have additional drawbacks: generally the efficiency of these components cannot be studied in isolation. They are dependent on building characteristics whereas interaction between components can have a substantial effect on the efficiency of each individual component. The impact of climate conditions and occupant behavior add to the complexity and make it almost impossible to predict performance without use of computational tools. Accordingly, a more thorough selection procedure is needed.

The results of the survey also show that architects and consultants have a different perception of the same design process. This is undesirable, as the activities of all participants in the design process should be interrelated and should contribute to achieving the common goal: the design of an 'optimal' building. The reasons for the differences in perception remain unclear; possible explanations could be a lack of interaction (the proverbial exchange of evaluation request and computational results by writing) or a possible underestimation / overestimation of specific activities or contributions. Also, consultants might experience their own involvement as the start of the design process, even if this coincides with a later phase of the overall design process; however, this does not explain all differences, as the same results have been obtained for projects where the consultant joined the design team in the very beginning.

7. REMARKS ON REQUIRED DEVELOPMENTS IN THE FIELD OF 'DESIGN TOOLS'

As demonstrated by this paper the current contribution of computational tools to building design is limited by the course of the design process. How does this relate to current developments in the field of building performance simulation? As far as 'simulation for design' is concerned, the following main efforts can be identified:

- (early) design tools for architects
  This work aims at development of tools for the non-specialist in building simulation by simplifying and/or automating the modelling and simulation work. In order to deal with early design phases and the related incompleteness of building design information many efforts limit the number of inputs, some by using simplified computational methods, others by using (extensive) defaulting. Examples in this category are the LT-method (Martin Centre) and Energy-10 (SBIC).
- communication with architects and architectural tools (CAD)
  These initiatives try to improve the communication between architects, consultants and their specific tool(s). One important aspect is the coupling of CAD tools and simulation programs, as demonstrated by SimCAD (Pelletret and Keilholz 1999); other issues are the development of graphical user interfaces to facilitate the use of computational tools in a design context, post-processing of simulation results into relevant performance metrics, and development of automated reporting facilities.
- integrated analysis platform
  This work addresses the issue of sharing and exchanging information between a number of building simulation tools used to evaluate different performance aspects, like energy consumption, lighting and acoustics. Mostly these efforts also include a link with an architectural CAD tool. The shared data models

involved are known as product models. The most well-known example is the EU Combine project (Augenbroe 1995); a current example in this category is Semper, with an internet-version known as S2 (Semper).

The results from the work presented in this paper demonstrate that a new spearhead needs to be added to the above-mentioned efforts: the development of clear procedures or scenario's ('process templates') for specific parts of the building design process that require computational support, like a procedure for the selection of energy saving components.

These process templates can provide a framework for the interaction between 'design' and 'simulation' by:

1. acting as checklist that shows which activities are needed to tackle this specific part of the design process, and - where needed - dictating an imperative sequence of these activities;
2. helping to specify design objectives and relevant performance indicators that describe the extend that these objectives are achieved;
3. making clear for all members of the design team which design options are being considered;
4. showing which 'design analyses' / simulations are needed in the procedure, and suggesting which type of computational tools should be used for these design analyses;
5. providing an unambiguous method to make the intended design decision, balancing multiple objectives for several design options.

Presently a prototype 'design support system' for the selection of energy saving components based on these ideas is being developed at Delft University of Technology in the frame of an ongoing Ph.D.-project. This involves simultaneous development of procedures, study of required computational support and fitting in of (existing) computational tools.

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