EARLY SUPPORT FOR BUILDING SERVICES DESIGN

A Feasibility Study

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ABSTRACT

There is a need for Dutch design support tools for building services that can be used in early design stages. TNO Building and Construction Research has therefore initiated the research project described here. The project will result in guidelines for design support tools for early design of building services in the Netherlands. These tools should make it possible to quickly compare alternative conceptual design solutions and to visualize possible consequences of the underlying design decisions.

INTRODUCTION

During the first three stages of the building design process (feasibility, briefing, design) important decisions are made which have a large impact on the final result in terms of building flexibility, effectiveness and efficiency, see **Figure 1**. These decisions cover conceptual design issues and are directive and, at the same time, restrictive and irreversible. Further, they are often based on incomplete, complex, and often incorrect information[1]. Furthermore, these decisions are related to the fields of work of all participating members of the building team. Very often the participants involved in early design are not able to understand the impact of their design decisions; not only on their own design task in the following stages of the process, but also on other participants' field of work[2]. Having access to information and being able to communicate are therefore important, and tools to support these functions are needed.

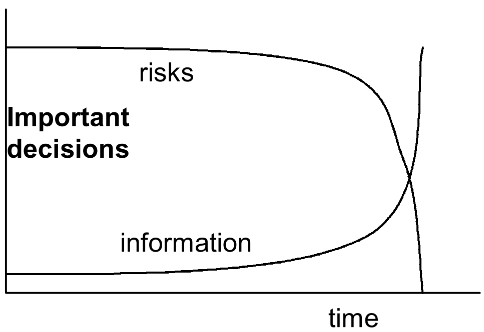

Figure 1: Impact of design decisions.

Until recently, it was common practice that Dutch building services engineers were being involved in design at the evaluation stage of the design process. Therefore, many simulation tools exist to support this task, such as DOE-2[3] and Radiance[4]. Nowadays, with large building projects a building team, including the building services engineer, is initiated right from the start. This requires an integrated design approach. Many research teams around the world are looking into this topic. For example, IEA Solar Heating and Cooling Task 23 is investigating whether integrated design can result in optimal use of solar energy[5]. In IEA task 23 several design tools are being developed to support integrated design. Other examples can be found at the Martin Centre in Cambridge, UK, where simplified models are being developed to estimate lighting and temperature consequences of design decisions[6], the MIT in Massachusetts, where recently the MIT Design Advisor for preliminary estimates for the performance of building facades was presented[7], and LBNL in Berkeley, California, where the Building Design Advisor for inner climate issues is being developed for several years now[8].

Nevertheless, no ready to use design support tools for the earlier design stages are available yet for Dutch climate and regulation. These tools should make it possible to quickly compare alternative conceptual design solutions and to visualize possible consequences of the design decisions on the users own work or on the work of others. At the moment, these consequences often are initially overlooked initiating the risk that the final design does not match the client's demand, which enlarges the chance on complaints during the occupation phase. Mismatches must then be fixed at high cost. Further, these tools should support the integrated design approach and improving communication between building team members.

Researchers have investigated what it takes to improve the use of design tools, presuming that this will lead to improved building performance. International workshops were held on next-generation building energy simulation tools inviting both developers and users[9]; surveys among users of simulation software were executed in New Zealand and USA to determine which improvements they seek to the simulation tool they use regularly[10]; and various interviews of practitioners on use of a range of different design decision support tools were done in New Zealand as well[11]. The main results of the workshops, surveys and interviews lead to the conclusion that the user interface is critical for the success of any simulation tool and that tools for ensuring quality are required.

TNO Building and Construction Research, having experience for many years in designing support tools for building services engineering in the Netherlands, has initiated the research project described here to find out if Dutch users of simulation tools agree with the international findings. Central importance is placed on early design decision making.

This initial feasibility study includes three tasks that have similarities to those of earlier mentioned researchers:

- A *desk study* that aims at retrieving information on the current use of existing design tools (for the evaluations stage),
- Five *field studies* at different engineering companies provide an overview of those situations in which the current tools are used, and
- A *workshop* in which the results of the studies are presented to inform users of current design tools about our results, and at the same time, to get feedback on the necessary adaptations to make the current tools suitable for early design stages.

During this first feasibility project, the Building Simulation program developed at VABI: VA114[12] has been the study object. VA114 is a dynamic model for the calculation of temperatures, temperature peaks, weighted peak and off-peak hours, and heating and cooling requirements in rooms and is used by 120 engineering companies and research institutes in the Netherlands.

DESK STUDY

During this first task of this project the current use of VA114 has been studied. Six building services engineers have been interviewed and with each of them building projects in which VA114 was used have been discussed. Suggestions for early support tools were collected. The summaries of these interviews are given below.

Engineering company 1

The first engineering company is often involved in large projects starting early in the design process. The company developed their own early design support tool to compare the energy implications of building concepts. With this tool different conceptual designs are evaluated and, based on the results, one is selected. After this VA114 is used in all projects to estimate overheating hours in summer and heating demand in winter. If the outcomes are not satisfying, changes of details in the design may be executed.

According to this company an early design tool should give access to a case base of example buildings from all over Europe presenting specifications and experts opinions on these buildings. The tool should support quick comparison on different aspects of building services concepts, including costs, and provide the possibility to present the outcomes graphically.

Engineering company 2

The second engineering company is not frequently involved in projects starting early in the design process. In their projects they use VA114 to determine energy demand and required capacities for one or two building services alternatives. Further, they check whether the found solution meets the Dutch building codes.

This company is looking for a tool in which the parameters of various building services systems are collected. For different stages of design, different levels of accuracy are needed. For example, for early stages of design it will be sufficient to have a bandwidth for the heating and cooling capacity of a system, but later in the design exact numbers are needed.

Engineering company 3

The third engineering company is often involved in early design projects. In these projects most often essential decisions are made based on a few critical aspects that are looked into in detail. Therefore VA114 is used to determine the consequences of changing these details.

This company has the opinion that VA114 should be expanded with a case base of earlier projects. These (parts of) earlier projects should be easy reusable and adaptable for new projects. It would be better if all design aspects could be entered either globally or in detail depending on the critical aspects in the project.

Engineering company 4

Half of the projects of the fourth engineering company start early in the design process. In these projects VA114 is used to determine the energy demand for different alternative designs concepts (with or without cooling, with a light or a heavy construction, with large or small amounts of glazing). After this, together with the architect and other building team members, the most promising solution is selected. Then a heating and cooling system is proposed based on their experience, and its minimum capacity is determined with VA114.

At this company a number of possible additional functions for VA114 were proposed, of which three could be transformed into criteria for early design tools:

- Include an optimization mechanism for cooling and heating capacity; the tool should be able to determine the demanded minimum capacity;
- Access to a library with building services systems; this library should be extendable with new innovative systems;
- Easier interface to input geometry; especially input of not rectangular rooms is cumbersome.

Engineering company 5

The fifth engineering company is involved in all aspects of the design process, except architectural design. The building services engineers of this company often are involved early in the design process. During the first meetings of such a project the engineer tries to guide the building team towards the optimal solution that meets the brief and the budget. Together with the building team decisions are made on the amount of glazing, the way of construction, and ceiling and floor types. With VA114 the most promising alternatives are evaluated to determine energy demands and recover periods of costs of investment of various building services systems.

This company wants to have better tools to present the different design solutions to the rest of the building team. An adequate way of presenting design concepts is of vital importance.

Engineering company 6

The last engineering company is working mostly for project development companies of large office buildings. This is very early in the design process when the brief is just ready and the overall budget is just decided upon. With only numbers for square meters office space and percentage glazing an estimate can be made for the budget for buildings services. Based on earlier research outcomes and experience the most promising building services system is selected. Initial and operational costs plus reliability are the critical aspects.

This company is looking for a tool that can accurately estimate energy demand and globally estimate initial and operational costs.

Conclusions Desk study

All interviewed engineering companies are frequently involved in projects starting early in the design process. To identify the most promising concept for the building services systems they use:

1. Rules of thumb;
2. In the company developed spreadsheets or other tools.

Next, the most promising alternatives are evaluated in more detail with VA114.

All together the six companies came up with five main guidelines for the decision support system for early support of building services design:

1. Access to a library with characteristics of building services systems, including initial and operating costs;
2. Graphical way of presenting outcomes;
3. Access to a case base of example buildings that can be reused completely or partly;
4. Include an optimization mechanism for cooling and heating capacity;
5. Include an user-friendly interface to input geometry.

FIELD STUDIES

The second task in this project involves field studies in cooperation with engineering companies during which five design projects will be closely looked into. Decisions made during the project will be analyzed and project meetings of the design projects may be attended. The involved architect and building services engineer will be interviewed. TNO attends the project team meetings as an independent party on invitation of the building services engineer. The gathered project dependent information is treated confidentially.

The results of the first field study are presented below.

Field study: Office building in Amsterdam

One of the ongoing field studies involves an office building in Amsterdam. In this case the city council developed a very ambitious set of guidelines in relation to energy and environmental issues. The building process of this project is shown in **figure 2**.

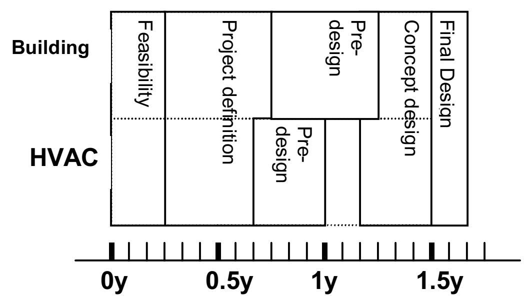

Figure 2: Building process field study: Office building in Amsterdam.

The building team consisted of the project developer, the architect, the environmental department of the city, the structural engineer, and the building services engineer. In three months time energy studies for the building were executed and a sketch design was developed by the building team. This period is indicated as the feasibility phase in **figure 2**. Six more months were needed for project definition during which the basic brief for the building was developed. With this brief a preliminary design for the building services and for the building structure was developed. The conceptual design was finished within 1.5 years after the first project team meeting, and shortly after that the final design was presented.

During the Feasibility phase, the building services engineer studied the costs, the space needed for technical rooms, and the feasibility for the specific building of eight different solutions for energy delivery & distribution systems. Together with the other building team members two most promising solutions were selected. During this phase (graphical) presentation tools are most important.

In the Project definition phase the energy consequences of the two options were addressed. The options for funding of energy saving components, such as façade-integrated PV-cells were studied. This phase resulted in a basic brief which guidelines and agreements for the project. The energy delivery & distribution system that met these guidelines best was selected for the project. Simple calculations, based on rules of thumb, must be done during this phase.

Based on the basic brief a Preliminary design for the HVAC-system and after that a more detailed Conceptual design were developed. For each office room, elevator, kitchen, toilet etc. the building service systems were described in detail. Now simulation tools, such as VA114, are used to calculate heating and cooling requirements in rooms.

Conclusions Field study

Although only one field study has been started, it is obvious that the building service engineer needs different support in different phases of the building design process.

During the first Feasibility phase s/he needs presentation possibilities to communicate with the rest of the building team. Graphical ways to present the pro's and con's of different HVAC systems for the particular project are needed.

Further, during the Project definition phase up to date information on funding possibilities and state of the art in HVAC innovations are needed to elaborate on the HVAC components.

Finally, simulation tools will support the Design phase in which accurate calculation of heating and cooling requirements per room are made. The tools must be able to implement new innovative solutions of HVAC components.

Preferably, these functions are combined in one tool that supports the development of the building services design throughout the whole building process.

WORKSHOP

The workshop is the third task of this project, which was organized on April 3rd, 2001[13]. For the workshop an electronic meeting facility was used.

Figure 3 shows an example of such a meeting facility consisting of a setting with several computers, on which special software is installed :"GroupSystems", developed by the University of Arizona. One computer is used as a server by the facilitator who manages the software during the meeting process. During the meeting the attendees can enter group discussions electronically by using the software. The facilitator's computer can be connected to a projector that can be used to show the group results or to show an electronic presentation.

According to De Vreede[14] four advantages exist of using this electronic meeting facility instead of the traditional workshop format. The first advantage is that the participants can contribute anonymously. This increases the quality of the meeting results and the satisfaction of the participants with the meeting itself. By being able to enter ideas, comments, and votes anonymously, silent or shy participants are more encouraged to enter ideas. Ideas appear to be judged on their merit, not on the personality or position of the participant that has entered it. Another advantage is that parallel information gathering is supported, which yields increased group productivity and satisfaction. This implies that participants do not have to listen to others before they can submit their own views, nor have to remember their ideas and criticisms until they have the attention, and therefore

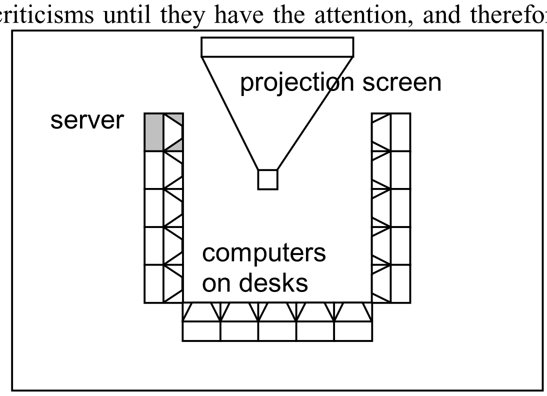

Figure 3: Example of a Group Decision Room lay out.

Timetable of the workshop	
13:30	**Presentation**: Introduction to the project and the goals of the workshop.
14:00	**Instruction**: "How to meet electronically?"
14:15	**Brainstorm**: "Which tasks during the early design process of building services need support?"
14:40	**Plenary discussion**: "Which items are similar and can be clustered?"
14:55	**Voting**: "Which items can be supported with computer tools?" and "Which are most important?"
15:15	Coffee break
15:30	**Group session**: Four groups elaborated on the four most important items.
16:30	Closure

Figure 4: Formal workshop outline.

spend more time on generating new ideas. Further, voting techniques can be supported, which make it possible to quickly determine which of the issues identified during a brainstorm session are considered important by the group. Finally, all ideas, comments, and votes that are entered during a meeting are stored electronically, which decreases the amount of time needed to produce the meeting results.

A disadvantage that is often mentioned according to De Vreede[14] is that electronic meeting facilities lacks social cues. Since information is only communicated electronically, certain types of information, such as ironic remarks, may be interpreted out of context. Further, the advantage of anonymity sometimes is considered a disadvantage, as well, if generated ideas or voting results need clarification.

Participants

In total 12 Dutch building services engineers and researchers attend the electronic meeting.

Time table

The meeting lasts one afternoon and starts with an informal lunch gathering and ends with a informal reception where attendees can socialize with each other.

Figure 4 shows the formal outline of the workshop which starts with a short presentation on the project and the goals and objectives of the workshop by TNO, and an introduction on the electronic meeting facility by the facilitator.

After this, the brainstorm session starts and the attendees must identify tasks during the early design process of building services that may need support. Every attendee can respond to this question by typing the items. S/he can also react to items that appear on his or her screen that were typed by other attendees.

After the brainstorm all the items are discussed with the group in a plenary discussion. Items that were typed in more than once or are similar to other items are clustered.

Then the group indicates whether these items can be supported with computer tools using the voting facility (Yes/No) of the GroupSystems software. The results of the voting are shown to the attendees and discussed orally, after which another voting takes place to find what are the most important tasks that need support (on a 4-point scale).

Results

The brainstorm resulted in more than 100 items of tasks that may need support during the early design of building services. After the clustering of similar items 19 tasks remain. Of these tasks is indicated whether these can be supported with computer tools.

In **table 1** the results of the voting on whether the tasks could be supported by computer tools is prestented.

***Table 1**: Results of voting: "Which items can be supported with computer tools?".*

Task	**%**
To evaluate alternative solutions	**100**
To keep track of the design process	**100**
To make decisions on room level and on building level	**100**
To gather information on consequences of choices	**92**
To interact between various building functions	**92**
To find data on average use and bandwidths	**92**
To find examples of good practice	**83**
To communicate and to exchange information	**75**
To check with the brief	**67**
To gather information on the location	**67**
To reuse implemented data in later stages of the design	**67**
To manage the design process (innovatively)	**58**
To check the quality of the façade	**58**
To find professional/expert knowledge	**50**
To find information on the user of the building	**50**
To present innovative techniques to the architect	**42**
To learn about experience	**33**
To learn about vision of architect or client	**17**
To learn about the design process	**17**

Only the items of which more than 50% of the attendees indicated that these could be supported with computer tools were carried over to the second vote. Of each of these 13 items the attendees indicated whether it was very important (VI), important (I), less important (LI), or not important (NI) (a 4-point scale) to support this task. The four items that came out of this vote as being most important are presented in **table 2**.

Table 2*: Results of voting: "Which items are most important?".*

	Task	VI	I	LI	NI
1	To evaluate alternative solutions	10	1	1	0
2	To gather information on consequences of choices	8	3	1	0
3	To keep track of the design process	7	3	1	1
4	To make decisions on room level and on building level	6	5	0	1
5	To reuse implemented data in later stages of the design	4	4	4	0
6	To check with the brief	3	5	4	0
7	To interact between various building functions	2	7	3	0
8	To find data on average use and bandwidths	4	2	4	2
9	To gather information on the location	2	5	3	2
10	To communicate and to exchange information	2	4	5	1
11	To find examples of good practice	2	4	5	1
12	To manage the design process (innovatively)	3	3	2	4
13	To check the quality of the façade	2	3	4	3

During group session the workshop attendees were divided into four groups of three persons. Each group elaborated further on one of the four most important tasks. Each group presented how the tool that supported their task would look, what input it needed, and what results would be generated by the tool.

Conclusions of the workshop

The workshop has proven that it is possible to discuss the possibilities of supporting the early design of building services with a group of twelve building services experts. The four items that came out as most important, were also the ones of which the group had no doubt that it would be possible to support them with computer tools.

In general the group is looking for a tool that can evaluate the quality of different building services solutions on room level. The consequences of particular choices must be presented on building level. It would be preferable that reference solutions could be used and that information can be exchanged with other tools. The tool must support the very early stages (feasibility and project definition) as well as the later stages (preliminary and conceptual design). The output of the tool must be such that it can be used in presentations for other building team members, such as the architect (preferably graphical).

CONCLUSIONS

The most important decisions in building services design in the Netherlands are made based on rules of thumb and experience, because no Dutch decision support tool are available that supports the early design stage.

During the desk study it was concluded that building service engineers want access to a library with building services systems characteristics and to a case base of example buildings combined with a user-friendly interface and a graphical way of presenting outcomes.

The first field study made clear that the building service engineer needs different support in different phases of the building design process. Preferably, these functions are combined in one tool that supports the development of the building services design throughout the whole building process.

During the workshop the field study conclusion was repeated and three also important issues were added. The tool should not only support all stages in the design process, but also make it possible to evaluate alternative solutions, clarify the consequences of choices, and support designing on room level as well as building level.

FUTURE WORK

Based on the results of the feasibility study presented this paper it can be decided to continue the project The following step will be to develop a model for a design decision support tool that meets the guidelines that came forward during this study. If that model proves to be successful the second step will be to develop a prototype decision support system for the early design of building services in the Netherlands.

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