EARLY DESIGN SUPPORT TOOL FOR BUILDING SERVICES DESIGN MODEL DEVELOPMENT

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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

This is the third paper on this research topic. The results of the feasibility study were presented at the IBPSA conference in Rio de Janeiro (De Groot et al., 2001) and the model description results were presented in Ellecom (Maassen et al., 2002). This paper supports the presentation of the developed user interface. This ‘dummy’ user interface is indispensable to verify its aimed applicability in design practice. In a workshop with potential users its applicability was discussed and the results of the workshop are presented in this paper.

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 (Rutten et al., 1998). 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 (De Groot, 1999). Having access to information and being able to communicate are therefore important, and tools to support these functions are needed.

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 (Winkelman et al., 1993) and Radiance (Ward, 1990). 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 investigates whether integrated design can result in optimal use of solar energy (Van Cruchten, 2000). 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 (Robinson et al., 2001), the MIT in Massachusetts, where recently the MIT Design Advisor for preliminary estimates for the performance of building facades was presented (MIT, website), and LBNL in Berkeley, California, where the Building Design Advisor for inner climate issues is being developed for several years now (Papamichael et al., 1997).

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 (Crawley et al., 1997); 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 (Donn, 1997); and various interviews of practitioners on use of a range of different design decision support tools were done in New Zealand as well (Donn, 1999). 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 project is executed in three phases:

Phase A: Feasibility study;
Phase B: Model development;
Phase C: Prototype development.

Phase A and phase B have been executed. The results presented in this paper are:

Phase A, Feasibility Study, includes three tasks that have similarities to those of earlier mentioned researches:

- 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.

Phase B, Model development, includes:

- A *Model description* of the design support tool which will be developed and that fits the main requirements of a design support tool as concluded in Phase A,
- A 'dummy' *user interface* that shows the users/engineers the functions of the design support tool, and
- A *workshop* in which the model description and the user interface are presented to inform users of current design tools, and at the same time, to get feedback.

In this project, the Building Simulation program developed at VABI: VA114 (Jordaans et al., 2002) has been the study object.

VA114

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.

The program is used and initially developed to check indoor temperature requirements to validate a completed design. The program is also used to calculate the energy demand on room level. The accuracy of the calculation of the energy demand is guaranteed by passing the BESTEST in 1999. The BESTEST is developed under IEA SHC Task 22 (Judkoff et al., 1995).

The functions of VA114 are expanded. Not only it is now possible to calculate the energy demand of a whole office building but it is also possible to check the performance of several HVAC components, i.e. different room level heating units. The range of HVAC components will be expanded and also include distribution and generation. It is also planned to expand the flexible way of multiparameter control strategies which can be opposed on room and building level.

The research project described in this paper aims to give guidelines to how this reliable energy and temperature calculation tool, VA114 which is now only used to evaluate a design, can be used to support the process in creating a design of a building and its building services.

A: DESK STUDY

During the 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 in the paper (De Groot et al., 2001), which was presented at the IBPSA Conference in Rio de Janeiro 2001 below. The conclusions are also included below.

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.

A: FIELD STUDIES

The second task of phase A of this project involves field studies in cooperation with engineering companies during which design projects were closely looked into. Decisions made during the project were analyzed and project meetings of the design projects were attended. The involved architect and building services engineer were interviewed. TNO attended 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 a field study were given in the paper (De Groot et al., 2001), which was presented at the IBPSA Conference in Rio de Janeiro 2001. The conclusions are also included below.

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.

A: WORKSHOP

The workshop was the third task of phase A of this project, which was organized on April 3rd, 2001 (De Groot et al. 2001). For the workshop an electronic meeting facility was used.

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

A description and the results of the workshop were given in the paper, which was presented at the IBPSA Conference in Rio de Janeiro 2001. The conclusions are also included below.

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).

B: MODEL DESCRIPTION

Based on the findings of phase A the model, which describes the design support tool, is presented in figure 2. This model is also related to the research, which is being conducted at the TU/e (Rutten et al., 1998).

The main objective is to easily get (in a quick and easy manner) a set of parameters, which describe a design, at both room and building level that fits the design requirements and can be used by different simulation tools. The tool is not fully automated but allows the engineer to use information, which is already available and to add additional design aspects. The total set of requirements of the design is called the performance scenario.

In Figure 3 the structure of the support tool is shown. All source data describe a design and the target data indicate the performance of the design. The structure of the support tool is applied on room and building level.

Starting with a default design and changing the given source data the selection of the additional design aspects is assisted by knowledge based systems

[KBS]. The knowledge-based systems which are used are a Case Based System [CBS] and a Rule Based System [RBS]. The KBS are used to select a set of parameters, which describes a specific design aspect. The various design aspects are shown as source data in Figure 3. A design aspect is selected by comparing the requirements of the design with performance indicators of the specific design aspects, which are available in the KBS.

This project focuses, as mentioned in the introduction, on the development of a Model and a set of parameters that describe the design that can be used in VA114. Later the design tool will be extended so it can be used for other simulation tools as well.

Case Based System

The CBS consists of sets of parameters that describe earlier designs of a building and its building services (HVAC systems). The performances of these designs are known and indicated in the CBS. It should be possible to combine different design aspects, see various design aspects indicated in Figure 3, of different cases to create a design, which can be evaluated by simulation tools.

When combining design aspects of different cases in a new design the situation can occur that some parameters are simultaneously changed by the selected different design aspects. These problems of conflict will be indicated and the engineer will be able to set the values of these parameters to his or her preference.

Rule Based System

The Rule Based System consists of protocols with design rules that change a set design parameters to implement a selected design aspect. In this case a total installation concept including for example boilers, distribution and local units can be a design aspect. It should be possible to add protocols. Problems of conflict, which occur when parameters, which have been set earlier, are about to be changed again, will be indicated. The engineer will be able to adjust these parameters.

In Figure 4 the steps of adapting and changing a design starting with a default design and using CBS and RBS are shown. The main steps of CBS are retrieve, reuse, revise and retain. The design can be revised by using RBS. In RBS the steps inventory, preselection and definite selection are taken to decide which design concept (protocol)should be used.

B: USERINTERFACE

Based on the model description a ‘dummy’ user interface (so-called: Criterion) was developed. This user interface shows engineers/users in a clear way what the functions and possibilities of the tool are and why it is different form other design support tools: e.g. Climasim (Taal, 2001), Conceptmodelleur (Rijswjk, 2000), VA114 UO (Jordaans et al., 2002), ORCA (Van Dijk, 2002), h.e.n.k. (VABI-website), EPV (NOVEM-website), ISSO 43 (Aerts, 1998), although aspects of these tools are used. The user interface helps to select the different functions of the design support tool, and their applications, which are most relevant to the engineers/users.

The functions of the Model are being able to use a performance scenario, to focus on room as well as on building level, to keep track of changes which have been made in the design and to set personal preferences. In addition Case Based Systems and Rule Based Systems are included. The user interface shows in a practical manner how the engineer can use the tool in the design process.

In this paper some figures are included which show some aspects of the user interface, e.g. performance scenario with bandwidths (figure 5), selection of design aspects from earlier designs using the CBS with performance indicators (figure 5), adjusting the geometry and envelope and design of HVAC system (figure 6).

The bandwidths used in the performance scenario set up the space of source and target data where a applicable design can be found. The performance indicators used by the CBS system show the projection of an earlier (detailed) design case in the set up space. Using this projection it is possible to decide whether to use design aspects of this earlier design case. When creating a design the geometry of the building can easily be changed. In later design stages the geometry can be adjusted in more detail. In a graphical way the various design aspects of a HVAC system can be selected.

B: WORKSHOP

During the workshop the model description and a presentation of the user interface were given. In total 4 different engineering companies, the EUT and VABI were present.

The participants stressed the importance of the flexibility of the tool and the possibility to set personal preferences. The tool should be flexible in way that it is possible to use certain parts of stored designs in the CBS and should be able to perform detailed calculation on a certain design aspect using more general information on other aspects.

Other comments of the participants were:

- Parameters changed in the base variant should also be automatically changed in the sub variants.
- Controls should be added in a separate group next to the HVAC system design aspects.

- The user should be able to add his own design rules to the rule based system.
- It should be possible to simulate at different levels of detail, e.g. it should be possible to use the design data in a later design stage for CFD calculations enabling coupling of BPS and CFD.

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.

A model description and user interface is developed and evaluated in a workshop with potential users. The participants of the workshop stressed the importance of the flexibility of the tool and the possibility to set personal preferences.

FUTURE WORK

The next phase will be the development of a prototype.

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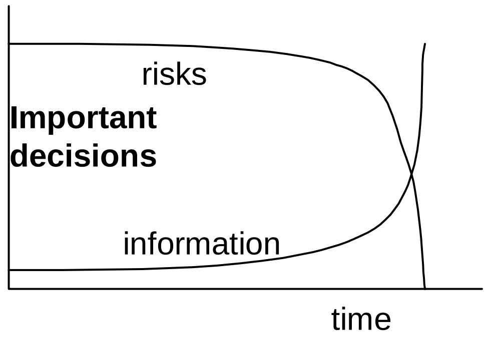

figure 1 *Impact of design decisions.*

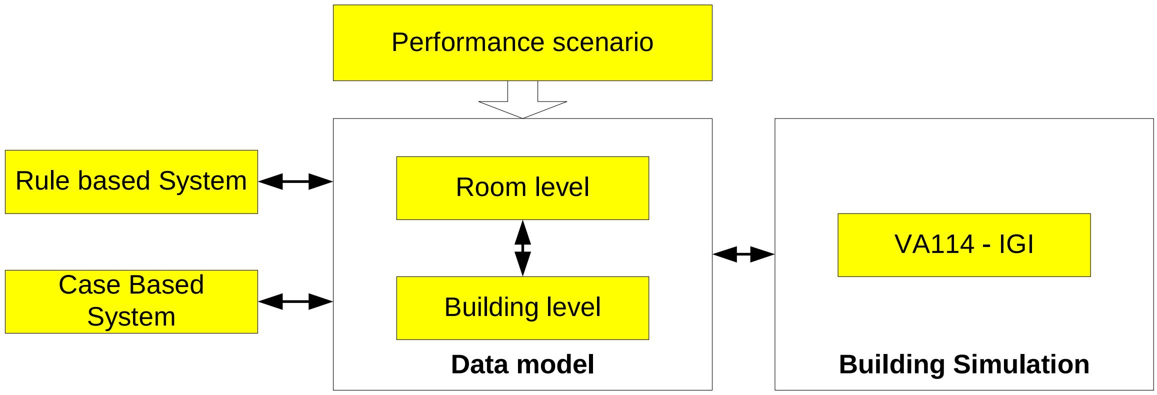

Figure 2 *Schematic presentation of the design support tool.*

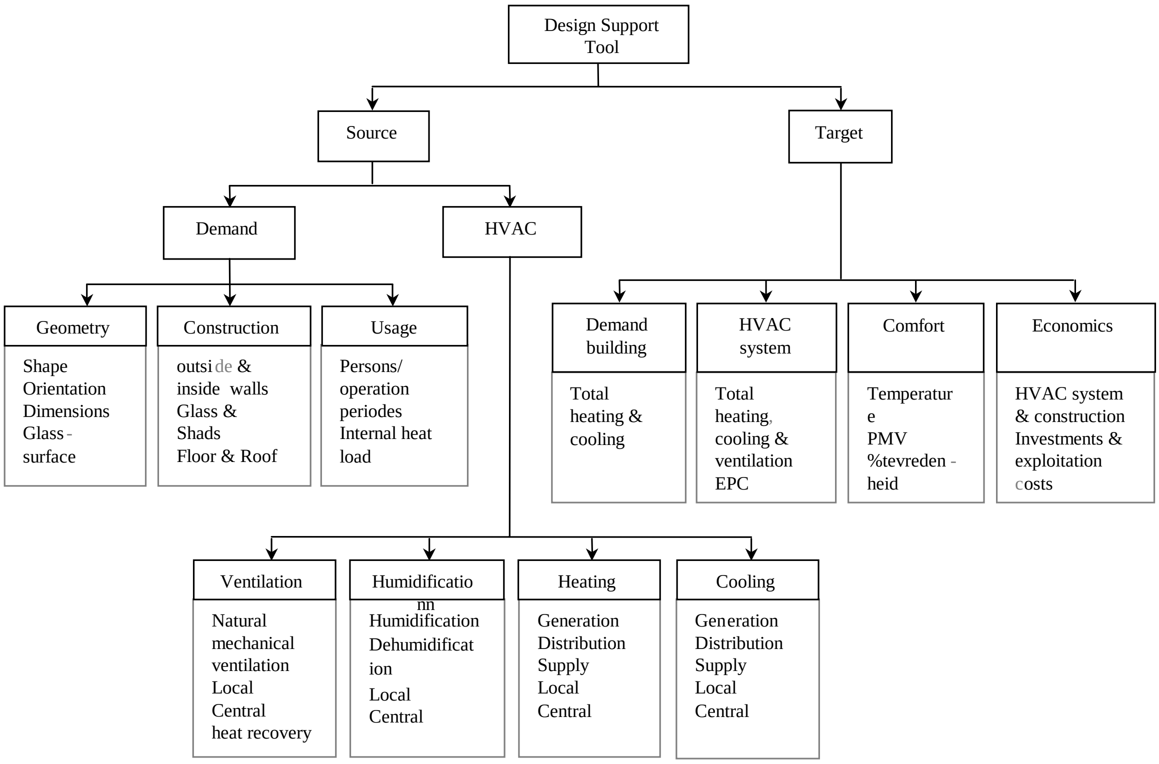

Figure 3 Data structure with the various design aspects applied both on room and building level.

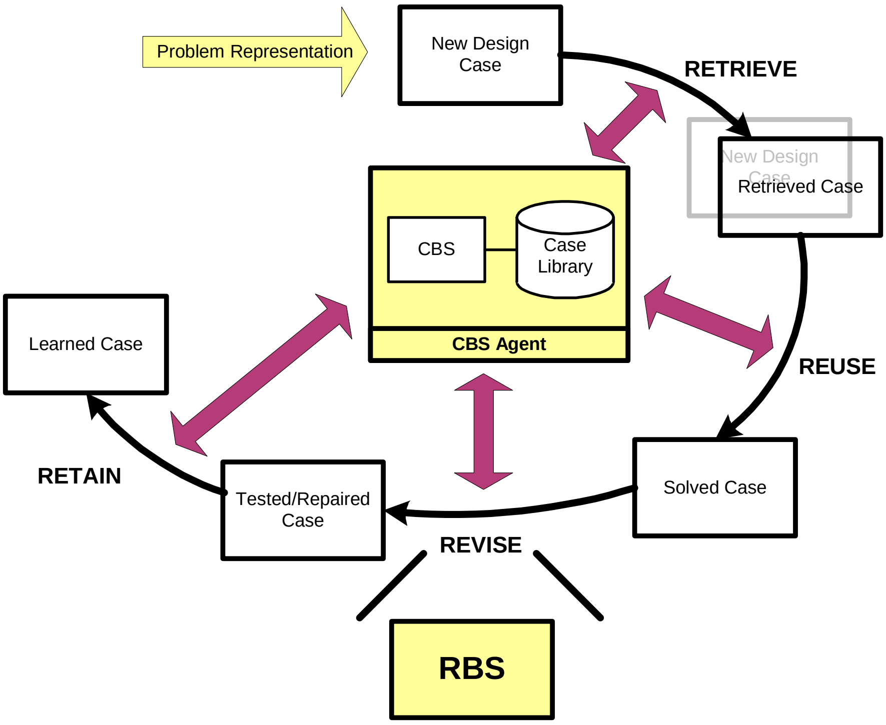

Figure 4 Method to use CBS to create a new design.

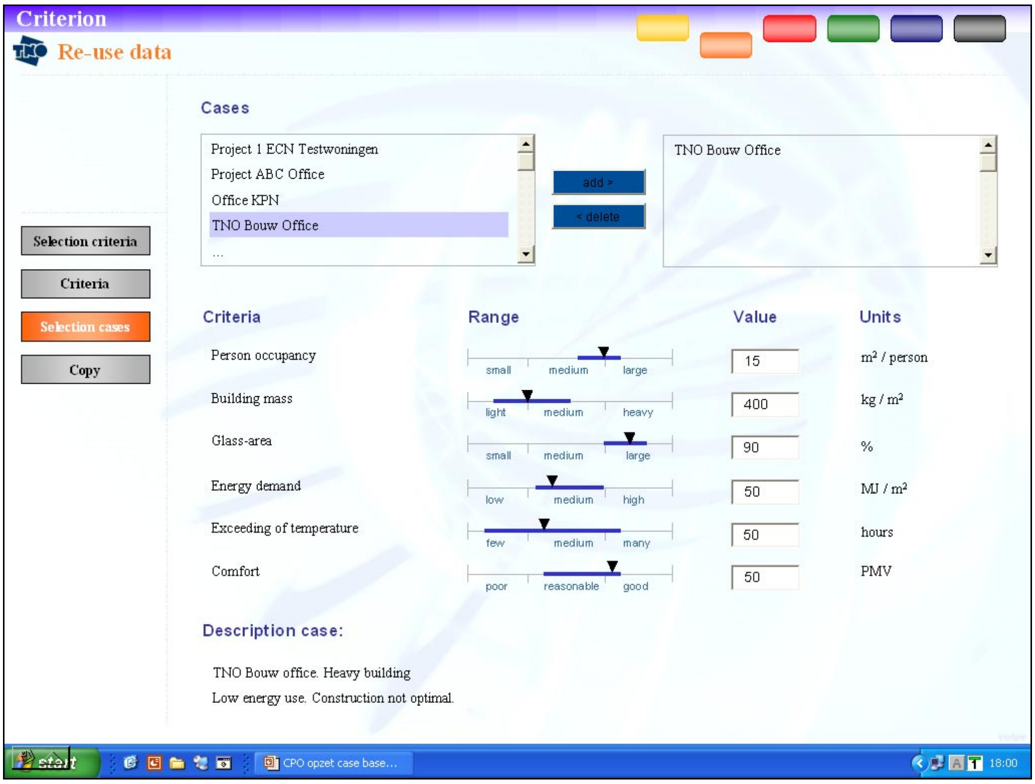

Figure 5 User interface: selection of design aspects from earlier design projects using the CBS with performance indicators.

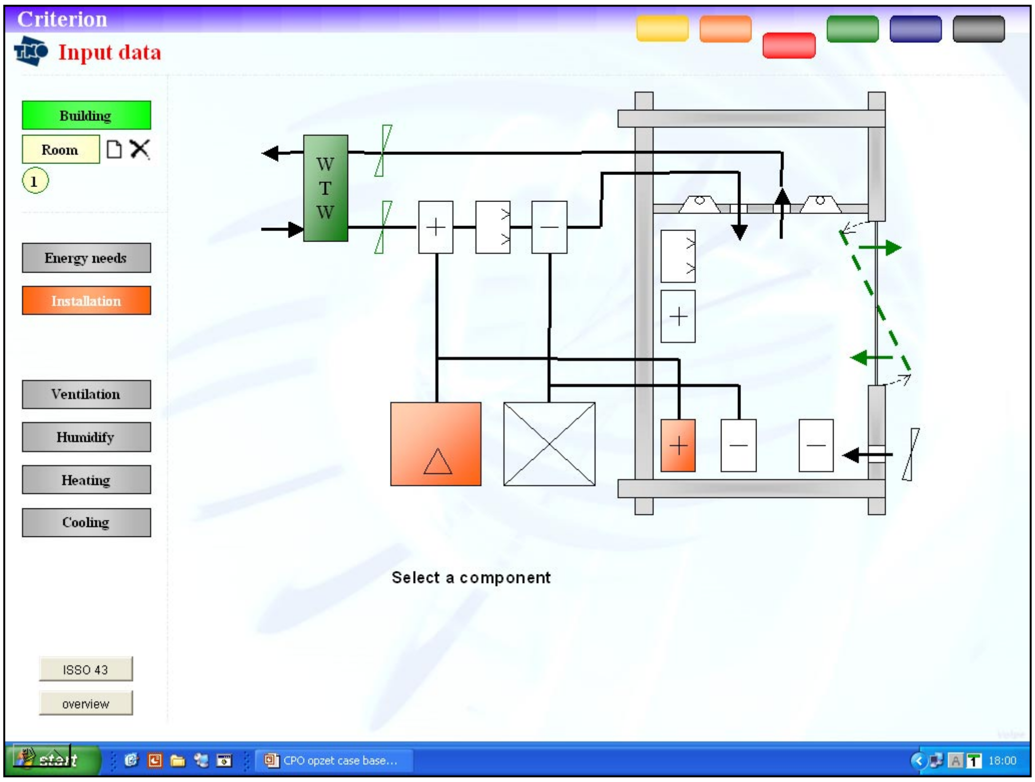

Figure 6 User interface: design of HVAC system.