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Research and Development in The Netherlands in the area of Building Performance Simulation

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Introduction

Research in the area of building performance simulation is a wide concept. A distinction can be made between different topics related to simulation: simulation environments, development of design tools, (Simplified) methods, (feasibility) studies with use of building simulation, quality assurance of tools and simulations. This paper focuses on the development of design tools/environments and is limited to a few research developments: Climasim, developments at TNO, and the foundation of the Knowledge Center Buildings & Systems.

In the area of development of design tools a number of parties varying from consultancy firms to universities are active. A short overview that is certainly not complete is: Deerns with HENK[1], Technical Universities with Climasim, TNO Building and Construction research together with VABI[2], TNO Mep for heating and cooling generation models, VABI with the building simulating program VA114 and the Uniform Environment, Krijger[3] with DYWAG and the BINK environment, DWA[4] with several tools for thermal storage concepts and energy savings.

Because we are more familiar with it, in this paper we focus on research and developments at academic and not-for-profit research institutes in the Netherlands

Climasim

On initiative of the Haagse Hogeschool a project is started in which a simulation environment is developed, specifically targeted at building services. In this simulation environment a designer will have the possibility to connect different system components together to form one model of a total system. This system model can be connected to a building model.
The system will be flexible and be applicable to different buildings. The environment will be extendable to adopt it to new components and new developments. Finally the system should be usable in the design stage, the realisation phase and the maintenance phase. For this reason the concept of a open system with a large model library is chosen. The Haagse Hogeschool is co-ordinator of this project, which is carried out in corporation with other research institutes and companies from the building services sector.

Developments at TNO

Integration of Building and Systems
Integration of building and system is one of the most important topics at this moment. Traditionally here are two types of simulation programs. There is either a focus on the demand side or on the generation side. In the last years the awareness has risen that it is very important to look at both levels in a integrated way. The emphasis has shifted from the building to the system. There are a numerous number of system concepts. So it is not feasible to integrate them all in one simulation model. The complete simulation exercise can be divided in four parts:1 Demand, 2 Supply , 3 Distribution, 4 Generation.

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[1] www.deerns.nl
[2] www.vabi.nl
[3] www.binksoftware.nl
[4] www.dwa.nl

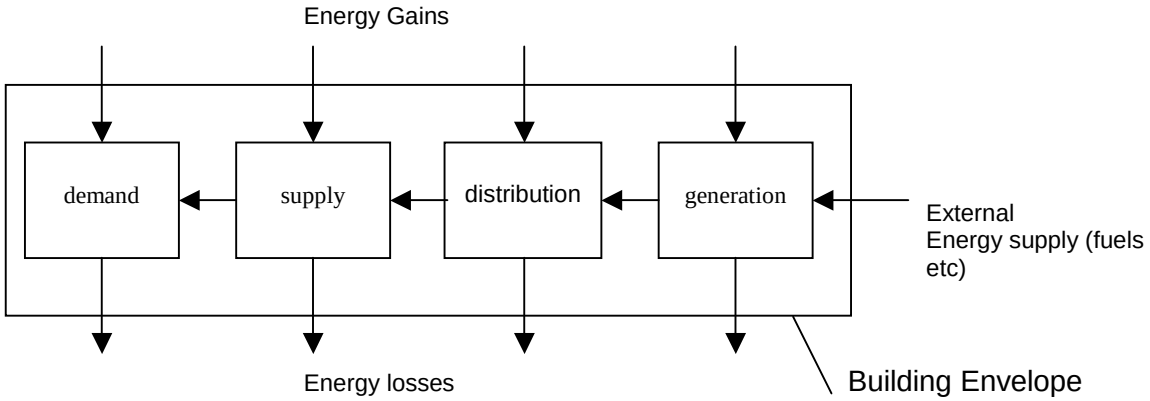

Figure 1 Schematic Overview Demand, Supply, Distribution, and Generation

TNO started a research on how to solve this problem. The basic idea is to use an existing building simulation program as a kernel for a simulation environment. This kernel will be equipped with interfaces towards distribution networks and heating and cooling generation plants. In this way an existing building simulation program can be used together with existing models for heating and cooling generation. The first phase of this project focuses on the set up of the whole framework, the definition of the interfaces (which physical properties has to be exchanged). This phase will and with a first implementation of the coupling between VA114 and Boilsim. Next in line are Solar Combi generation, asphalt collector, solar desiccant cooling. The following phase will focus more on cooling equipment.
The software technique for coupling will be the use of DDE's. By the end of the year a first description of the call made to the DLL will be available. In this way developers of installation models will be able to connect their model to a building kernel.

Early Support for Building Services Design
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. 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 & Trum 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). Being able to communicate is therefore important, and tools to support this communication are needed.

In the old days, building service engineers were involved in design at the evaluation stage of the design process. Therefore, many design tools exist to support this task. Nowadays, with large building projects a building team including the building service engineer is initiated right from the start. Nevertheless, no design support tools were developed that can be used in the earlier design stages. These tools should make it possible to quickly compare alternative conceptual design solutions and to visualise possible consequences of the design decisions on their own work or on the work of others. At the moment, these consequences often are initially overlooked initiating the risk in the final design not matching the client's demands as well as it should, which enlarges the chance on complaints during the occupation phase. Mismatches must then be fixed at high cost.

TNO Building and Construction Research, having experience for many years in designing support tools for building service engineering, has initiated the research project described here. The project will result in design support tools for early design of building services. The initial feasibility study includes three tasks: a desk study, five field studies, and a workshop.
- The desk study aims at retrieving information on the current use of existing design tools, for example by studying recent inquiries among users.
- The field studies at five different building service companies provide an overview of those situations in which the current tools are used. The benefits and shortcomings of the tools are captured. Further, some case studies of projects that resulted in a mismatch of design and demands are analysed.

– Finally, the results of the studies are presented in a workshop with users of current design tools to inform them 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.

Initially, the project focuses at 'Building Simulation' and 'Lighting Techniques'.

Control engineering

In line with the project of the integration of building and installation there is also more emphasis on the simulation of different control strategies. Within most simulation environments it is difficult to define your own control strategies. An exception is made her for simulink, which has excellent possibilities to define control strategies. The coming year a project is started with support of VABI on who to set up an environment around a building simulation program in which it is possible to define your own control strategies.

Knowledge Center Buildings & Systems TNO - TU/e

Technische Universiteit Eindhoven and TNO have joined forces in co-operative research in the area of building physics, building services and human health. A multidisciplinary and international approach is the cornerstone of this endeavour that will embrace PhD students, some postdocs and visiting professors from different countries. A number of PhD vacancies are available. The centre will generate scientific, technological and (design) process knowledge to contribute internationally to human well-being and welfare in a sustainable built environment. The overall theme of research is **Strategic Design Support Tools**. It incorporates in depth scientific and engineering knowledge into new and innovative ICT-tools to guide and support the design process of modern buildings. Research is performed in 6 different Task Groups and may lead towards a variety of design and evaluation tools:

– Building Acoustics
– Building Modelling and Simulation
– Heat and Moisture
– Human Lighting Demands
– Public Health Engineering
– Renewable Energy Installations

The center will officially start next month.

All the research themes are described further on the web site http://www.busy.tue.nl/. We will now focus on the research theme building modeling and simulation.

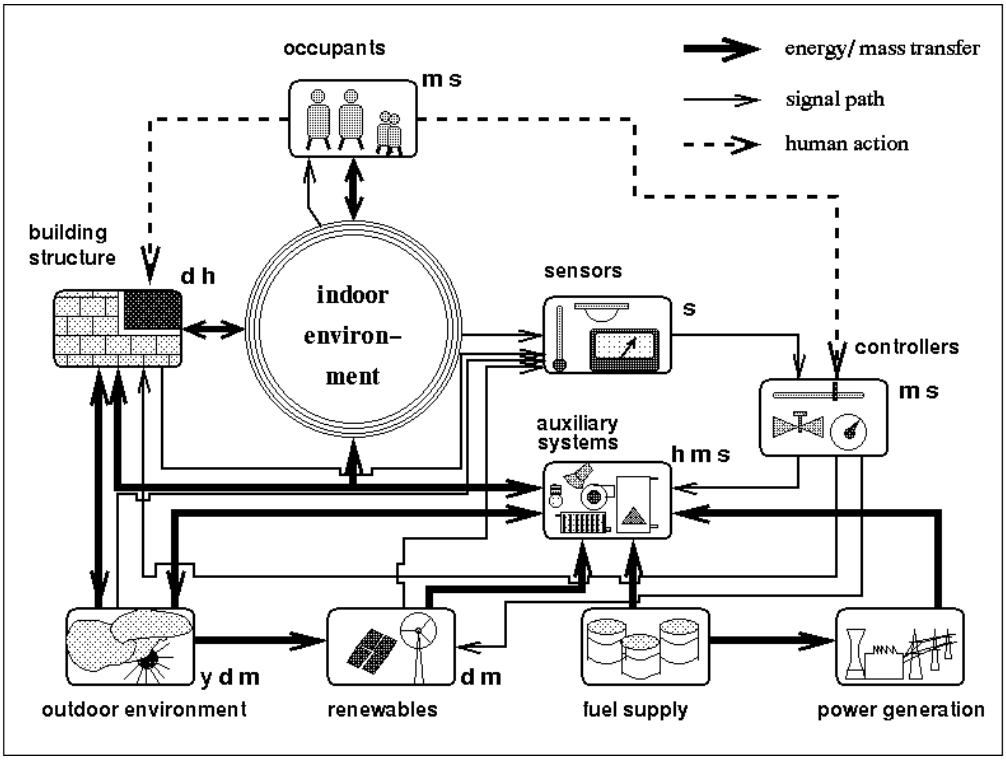

Figure 2 : Schematic overview of research field: the building as an integration of energy systems

Building Modeling and Simulation
The mission of this Task Force is development, advancement and application of conceptual (strategic) design phases. Work aims at a better understanding of the underlying principles for an integrated, performance based approach of traditional and renewable energy systems in the built environment. Research in this theme leads towards developing strategic design support tools.
The applied part of Building Modelling and Simulation starts from the premise that strategic design support tools should -primarily- be based on building modelling and simulation in combination with other information and communication technologies. Tools are applicable to building structure and indoor environment, while simultaneously taking into account the outdoor environment, mechanical, electrical and structural systems, and traditional and renewable energy supply system. The innovative tools we aim at are not restricted to the detailed design phase, which is current practice. They may be employed both earlier in the design and -after completion- during the whole life cycle of the building.

The following initial PhD research themes are defined in this task.

Design Tool for Innovative Integrated Building Control Strategies
Starting from the observation that currently it is extremely difficult, if not impossible, to predict the overall effect of innovative control rules/ strategies for integrated building systems (HVAC, Lighting, Shding, ventilation, openable windows, thermal storage systems, embedded renewable energy systems etc.), the main aim of he project is to develop/ extend a design tool which will allow integrated performance assessment of new building control strategies.
The project will make use of an existing advanced building research environment. One of the shortcomings in current modelling and simulation tools is that - in terms of control – they only allow in built control rules to be assessed. However in practice, innovative designers very often want to consider control options/ combinations not (yet) featured in the simulation environment. Thus a key feature of the new functionality will flexibility in terms of building control definition from the user point of view. This should be achieved by 'externalising' control definition: i.e. the user should not be restricted to control options/ strategies on offer, but should have the option to define any control loop/ strategy using a simple 'language' which can be understood/ interpreted by the program. The extended design tool will then be used/ tested to assess and compare the performance of various control strategies for environmental benign, low energy cooling techniques for buildings, such as; structure assisted cooling, earth coupled heat exchangers, controlled natural ventilation, nightime purge ventilation, and usage of controlled shading devices.

Design Tool for Innovative Integrated Building Systems
In terms of modelling and simulation of innovative buildings and systems (HVAC, lighting, shading, vents, openable windows, thermal storage systems, embedded renewable energy systems, etc.), two of the most restrictive shortcomings of current tools are (1) that each tool only has a limited number of systems it can represent, and (2) that inter-process communication is not possible.
The main aim of this project is to research and implement (options for) inter-process communication. This, in turn, should enable run-time coupling of simulation environments and thus alleviate restriction (1) above; i.e. it should become possible to run two or more simulation programs in parallel where each program represents only that part of the building and systems which it is able to model.
The inter-process communication should be developed in a general sense.
The result will be implemented and tested in at least three different simulation environments, two of which will be building domain specific (ESP-r and TRNSYS) and one will be domain independent (SIMULINK).
Thus a key feature of the new functionality will be flexibility in terms of building systems definition from the user point of view; i.e. the user will no longer be restricted to system (and system component) options/ features on offer in a particular tool, but, by combining simulation tools, will be able to model any building and system combination.
The extended design tools will then be used/ tested to assess and compare the performance of various innovative building and systems combinations such as, for example, earth coupled heat exchangers, combined heat and power, embedded renewable energy systems, etc.

System Based Approach for Simulation of Building Systems
In terms of modelling and simulation of building systems and the associated heat and mass transfer processes various approaches exist. At one end of the spectrum are the conceptual approaches. Here usually only the room processes are specified (for example whether it is floor heating, a chilled ceiling, or an air based cooling system) without considering how the heat is generated/ rejected and how it is distributed to

the room. At the other end of the spectrum are explicit approaches in which every component of the system (generation, distribution and delivery) is modelled and specified individually.
There are tools which have an intermediate approach in which the user can specify the system in terms of its functionality; e.g. a VAV system, a dual-duct system, etc. In this approach it is often not clear how the system is really modelled; i.e. for a particular system what does it actually mean and how are systems/components/controls represented both in a numerical sense and from a user point of view. Moreover, in case two different simulation tools offer a particular system, say a VAV system, do they really model that system in the same way.
It is this latter intermediate approach which is often favoured by building system designers. However there are some associated quality assurance issues as indicated above.
The project would aim to alleviate these concerns by researching and implementing a methodology based on well-defined templates for various common building systems which can make use of both conceptual modelling concepts and explicit modelling concepts.
The templates should be developed in a general sense. The results will be implemented and tested, at least in one existing advanced building simulation research environment (ESP-r), but probably also in another simulation environment such as EnergyPlus.
The extended design tool will then be used/ tested to assess and compare the performance of various building and systems combinations.

Use of Modelling and Simulation throughout the Building Lifetime
Modelling and simulation of buildings and systems is currently mostly restricted to the detailed design phase. However there are various additional simulation application areas in the subsequent lifetime of the building. Simulation can be used, for example, to aid in the commissioning of a building, for simulation-based predictive control of the building, and for other operational and maintenance purposes.
The model used for the design of the building and systems can become a useful dynamic live document in addition to the traditional static drawings.
The aim of the project would be to research the model requirements for the range of applications mentioned above, and - in case the models are not the same in terms of scope and/or resolution - to research whether it is possible to generate the later-in-life models from the design model.
The main outcomes of the project should be software independent. For testing purposes, however, the results will have to be implemented and tested in an existing advanced building simulation research environment (ESP-r).
The extended design tool will then be used/ tested in the design, control and maintenance of an experimental building.

Strategic Building Systems Design Support Using Case-Based Reasoning
Starting from the premise that most good engineering designs are innovations of existing examples or past experience ("design by example"), a "knowledge base" consisting of real case studies and accessible via the Internet would be of major benefit to designers in practice as well as to students in a learning context.
The main aim of this project is to research the feasibility of case-based reasoning for strategic design of building systems.
Important aspects to be addressed are where the case-base would reside, in which format it should be, which topical information should be included, etc. Some associated research topics include: how to deal with dispersed information; how to deal with variety of information; how to deal with information overload; which information should be included; how to acquire the necessary information; how should information be (re)presented.
The outcome of the project would be a pilot implementation of a case-based reasoning system for strategic design of building systems.

Strategic Building Systems Design Support Using Modelling And Simulation.
In the area of indoor environment, building physics and building systems complex interactions exist which are very difficult - if not impossible - to capture and represent in rules or other forms of explicit knowledge for use in knowledge based systems. Until now it has only been possible to address this complexity by simulation. However, currently modelling and simulation of buildings and systems is almost exclusively restricted to the detailed design phase.
The main aim of this project is to research the possibilities for use of modelling and simulation at an earlier stage in the design process.

Conclusions

Current research focuses on integration of building and systems biased towards systems. Also a lot of attention is paid to possibilities to support control engineering. There is also a shift away from the detailed design phase both towards the early design phase in order to support strategic design, as well as towards the operational phase of the building in order to support operation, maintenance and control.