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CENTER FOR BUILDING AND SYSTEMS TNO-TU/e: A MULTI-DISCIPLINARY APPROACH FOCUSSED ON WELL-BEING OF PEOPLE

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ABSTRACT
The Centre of Building and Systems is a cooperation agreement between TNO and TU/e in The Netherlands, in which several expertises were brought together for a large investigation on buildings and systems. The well-being of people (comfort and health) is the main focus. This multi-disciplinary approach has to result in innovative insights on lighting, indoor climate control, building acoustics, health and comfort, but also on sustainable energy. And, it has to result in knowledge to support the integral design process. This large and ambitious project will need approximately 12 MEuro in the first phase (2001- 2005). After 2005 the intention is to become an independent centre, without any additional investments of TNO and/or TU/e.

INDEX TERMS
Innovation, research centre, indoor environment, strategic design, simulation

INTRODUCTION
A number of important shifts in the building and system industry are becoming increasingly clear. Thus, attention is focusing more and more on the buildings' occupants, emphasising their comfort, health and safety in the living and working environment. The users' ambitions and flexibility of buildings are other important factors in this trend. The previously investment-oriented approach is transformed into an exploitation-oriented approach, increasing the importance of expected maintenance and the 'liveability' of buildings in the architectural design. Significant steps towards a sustainable society have already been taken; environmental aspects such as well-considered energy consumption are increasingly self-evident; and the design process itself is evolving towards an integrated process that takes the complete life cycle of the building (from initiation to demolition) into account.
These shifts open up new challenges and opportunities in the market. To exploit these and really improve the design of buildings and their systems, the acquired knowledge of multiple disciplines is required. The objective of the Center for Building and Systems TNO-TU/e is to lay the foundation for innovation.
The Center for Building and Systems is the result of a partner-ship agreement between TNO and the Technische Universiteit Eindhoven (TU/e), in which the expertise of TNO TPD, TNO Building and Construction Research, and the TU/e faculties of Applied Physics and Building and Architecture join forces to conduct large-scale research on buildings and systems. The main focus is the well-being of people (their comfort and health). This multidisciplinary

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approach is expected to result in innovative insights in the field of lighting, indoor climate control, building acoustics, health, and comfort, but also with regard to sustainable energy. In addition, the research is intended to yield knowledge that will feed further research on strategic design processes, building simulation and new building techniques.
TNO's role is to ensure that the acquired knowledge can be deployed and that the new products are marketed as tools, design resources and evaluation methods. The TU/e will use the research results in its educational programme to offer a unique curriculum, but will also use feedback from the market (via TNO) to give direction to and focus its research activities. This large-scale and ambitious project will require an investment of approximately EUR 12 million for the first phase (2001- 2005). A large part of this investment is funded by TNO and TU/e. After 2005, the plan is for the center to become an autonomous and self-reliant organisation, with limited additional investments from TNO and/or TU/e.

METHODS

The research will focus on answering five basic knowledge-related questions:

1. How can the impact of buildings and systems on human health be understood to such an extent that an acceptable level of comfort and health can be assured for new systems?
2. How can the heat and moisture balance in building constructions and buildings be modelled in such a way that architects and constructors can select materials and structures limiting the growth of harmful organisms?
3. How can sustainable energy systems be designed in such a way that they fit within the building design and link up with the energy infrastructure?
4. How can the design process be structured in such a way that the entire field of building physics and system technology is incorporated, but that an effective understanding of the design phases can also be achieved?
5. How can this design process be supported with new simulation tools and ICT (Information Communication Technology) for the building and systems industry, which also link up with the strategic design protocol?

In order to find the answers to these five questions, the knowledge centre focuses on five distinct technological research areas: Human Lighting Requirements, Healthy Buildings, Building Acoustics, Heat and Moisture, and Sustainable Energy Systems (Figure 1).

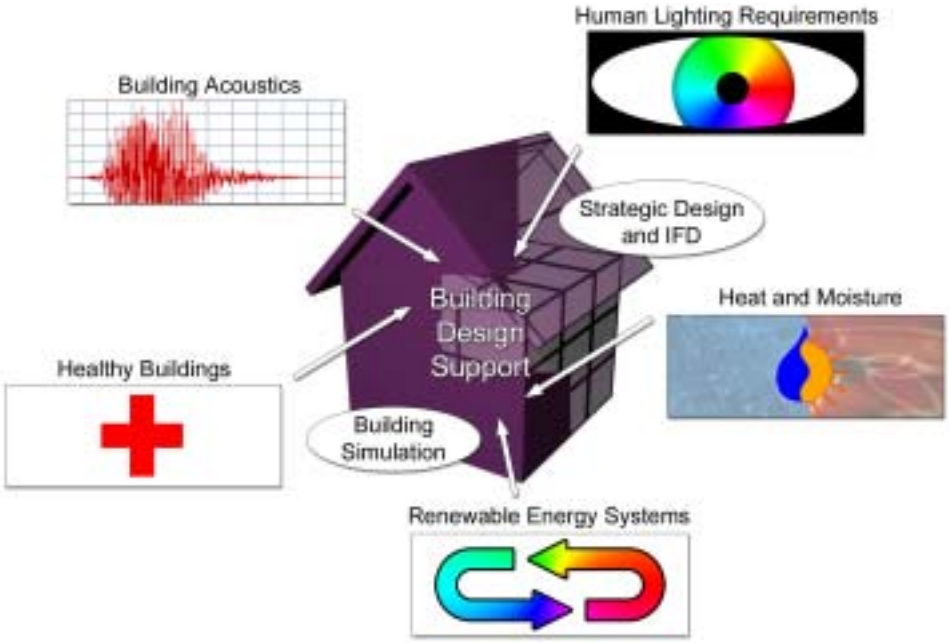

Figure 1. Schematic overview of KCBS and her topics of research.

In each area, knowledge will be acquired that can be put to practical use. Furthermore, the results of the five research areas will provide a foundation for the development of 'Building Design Support', a field of research that is split up into two areas: Strategic Design and IFD (Industrial Flexible Demountable), and Building Simulations.
To broaden the range and depth of the research conducted within the knowledge center, PhD and postgraduate students will be recruited. The ambition of the center is to attract approximately 24 PhD students, who will be supervised by experts of both TNO and TU/e. The intention is to promote the influx of new students and researchers at the TU/e and, at the same time, to recruit some of these fledgling scientists as academic staff for TNO to constitute a driving force for its own activities and projects in the various disciplines.
The research of the Center for Building and Systems will not be limited to the Netherlands. Existing international contacts of both partners will be extended and new partnerships will emerge.

STRATEGIC DESIGN AND IFD

Design of buildings with sustainable value

The mission of the research area Strategic Design and IFD is to

The objectives of this area are:

- To develop models and performance criteria for the design process itself, in which the communication of the different parties is the main focus.
- To develop a basis package of design criteria for IFD technology to be able to design a more sustainable building

This focus of research is divided into two directions:

- Strategic Design Support Tools: the research will be focussed on decision conceptual models and strategic criteria for design team for different building concepts and different users of buildings.
- Industrial, flexible and demountable building (IFD): the research will be focussed on the knowledge management of IFD construction itself (construction methods, use of materials and flexibility of the main, structure of the building).

BUILDING SIMULATION

For better, faster and more cost-effective design of innovative and integrated solutions.

The mission of the research area Building Simulation is a better understanding of the underlying principles and improvement of simulation based design tools for an integrated, performance based approach of traditional and renewable energy systems in the built environment. The overall objective is to develop, advance and apply computer modeling and simulation for building performance analysis and design. Apart from having obvious importance in its own right, both the main research method of computer simulation and its focus point of integration of building systems, can be expected to play substantial roles in the other research themes.
The main research methods are computer modeling and simulation, experimental work for model improvement and quality assurance, and other information and communication technologies for simulation support and knowledge transfer. The research is expected to mainly take place in the following general categories of, more or less, equal importance:

- General research on domain specific issues, such as integrated building energy performance appraisal, novel building systems approaches, low energy heating and cooling techniques and/or systems, strategic design of building systems,

- Application of this knowledge through consultancy for both the construction industry and the building energy modeling community , and
- Advancement of building energy modeling and simulation tools, guided by short-comings encountered while pursuing the above.

HEALTHY BUILDINGS

An increased healthy life expectancy for a maximum number of people and improved productivity are not necessarily contradictory concepts

The mission of the research area Healthy Buildings is the development of innovative concepts and systems for the control of the indoor environment (air quality, heat and moisture, lighting and acoustics), to increase to number of healthy and productive years of life of an occupant, and to decrease sick leave and improve economy. The objectives are to make a basis for:

- Tools with which in the beginning of the building process different design choices can be translated to effects of measurable aspects of comfort and health;
- Ventilation guidelines focussed on specific indoor environmental sensitive target groups (for example people with lung diseases);
- The development of innovative techniques to monitor comfort and health related aspects of the indoor environment.

Knowledge will be developed with which

- The effect of indoor environment related aspects of building and systems on comfort and health can be translated into measurable units (such as productivity);
- The acceptable level of comfort and health related to indoor environmental aspect of building and systems can be determined;
- The effect of ventilation control principles on measurable aspects of comfort and health can be determined;

BUILDING ACOUSTICS

Reducing sound transmission to prevent noise pollution.

The mission of the research area Building Acoustics is to develop all that is necessary to create design tools which can be used in building practice to achieve a high quality acoustical climate in future, new and renovated, buildings. The objectives are to:

- Improve our understanding of the sound propagation in buildings and the physical behaviour of building elements, junctions and the sources of sound;
- Improve and extend the design tools for building acoustics;
- Improve and develop models and measurement methods for the acoustical performance of buildings elements, junctions and structures, necessary as reliable input for design models.

The research of this area will be focussed on two lines:

- *Structure-borne sound transmission from installations to building structures:* Essential elements in the sound propagation for various types of installations and equipment are the fluid supply and waste pipes. For the latter a modelling and experimental approach will be developed. For other parts and elements of relevant installations the modelling will by developed subsequently according to the same approach.
- *Vibration transmission across building junctions:* Essential is knowledge on the vibration transmission at building junctions for which experimental methods are needed. Laboratory set-ups for determining the building junctions' characteristics will be developed.

HUMAN LIGHTING REQUIREMENTS

Lighting for health, well-being and productivity!

The mission of this area is twofold:

- To gain insight in how lighting affects the performance, mood and health of people.
- To create and develop new ways of illuminating the build environment based on a natural lighting approach.

The main objective is to determine human natural lighting demands from the visual (physiological), biological and psychological point of view. The research will be focussed on three directions:

- *Lighting and working people:* in which the demands for light and lighting in the working environment (office, industrial, educational and healthcare environments) will be determined.
- *Integration of daylight and electric lighting*: in which the question How can we achieve a comfortable, energy efficient and pleasant atmosphere utilising as much daylight as possible integrated with a properly located and controlled electric lighting, will be answered.
- *Light, building and work:* in which items such as transparent buildings, building underground and lighting in educational buildings, will be investigated.

HEAT AND MOISTURE

Gaining insight into moisture transmission in building materials for healthy buildings

The starting points for research on transport of heat and moisture are the well-being of people in buildings, and 'Sustainability' of the building product. 'Sustainability' means in this context not only the effect of the environment on the product, but also the effect of the building product on the environment. The objectives are the development of:

- Concepts and tools necessary for the development of future product-services combinations. With 'Product' is meant materials, building elements, construction parts and buildings.
- Technology to optimise the extension of life of building products
- Concepts and strategies to minimise health risks from growth of biological organisms in the indoor environment.

Research will be focussed on transport of heat and moisture (as well as the compounds dissolved) in building materials and constructions, and, on performance of materials and constructions in relation to this transport. Specifically it concerns (sustainability: degradation phenomena, such as salt crystallisation, corrosion of reinforcement, biodegradation) and growth of biological organisms on the surface area of the construction, which are possibly the cause for degradation and health effects.

SUSTAINABLE ENERGY SYSTEMS

Renewable energy is strongly embedded in government policies and represents a commercial attraction for developments in this field.

The mission of the area sustainable energy systems is to better understand the possibilities of system integration into the built environment (on district and building level) by developing tools and methods, applicable to renewable energy installations for the build environment that create opportunities to introduce renewable energy on a professional bases.

Research and objectives will be focussed on three directions:

- *Design tools on district level:* The objective is to develop design tools starting from the existing dynamic tools for single installations for an earlier phase of development: the design of the energy infrastructure for newly build or renovated district areas..
- *Environmental performance indicators:* tools the objective is to get knowledge on the most important/relevant aspects and to find a way to quantify environmental impacts.
- *Functional integration in buildings:* The main challenge for future developments of renewable energy installations is to reach an acceptable price level and a minimised

environmental impact. The objective is to study options in which renewable energy installations are no longer a complementary measure but a substitution measure.

RESULTS AND CONCLUSIONS

Although some start-up problems were encountered, the formation of the KCBS has shown already to be successful for both parties involved in 2001:

- 3 PhD students have started their research in 2001 and 10 PhD students continued their work.
- Several European sponsored projects were accepted (for example HOPE (Bluyssen, 2002)).
- The organisation of the 8th two-yearly conference Building Simulation 2003 in Eindhoven.
- Several national workshops have taken place (for example the 3rd IBPSA-NL symposium (IBPSA, 2001).
- A joint web-site (www.kcbs.nl) was put into the air.
- A Dutch and English leaflet describing the general activities and structure of the KCBS were printed.
- Several publications in scientific and non-scientific journals were published.

From these results in 2001, we can conclude that the cooperation within the KCBS has both given TNO and TU/e an advantage, even though the difference in cultural organisation and targets. The internal communication was an import aspect in 2001, comprising of frequent meetings, internal workshops to disseminate the knowledge to each other and the set-up of the organisational structure. The daily management comprises of four persons: a Business manager (Aart de Geus), a Director of research (Paul Rutten), a Research programme manager (Jan Hensen) and a Marketing manager (Philo Bluyssen). Furthermore, for each research area, two leaders are appointed, one from TU/e and one from TNO.
For 2002 it is estimated that another 3 to 5 PhD students will be attracted. Furthermore, the number of European and national sponsored projects (both through industry and governmental organisations) are expected to increase, as well as the output measured in scientific and non-scientific publications. International cooperation has started among others with USO-BUILT (the first graduate school of CLUSTER) (van Bronswijk, 2001) and the Danish-Finnish programme Moulds and Health (Nielsen, van der Wel and Adan, 2001), but also national with the technical university of Delft, and will be continued and extended in 2002 and onwards. For the 2002, the external communication will be the focus of attention. With the foundation of the Center for Building and Systems, an important step towards a nationally and internationally leading knowledge center in the field of building and systems has been made.

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