BETTER IAQ THROUGH INTEGRATING DESIGN TOOLS FOR THE HVAC INDUSTRY

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ABSTRACT

There is currently no effective combination of interoperable design tools to cover all critical aspects of the HVAC design process. Existing design tools are separately available, but require expertise and operating time that is beyond the scope of a normal design project. For example, energy analysis and computational fluid dynamics (CFD) tools are not used in practical design, leading to poor indoor air quality and/or unnecessary energy consumption in buildings.

A prototype integrated software tool for demonstration, process mapping and proof-of-concept purposes was developed under a new international, Finland/USA jointly funded development project Bild-IT. Individual design tools were simplified and adapted to specific applications and also integrated so that they can be used in a timely and effective manner by the designer. The core of the prototype linked together an architectural CAD system, a 3-D space model, a CFD program and a building energy simulation program and it utilises real product data from manufacturer's software. Also the complex building design, construction, maintenance and retrofit processes were mapped to get a template for the structure of the integrated design tool.

KEYWORDS: HVAC design, Integration, Thermal comfort, CFD

INTRODUCTION

Previous surveys [1] have shown that there is no effective combination of interoperable design tools to cover all critical aspects of the HVAC design process. Existing design tools are separately available, but require expertise and operating time that is beyond the scope of a normal design project. For example, energy analysis and CFD tools are not used in practical design leading to poor indoor air quality and/or unnecessary energy consumption in buildings.

These individual design tools not only need to be simplified and adapted to specific applications, but they must also be integrated to be used in a timely and effective manner by the designer. Also it was found that an accurate map of the complex design, build, maintain and retrofit building process is missing and is required as a template for the structure of the integrated design tool.
This paper presents an international, Finland/USA jointly funded development project Bild-IT [2], which will create an effective and highly integrated design tool for the building process. In the first phase a prototype software tool for demonstration, process mapping and proof-of-concept purposes was developed. As an example, this software package will permit the designer to model the geometry of the building and then define user requirements such as IAQ targets for the spaces. With this information, the

designer will then perform an energy analysis on the building envelope and HVAC system performance, use an integrated flow analysis tool to resolve IAQ/comfort/control issues, compare different equipment package performance and make easy-to-understand presentations on results to both building owners and architects. This tool is intended to accelerate both pre-design and design phases in building projects and improve communication between key players from various disciplines in the design-build process.

METHODS

It was found that an accurate map of the complex building design, construction, maintenance and retrofit process is not available and is required as a template for the structure of the integrated design tool. Eight workshops [3] were held with different players in building design process as a basic vehicle for gathering information of the current design process and mapping the whole building process:

1. IFMA Workshop, Gothenburg, Sweden, 1999 May 31st
   ➔ Facility manager focus
2. Workshop held in conjunction with ASHRAE meeting, Seattle, Washington, U.S.A., 1999 June 19th
   ➔ HVAC consultant focus
3. FIFMA Workshop, Finland, 1999 September 7th
   ➔ Facility manager focus
4. MIT Workshop, Cambridge, U.S.A., 1999 September 30th
   ➔ Architect focus
5. IFMA World Workplace Workshop, Los Angeles, California, U.S.A., 1999 October 4th
   ➔ Facility manager focus
6. Lean Construction Institute Workshop, Fort Collins, Colorado, U.S.A., 1999 November 12th
   ➔ Contractor focus.
7. Construct Canada Workshop, Toronto, Ontario, Canada, 1999 December 1st
   ➔ Charrett/design team focus
8. DOE/AIA Workshop, Washington D.C., U.S.A., 1999 December 6th
   ➔ HVAC consultant focus

RESULTS

Design process

Based on the results from the workshops there was a need for using different kind of design tools in different phases of the HVAC design process. It was also found that the need was not limited just to the design phase and, more importantly, that the HVAC data management should include the whole building life cycle (Fig. 1). To avoid multiple data input, reuse of existing data is important. This means that different design tools have to be interoperable with each other.

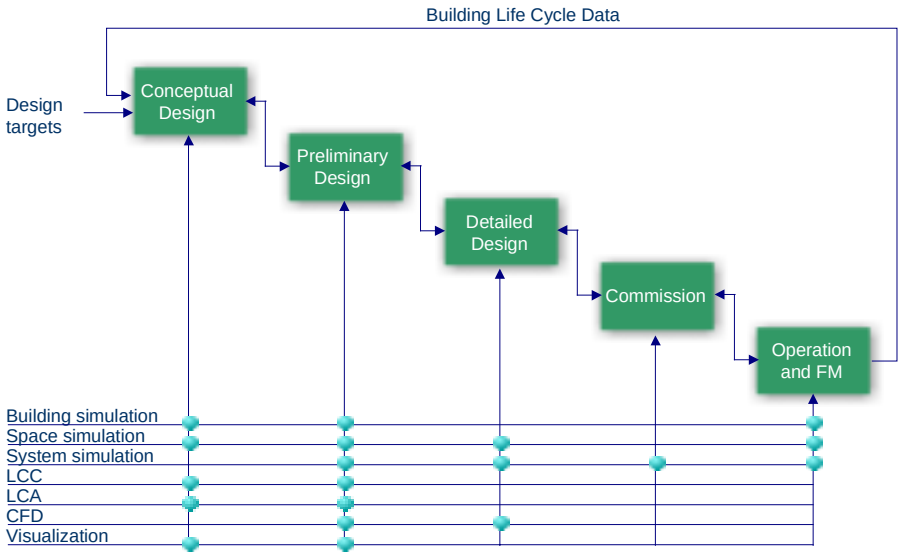
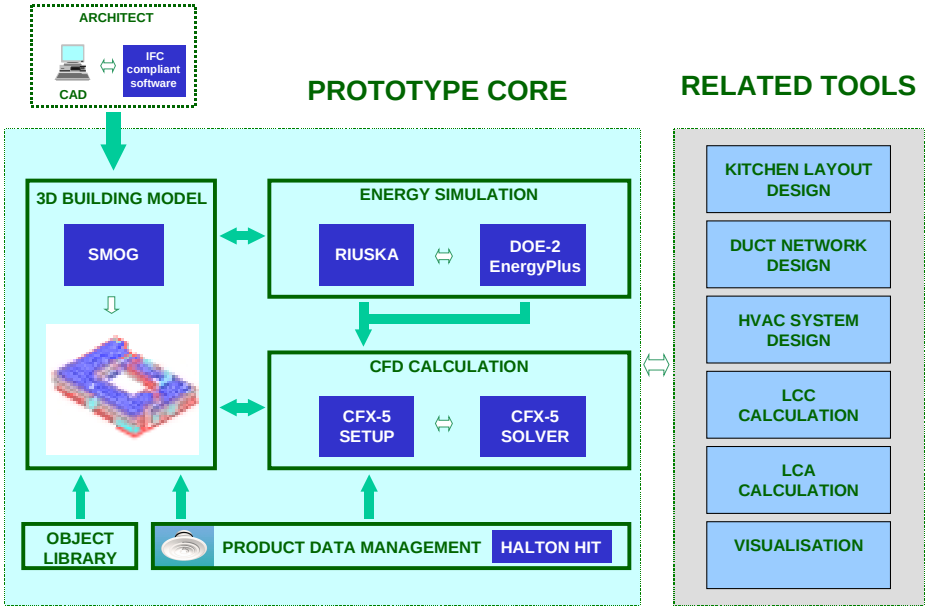


Figure 1. The need for design tools during the whole building process.

Prototype tool

In the Bild-IT project a prototype software package (Fig. 2) was developed for proof-of-concept and demonstration purposes. Each software in the prototype was implemented and tested as a stand-alone tool but the links between the different software tools were only partially implemented.

Figure 2. The structure of the integrated Bild-IT prototype.

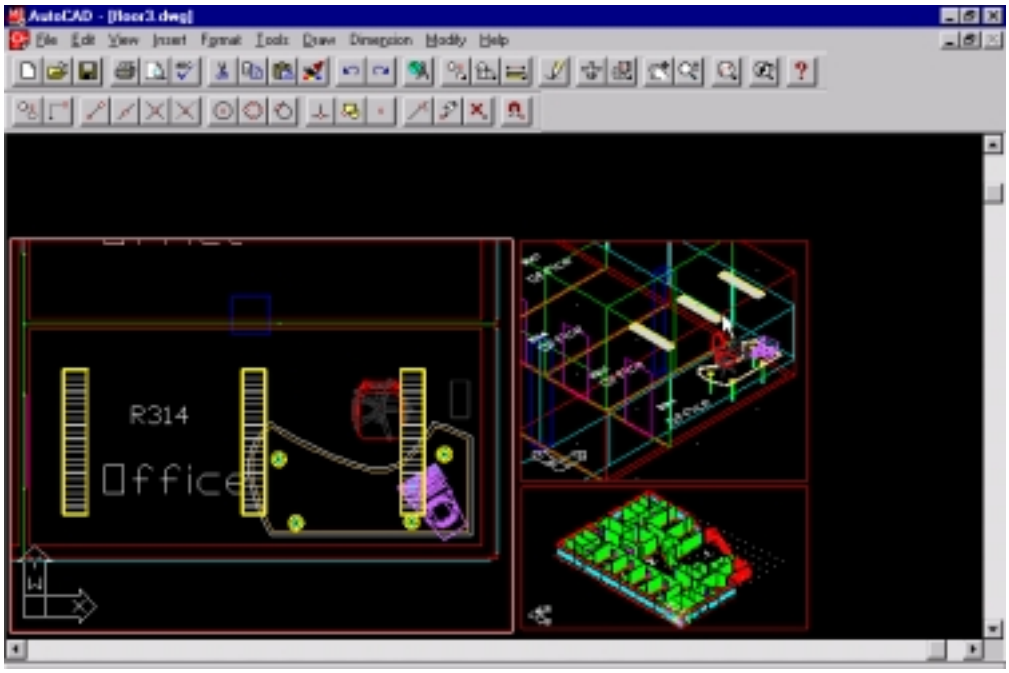


The core of the prototype linked together an architectural CAD system and 3-D space model, a CFD program and a building energy simulation program and it utilises real product data from manufacturer's software. Standard methods of exchanging design information within the tool and with other software tools were studied based on the Industry Foundation Classes (IFC) of the International Alliance for

Interoperability in order to provide an open, interoperable environment for equipment selection and HVAC system analysis.

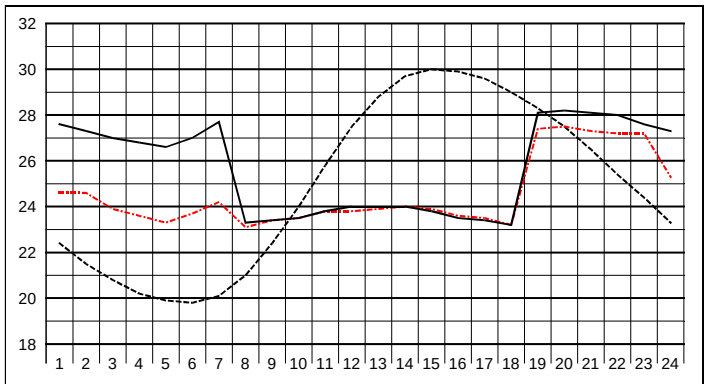
3-D space modeller

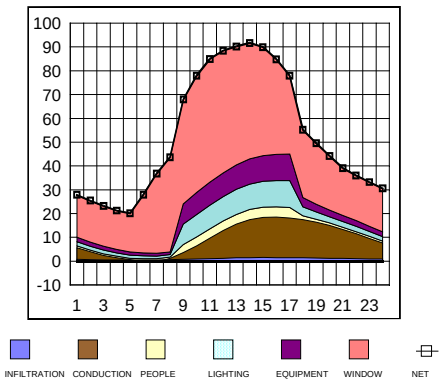
By modelling geometry, spatial relationships and objects like walls and windows using the 3-D space modeller, the information can be reused in other design tools such as energy simulation and CFD. The space modeller has IFC import and export features that enable direct transfer of digital building geometry and construction data between IFC-compliant architectural software. Functionality of the space modeller was extended to enable modelling of internal room objects such as furniture, equipment and persons. Inclusion of these objects in the model is important because they define thermal loads in energy simulation and CFD analysis and flow obstacles in CFD analysis.
Figure 3. 3-D space modeller (Smog) build on top of CAD software.



Energy simulation

An energy simulation tool, Riuska, is used for energy analysis and HVAC equipment sizing. The interface developed for Riuska is very user-friendly. The software uses DOE2.1 as a calculation engine.
Figure 4. Results from the energy simulation program (Riuska):office average temperature (left) and





cooling loads (right) during the summer design day.
Simulations over the whole year can be done also in practical design projects. Energy simulation programs provide limited information on IAQ and only calculate an average temperature in the space. In certain type of spaces, more accurate information about the temperature stratification, air movement, and contaminant concentration distribution is needed for thermal comfort and IAQ analysis. These can be calculated by a CFD program.

CFD calculation

With a CFD program, air-flow pattern and the distribution of air velocity, air temperature, and contaminant concentrations can be calculated. Most of CFD programs available require a high level of expertise and also require long execution times that exceed the time frame normally allowed for a project. Consequently, CFD simulation is rarely used in practical design, which can result in poor indoor air quality design and/or may lead to unnecessary energy consumption in buildings.

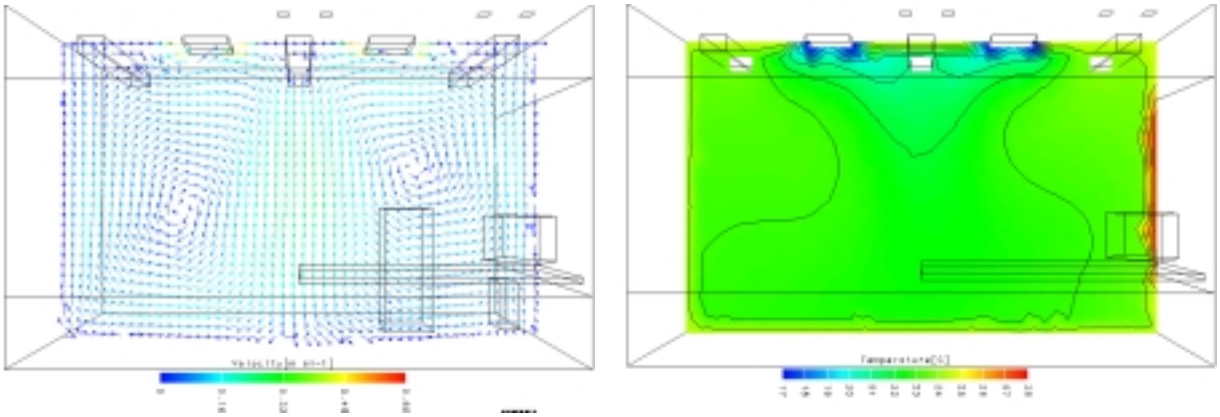


Figure 5. Results from the CFD program (CFX): air velocities (left) and air temperatures (right) at noon in the same office as in figure 4.

In the Bild-IT project, energy simulation and CFD are coupled. Energy simulation results, such as surface temperatures, can be used as boundary conditions in CFD program. The time of day and year for the CFD calculation can be chosen based on results from energy simulation. CFD can be used in the design of ventilation systems, including the selection of air-flow rates, and can generate estimates of convective heat transfer coefficients for use in energy simulation. It is currently too expensive computationally to be used at each time-step of an energy calculation but methods of using CFD results from different operating conditions to support energy calculations have been identified and will be investigated. The CFD and the energy simulation also use common input data. Geometrical information imported from the 3-D space modeller and the input data for heat sources in the energy simulation program are reused by the CFD program.

Product selection

In the Bild-IT prototype, one important integrated part is the product selection tool from manufacturer, where the HVAC equipment is selected and the actual product data exported to the energy simulation and CFD tools. The selection of ventilation equipment is made based on pressure loss and noise level diagrams. Product data contains also 3-D geometrical models that can be used in visualisations.

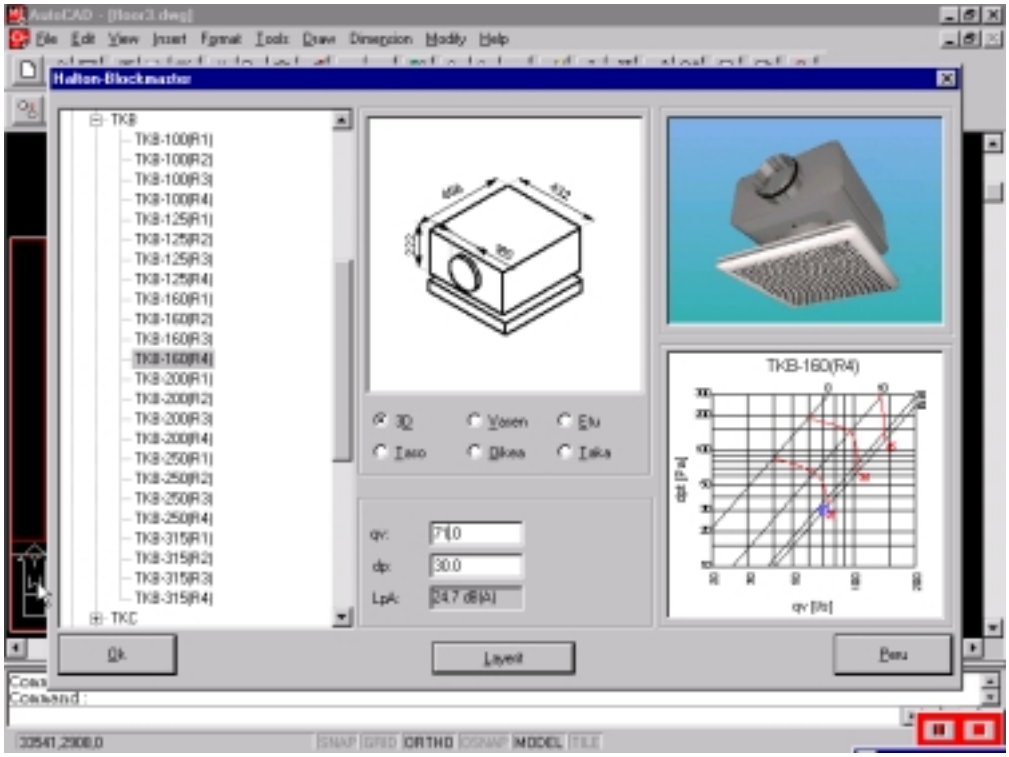


Figure 6. A product selection tool from a manufacturer (Halton-HIT/Blockmaster).

CONCLUDING REMARKS

A series of workshops have identified the need to develop an integrated building design tool with interoperability. This paper demonstrates an international effort to develop a prototype of such a tool by integrating a 3D-space modeller, an energy simulation program, a CFD program, and a product library. With the integrated tool, the effort for data input can be greatly reduced and more detailed information for building design (e.g. IAQ and thermal comfort) becomes available.

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