BENEFITS OF BIM IN THE THERMAL PERFORMANCE MANAGEMENT

Tuomas Laine, Reijo Hänninen and Antti Karola

Olof Granlund Oy, Malminkaari 21, 00700 Helsinki, Finland

ABSTRACT

The importance of analysing thermal performance in building design has grown, but it is still often done using simple static calculations or estimates. Accurate dynamic thermal simulation software have been available already for decades, but these tools are still not widely used by practitioners in building projects.

The main barrier of wider usage of dynamic thermal analysis methods has been the required big manual input work. By utilising BIM as a data source for thermal analysis, the data input will be more efficient and the existing data more reusable. BIM facilitates easier verification of the thermal performance in different phases of the building process.

This paper shows the recent developments for new concept and interoperable software environment to manage spatial thermal performance during the whole building life cycle. Results of using the developed concept are shown from real projects.

KEYWORDS

Thermal performance management, Energy simulation, Building information model, Benefits of BIM

INTRODUCTION

The importance of analysing thermal (energy and comfort) performance in building design is growing, because of the increasing awareness of the role of energy usage in building life cycle costs and environmental impacts and the role of indoor conditions in the personnel's productivity. However, thermal analysis is still often done using simple static calculations or even by statistical estimates.

Accurate enough dynamic thermal simulation software have been available already for decades. Also new tools, such as Energyplus (http://gundog.lbl.gov/EP/ep_main.html) and IDA (http://www.equa.se/eng.ice.html), have been developed for even more accurate thermal simulation. These tools are still mostly used by researchers, not widely by practitioners in building projects. The main barrier of wider usage of dynamic thermal analysis methods has been the required big manual input work. Most of the building element specific information needed in thermal simulation is described in the building information model (BIM).

Some of the public building owners, such as in USA (GSA 2006), Denmark (Erhvervs- og Byggestyrelsen 2006) and Finland (Senate Properties 2007), are starting to demand BIM in their projects, which creates also possibilities to get benefits for thermal analysis.

Other barriers for wider utilisation of BIMs in thermal analysis have been the missing interoperable data interface implementations in thermal simulation tools and the lacking guidelines. The Industry Foundation Classes (IFC) provides today an open standard for description and exchange of information within the life cycle of a constructed facility. To use BIM effectively however, and for the benefits of its use to be released, the quality of communication between the different participants in the construction process needs to be improved. The Information Delivery Manual (IDM) by the Norwegian BuildingSMART project (Espedokken and Wix 2007) is developed to provide the integrated reference for process and data required by BIM by identifying the discrete processes undertaken within building construction together with the information that is required for and results from their execution. There has also been several national projects in different countries, where guidelines for the BIM based design have been developed.

By using BIM it is easier to verify thermal performance truly in different phases of the building process. The experiences from many BIM based projects show that interoperable thermal analysis software is not enough for the management of thermal performance during the building process, but it requires also tools to manage different revisions of BIMs, to compare thermal performance of these revisions and to visualise this by easy-to-understand way. This paper shows the recent developments for methods and interoperable software environment to manage spatial thermal performance. The results show also examples of using BIM based thermal analysis in real projects.

METHODS

Thermal performance management can benefit a lot by utilising BIM: the data input will be more efficient and the existing data more reusable. The latter is especially important for continuous thermal performance management through the whole building life cycle.

Wider utilisation of BIM requires instructions both to the actual work and to the true understanding of the potential benefits. This paper presents the results of the development of new methods and interoperable software environment to manage spatial thermal performance. The key components in the interoperable software environment are thermal simulation and spatial requirement management, but it supports also building services system modelling and the later phases of building process by linkage to commissioning and facilities management. The Finnish ProIT (Romo 2003) guidelines for the BIM based building services design (Laine 2007) are used to describe the role of thermal performance
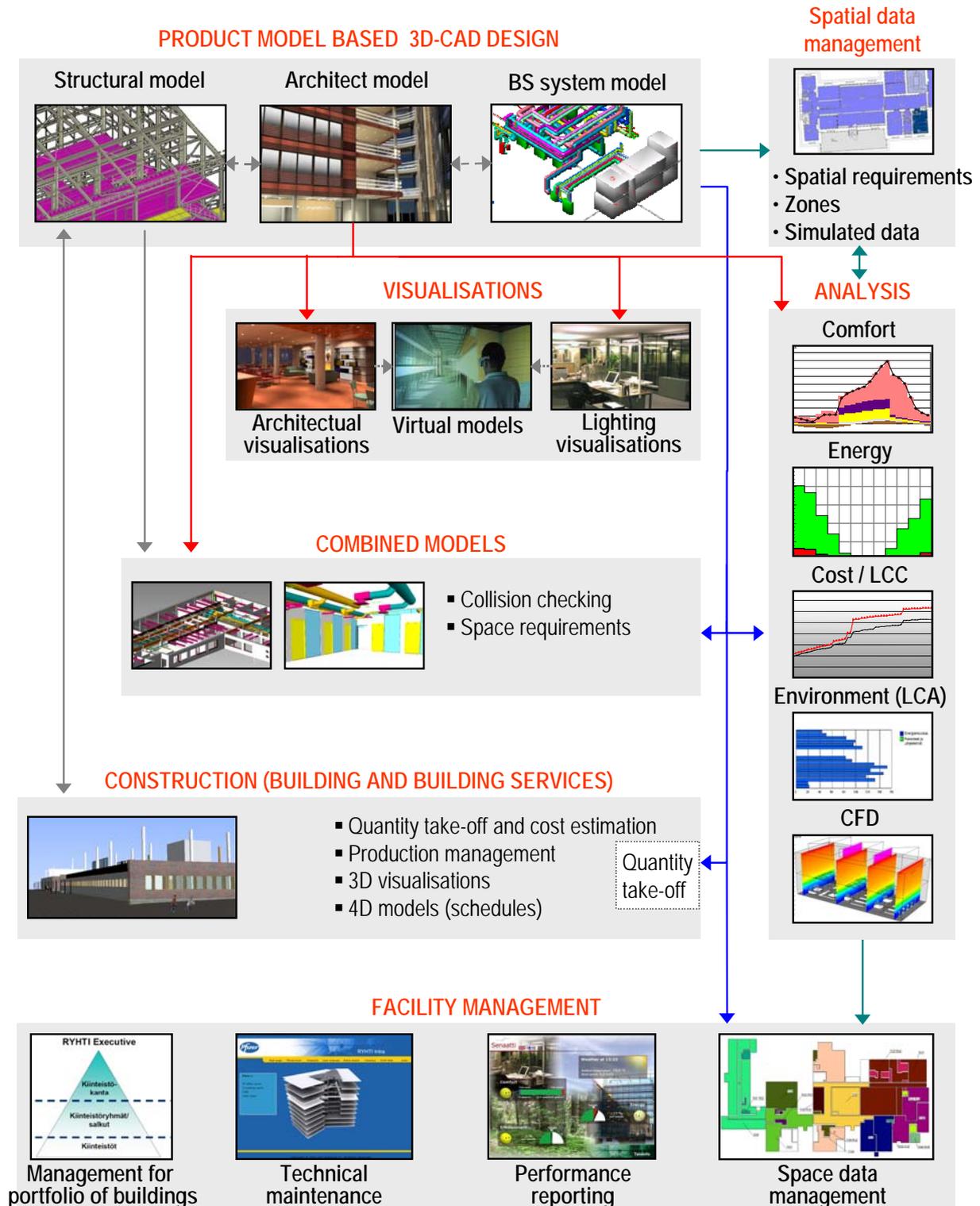

Figure 1. Thermal (energy and comfort) analysis has an important role in the use of building information modelling according to the ProIT guidelines.
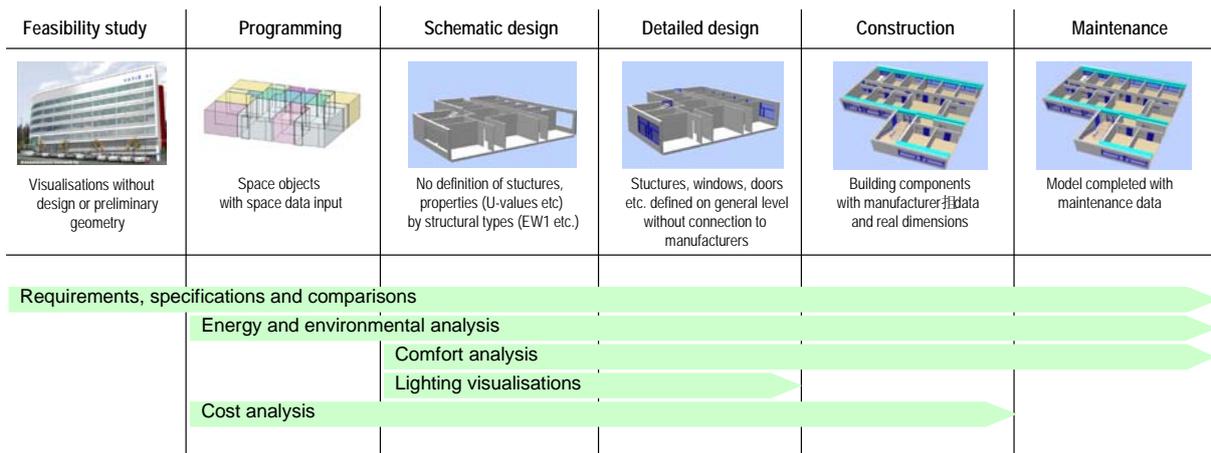
Feasibility study	Programming	Schematic design	Detailed design	Construction	Maintenance
Visualisations without design or preliminary geometry	Space objects with space data input	No definition of stuctures, properties (U-values etc) by structural types (EW1 etc.)	Stuctures, windows, doors etc. defined on general level without connection to manufacturers	Building components with manufacturer data and real dimensions	Model completed with maintenance data

Requirements, specifications and comparisons

Energy and environmental analysis

Comfort analysis

Lighting visualisations

Cost analysis

Figure 2. Thermal analysis supports decision-making and problem-solving in several phases during the building process, from early design to operation and maintenance.

management in BIM based environment (Figure 1) and utilisation during the building process (Figure 2).

The IDM has produced the most detailed guidelines for BIM based energy analysis (Wix 2006). It contains both the energy and condition analysis process description and the requirements for information exchange throughout the building process.

The IDM process of developing energy analysis throughout the design stages of a project is considered to be divided into 2 key parts:

1. Speculative

This is the analysis work undertaken during the programming stage of the project. It is about providing advice on the potential energy performance of a building and its systems to other design roles. The aim of this advisory role is to have an impact on the overall building design, determine the feasibility of concepts in an energy context and to establish energy targets.

2. Analytical

This is the analysis work undertaken during the sketch, full concept and coordinated design stages of the project and assumes the availability of geometric information about the building layout. The overall process is the same at each stage of work, the difference being simply about the extent of the information available and the level of certainty that can be applied to the information.

RESULTS

The main result of the development was the concept for thermal performance management utilising BIM based environment in building services design (Figure 3). The key components in the implementation of the interoperable software environment are thermal simulation software

RIUSKA (Jokela et al. 1997) and spatial requirements management software ROOMEX. It supports also BIM based building services system modelling and the later phases of building process by linkage to commissioning and facilities management.

Thermal requirements

Thermal requirements (task 1 in the figure 3) are defined at space type level and this does not require 3D model of the building. It is necessary to capture client's thermal environment requirements for different space types, to achieve all the later benefits of BIM based thermal performance management. This task defines both the thermal parameters and the equivalent thermal loads (Table 1). One relevant definition from electricity calculation viewpoint is also the required lighting intensity.

Table 1. The air quality targets and equivalent loads defined at space type level.

Air quality targets				Loads			
Attribute	Value	Unit		Loadtype	Design...	Max value	Unit
Indoor temperature, summer	26	°C		People	0,1		p/m²
Indoor temperature, winter	21	°C		Lighting	15		W/m²
Relative humidity, summer		%		Equipment	15		W/m²
Relative humidity, winter		%					
Air velocity, summer	0,25	m/s					
Air velocity, winter	0,17	m/s		Sizing val. = Load used in sizing			
Carbon dioxide content (CO2)		ppm		Max val. = Maximum load			
Supply air flow	1,5	dm³/s,m²		Values of relative humidity are agreed together with the client			
Supply air flow		dm³/s, per					
Sound level		dB(A)		Calculated air-flow/person = 15 dm³/s, per			
Filtering class		EU					
Air purity class		P					

Utilisation of geometry model

In the utilisation of geometry model (tasks 2 and 3 in figure 3) an architectural 3D model is imported to the environment and validated by automatic checking routines (to report of missing spaces, floors, etc.) and by visual checking (by 3D viewer).

Most of the building element specific information needed in thermal simulation is described in the BIM. This includes as mandatory spaces with code and name specifications and building structures (walls, windows, etc.) with type definitions. To illustrate the large amount of required building model related data for thermal simulation input: As an example a
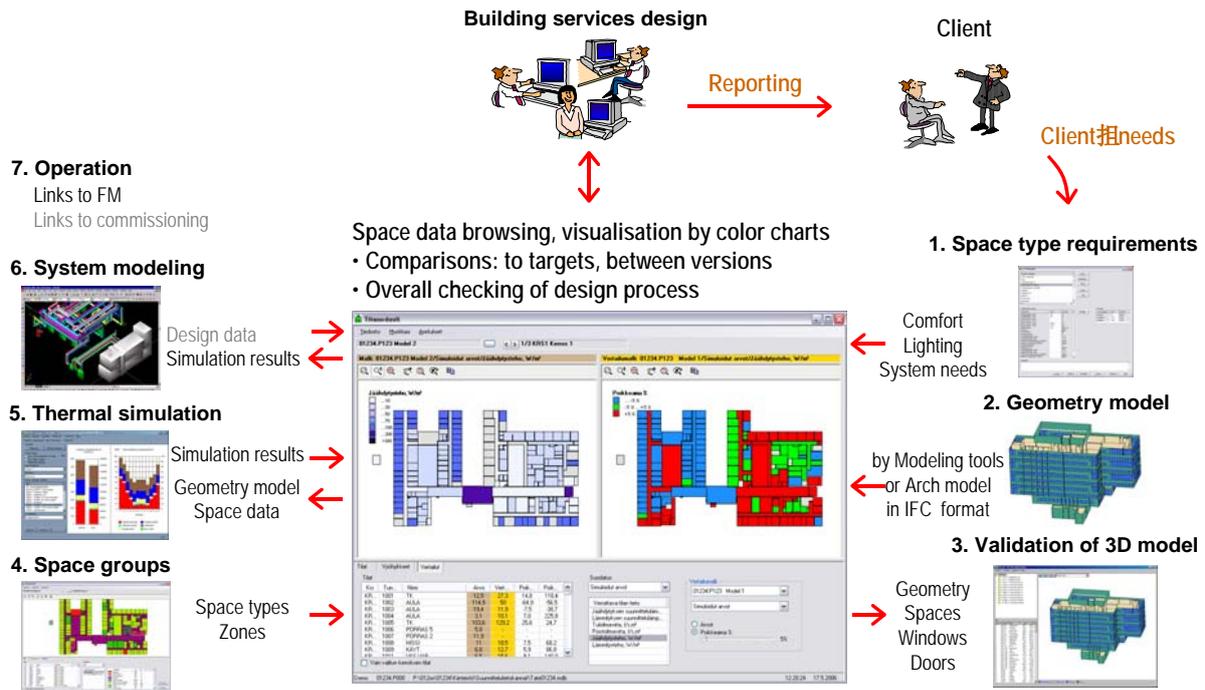
Figure 3. The developed concept for BIM based thermal performance management (the implemented tasks at black, still missing tasks at grey color). The interface in the center shows BIM revision comparison of required thermal parameters against simulated performance.

medium size building of 8000 m^2 contains 387 spaces, 295 exterior walls, 912 interior walls, 1439 windows, 760 doors and 57 different type of structures. All this information is needed for spatial level thermal simulation, and by utilising BIM this information can be imported to the thermal simulation software. The required information is too much for manual input, which means that traditionally whole building spatial simulation is not practical, and a simplified zone level approach is used instead.

To utilise BIM in thermal simulation, IFC model is simplified by pre-processing it. Some format of building objects (Proxys and BREP walls) do not contain the information needed for thermal simulation. Figure 4 shows an example from the HITOS project (Statsbygg 2006), where the biggest part of the architectural BIM was beneficial for thermal analysis to create the required input, but some of the facades were modeled by using BREP format wall objects instead of parametric representation. By visualising the problematic parts (red color) of the model, architect was able to correct the model in the next revision to meet also the requirements of thermal simulation.

Figure 4. The architect model can be imported to thermal analysis.

Space grouping

Space groups (task 4 in figure 3) are created both to
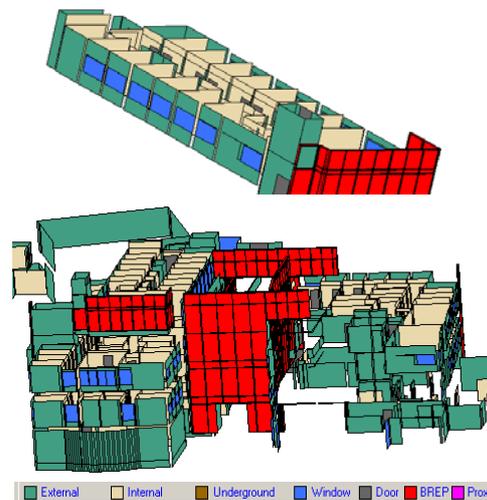
define spatial requirements by mapping the space type requirements to actual spaces and for zoning the spaces into different categories, such as air handling unit service areas or lighting control areas. These specifications should be done in the beginning of the building services conceptual design. The same information is needed as input data for thermal analysis.

Thermal simulation

In thermal simulation (task 5 in figure 3) the building geometry related data, spatial requirements, loads and air-conditioning and lighting system zones are imported as input data. Additional input, such as usage schedules, HVAC and electrical system specifications and weather data, is defined by using the thermal simulation software user interfaces. The simulation results of the spatial thermal performance are exported back to the BIM, allowing performance verification against targets and generation of input data for the HVAC system modelling.
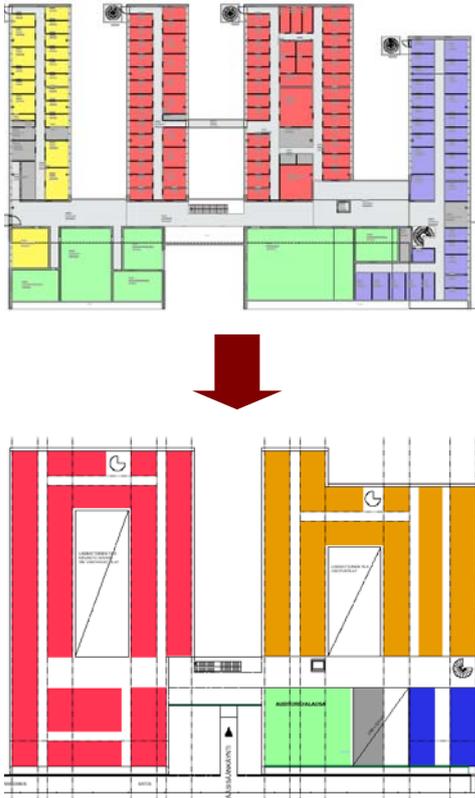
Figure 5. The energy efficiency of the architectural design of the Aurora 2 building (Karjalainen 2005) was developed during the programming phase by using BIM based energy analysis. From the first solution of cellular office plan with narrow building body (top, a "comb" type of layout), the envelope area was reduced by using glazed inner courtyards for distribution of daylight for the surrounding office spaces (below).

Energy analysis in several projects (Figure 5) has been done by using IDM process descriptions (Wix 2006) and information exchange requirements. The IDM supports also the creating of energy analysis software specific training material, like the example in figure 6 to describe the required actions in energy analysis to acquire construction type data and assign it to occurrences.

Key requirements for wider use of thermal simulation in practical projects are:

- modern user interfaces for practitioners instead of just researchers

- efficient data input by reusing the existing information by linkage to BIM and

- using of intelligent data libraries.

Efficient computing is required to move from zone based models to spatial whole building approach. This means also balancing between solver accuracy and efficiency.

Building services system modelling

The results from thermal simulation can be transferred as starting point to building services system modelling (task 6 in figure 3). The information, such as spatial air flow, heating and cooling needs, is used to select air conditioning equipment for HVAC system model.

Operation and maintenance

Thermal performance management should continue during operation and maintenance phase (task 7 in figure 3). Figure 7 shows an example how the self-reporting building system (Hänninen and Laine 2004) is used for thermal performance tracking during operation phase. BIM based approach also allows to react on the changes in the use of the building by easy updating of energy and condition targets for monitoring and management systems.

CONCLUSION

This paper shows how thermal performance management can benefit of the utilisation of BIM:

- Data input to energy analysis will become more efficient and the existing data more reusable.

- BIM based environment allows to use dynamic thermal simulation instead of traditionally used static calculation methods.

- BIM based environment allows dynamic energy simulation by whole building spatial approach instead of traditionally used zonal models.

- BIM allows easier verification of the thermal performance in different phases of the building process.

- BIM based environment allows an easy way to utilise simulated values from thermal analysis as the starting point for HVAC system design.

- Utilising BIM supports to continue thermal performance tracking during operation and maintenance.
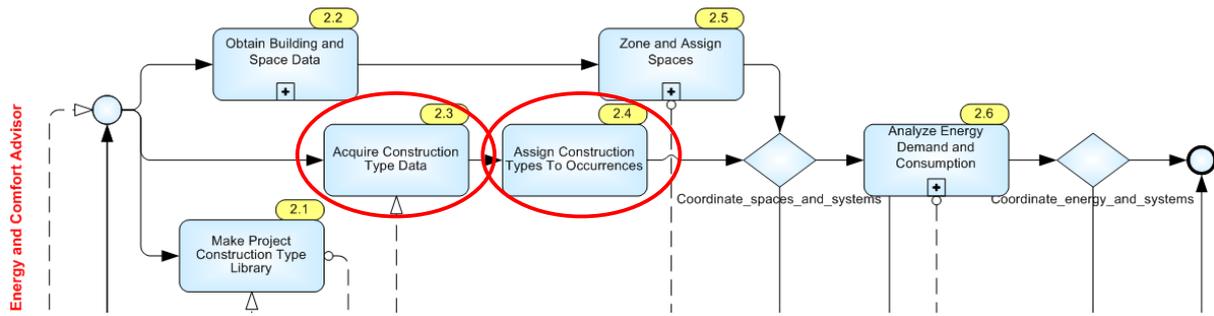
Types were defined to all constructions in the BIM of building elements and imported to RIUSKA in IFC format

In RIUSKA thermal properties of the construction type were assigned to the occurrence. The task benefited of the imported type definition data by allowing multiple selections based on that information.

Figure 6. The IDM process description can be used also as software specific training material.
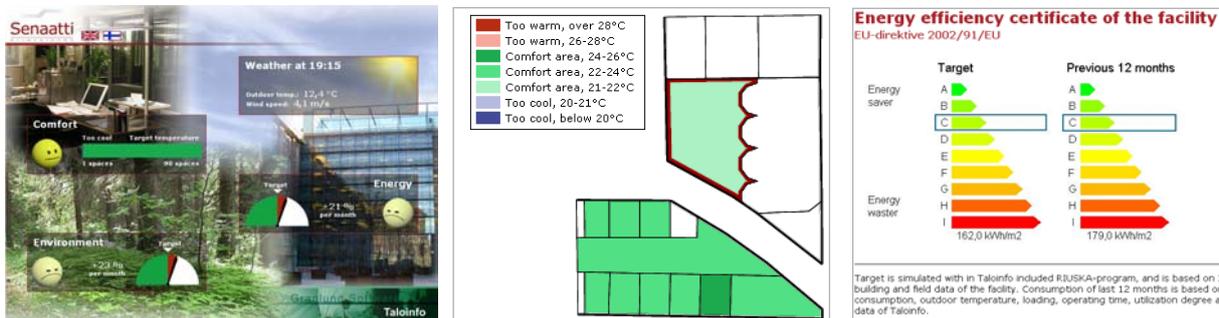

Figure 7. Self-reporting building system for BIM based energy and comfort management, including reports for top level performance evaluation (left), spatial comfort requirements verification (center) and on-line energy efficiency certificate (right).

The real project experiences also show, that successful BIM based thermal performance management requires:.

- Management of different revisions of BIMs

- Thermal performance comparison possibilities between different revisions.

- Easy-to-understand visualisations of the thermal performance for clients.

- Careful validation that the architectural model meets the requirements of thermal analysis.

ACKNOWLEDGMENT

REFERENCES

GSA. 2006. GSA's National 3D-4D-BIM Program, Washington DC: United States General Services Administration, Public Buildings Service, Office of the Chief Architect.

Erhvervs- og Byggestyrelsen. 2006. "Administrativ vejledning vedr. bekendtgørelse om krav til anvendelse af IKT i byggeri", only in Danish language. http://www.ebst.dk/file/5360/Administrativ_vejledning.pdf. 4 pages.

Espedokken K, Wix J. 2007. The Information Delivery Manual - IDM. The Norwegian BuildingSMART project. http://idm.buildingsmart.com.

Jokela M, Keinänen A, Lahtela H, Lassila K. 1997. Integrated building simulation tool - RIUSKA, Helsinki. Olof Granlund Oy. http://simulationresearch.lbl.gov/dirpubs/riuska97.pdf. 6 pages.

Hänninen R, Laine T. 2004. Product models and life cycle data management in real projects, ICCCBE-X conference, Weimar. 6 pages.

Karjalainen A. 2005. BIM at Senate Properties, presentation at BuildingSMART conference 2005, Oslo.

Laine T. 2007. ProIT TATE, "Product modelling in building services design", "Tuotemallintaminen talotekniikkasuunnittelussa", only in Finnish language, Helsinki. 46 pages.

Senate Properties. 2007. Senate Properties' product modelling requirements 2007, Helsinki: http://www.senaatti.fi/document.asp?siteID=2&docID=517. 1 page.

Statsbygg. 2006. Experiences in development and use of a digital Building Information Model (BIM) according to IFC standards from the building project of Tromsø University College (HITOS) after completed Full Conceptual Design Phase, Oslo: The Norwegian Agency of Public Construction and Property.

Romo I. 2003. ProIT leaflet, Product Model Data in the Construction Process, Helsinki: Confederation of Finnish Construction Industries RT. http://virtual.vtt.fi/proit_eng/newsletters/proit_leaflet_no1.pdf. 4 pages.

Wix J. 2006. IDM process model, Energy analysis, Oslo: The Norwegian BuildingSMART project. 17 pages.