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Virtual Buildings from theory to practice

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ABSTRACT: We have now during 3 decades worked hard within R&D and practice to define, design and implement Virtual Building models to support the entire life cycle of a building and to support experience capture and input to new projects. The Cambridge UK Building Design System was an early version of a system to handle rather formalized building design in the mid 1970s. Around 1980 the IGES standard supported Cad primitive drawing exchange and the PDES/STEP work in the early 1980s laid the foundation for an object oriented handling of building process entities and model data exchange. The first object oriented Cad systems appeared in the second half of the 1980s. The more operational IFC standardization work was launched 1995 and is to some extent implemented and used in real building projects today.
The paper discusses the trade-off between using highly formalized building models and more loosely coupled building systems models and descriptions from the perspective of Virtual Buildings models, building process organization, building requirements models, and digital hand-over of buildings to clients. References are made to our participation and input to the national Danish Digital Construction R&D program, DDB. A proposed XML scheme to facilitate digital hand-over of building data and core metadata handling is commented on as well as a tool developed to facilitate the actual work to augment the virtual building model and building systems descriptions. The DDB program will result in public client regulations for requirements formulation in 2007.

1 INTRODUCTION

We have now during 3 decades worked hard within R&D and practice to define, design and implement Virtual Building models to support the entire life cycle of a building and to support experience capture and input to new projects.

The paper discusses the trade-off between using highly formalized building models and more loosely coupled building systems models and descriptions from the perspective of Virtual Buildings models. References are made to our participation and input to the national Danish Digital Construction R&D program, DDB. A proposed XML scheme to facilitate digital hand-over of building data and core metadata handling is commented on as well as a tool developed to facilitate the actual work to augment the virtual building model and building systems descriptions.

2 MODELS AND MODEL ACCESS

According to Oxford American Dictionaries a model is 'a simplified description, esp. a mathematical one, of a system or process, to assist calculations and predications'. The building process comprises a number of actors involved in processes in different contexts as well as flow of information, materials and the building itself described as a virtual building, VB, from idea to physical completion and demolition (Christiansson 1999). Static product models build up the VB but it also contains embedded time dependent processes. The real world, as the building, can be described in form of systems containing partly common sub-systems and building elements. For example the esthetic building system, lighting system, indoors climate system, energy supply system, and human escape systems all contain window building elements and are part of the building usage system. See also figure 1.

During the design process client requirements are expressed as functional requirements on systems, evolving to detailed sub-functions and form, and systems given concrete content (instantiated) thus make paossible behavioral tests on the building systems to validate the building performance against input requirements. requirements.

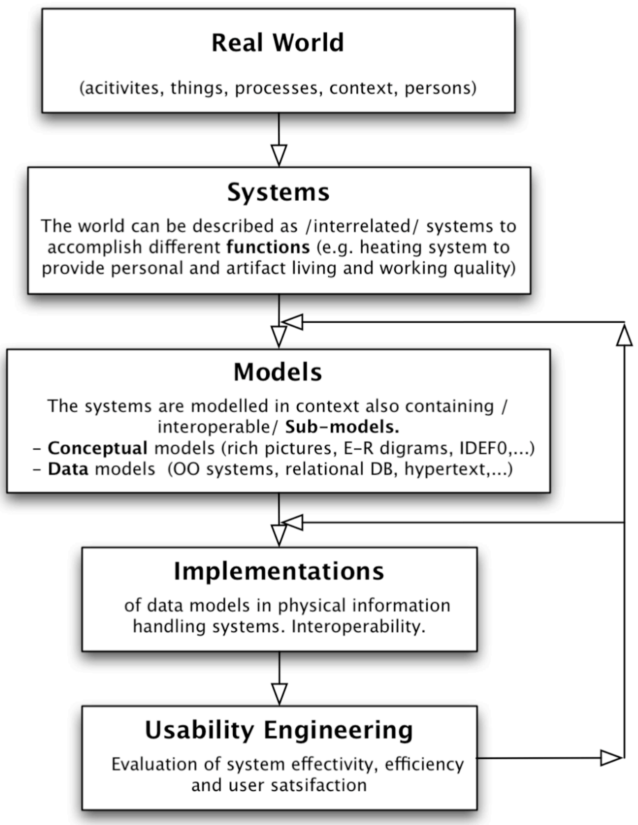


Figure 1. The real world is modeled and accessed from a User Environment, UE, to facilitate experience capture, design, construction, use and re-design of buildings.

The model of a building, in its different life cycle states, was traditionally made in paper and wood and 'accessed' through drawings and text documents on paper. During the latest decades the models are most often stored in digital format and accessed in diverse ways but most often through paper or digital documents (2D drawing and text documents). The distinction between storage and access media will get sharper in the future. We can see example on that now in the XML formatted information containers separated from XML based 'style sheets' description files (.XSL), to fit different user needs and available I/O resource (portable computer, PDA, mobile phone). See figure 2.

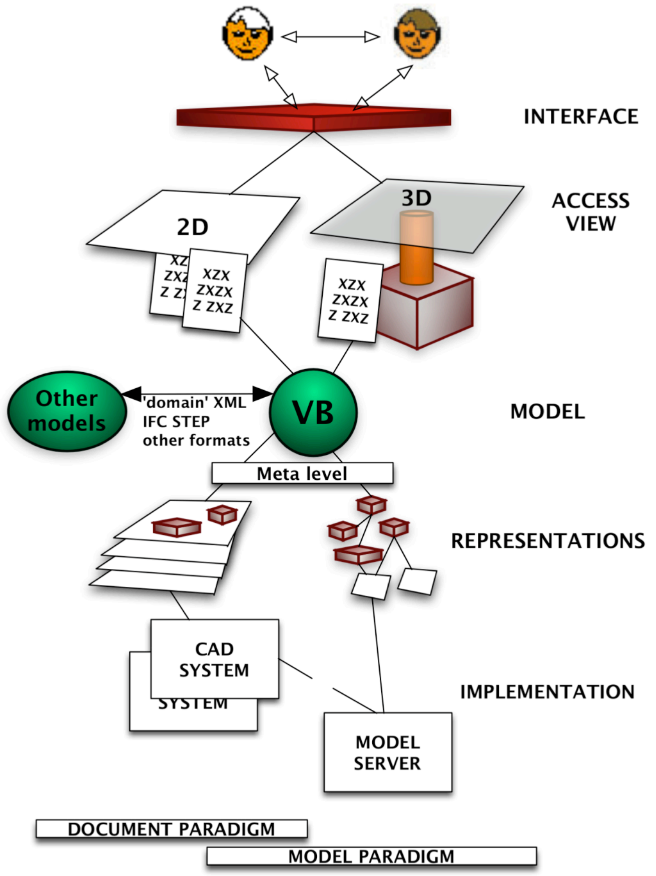


Figure 2. The Virtual Building, VB, model is accessed through more or less detailed representations. The VB sub-models may be partly overlapping and also contain redundant information.

The complexity and flexibility in organization of the building process leads to large difficulties to build up highly formalized non-redundant models except for certain more standardized buildings and process organization, see also figure 3.

The favorable degree of optimum formalization of the building process will be different dependent on which actors view it applied. The client, future building owner, engineer, architect, contractor, and maintenance personnel will have different needs and requirements on the models for efficient and effective use in different contexts. 3D models and short-term interaction with analyses programs may for example today have higher importance for designers than building owners.

The ideal situation is that the building process is organized in such a way that the total building life cycle cost and quality is optimal for given input resources. A partnering organization may lead to more efficient handling of responsibilities for VB sub models and their interoperability and integration with analyses and simulation programs. It would also then be possible to more efficiently handle a Requirements model for the whole process, see also figure 5. Research undertakings have started to formulate models for digital requirements management though they are yet focused on requirement handling in the detailed design phase. See (Solibri 1999) and (Kiviniemi 2005).

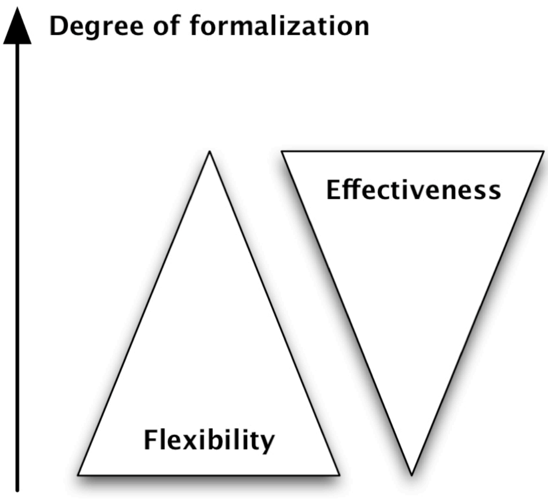


Figure 3 There might be a negative correlation between effectiveness and flexibility for different representations, from (Christiansson 1993).

3 BUILDING MODELING HISTORY

The building process models have during decades gone through de-formalization and subsequent formalization to more completely cover a wider building process domain. The building industry has now been engaged in building formalized digital descriptions (models) for more than 40 years of the building process and particularly of the building itself. An important driving force has been development of advanced Information and Communication Technology, ICT, tools from relational databases in the late 1970s to the Semantic Web in 2002.

Below are some highlights from the modeling/ICT history listed, see also figure 4.

- Ivan Sutherland creates SKETCHPAD (1960)
- Integration of building parts to a Product Model, (1970),
- Time-sharing computers (mid 1970s).
- User tools perspective. 3D modeling (1975),
- IGES. Initial Graphics Exchange Specification in USA (1979)
- Cad database integration (1980). Application spread physically in networks (1980).
- 1983. IGES/PDES. Product Data Exchange Specification/using step (USA) , ISO/STEP Standard for Exchange of Product Model Data
- First practical object orientation implementation (1985). CIB W78 conference in Lund 'Conceptual modeling of buildings' (1988)
- PDES/STEP General AEC Reference Model (1988)
- Integration of mixed representations. Knowledge bases (1990). Integrated networks on services level ISDN (1990), INTERNET accelerates. Process modeling focus (1990). WWW (1990).
- IFC Release 1 (1996).
- (1993). January, 40 known http servers. October, 200 known http servers.
- (1994). May, First International WWW Conference at CERN Geneva. (KBS-Media Lab, Lund University on the web in April). June, over 1500 registered http servers. 2.5 million computers on the Internet.
- XML (1998), Resource Description Framework, RDF (1998), Semantic Web (2001). See also (Christiansson, 1998 & 2003), (Lai et. al. 2003).

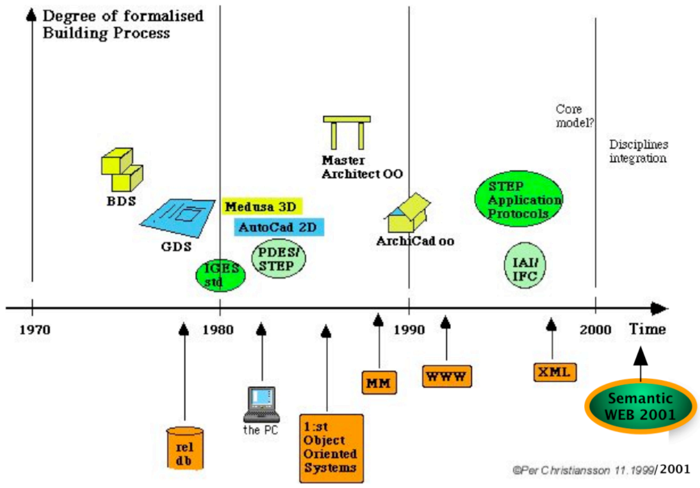


Figure 4. Building Process models development have during the latest decades had periodic focus on achieving a highly formalized non-redundant building product model, Virtual Building, VB.

4 THE DANISH DDB PROJECT

In 2002 the Danish national 'Digital Construction - a development program for the whole construction sector' in Danish 'Det Digitale Byggeri', DDB, was started. See also http://www.detdigitalebyggeri.dk. As a result the public clients will 2007 state a set of ICT requirements that the enterprises of the construction sector must meet if they wish to tender for public construction projects.

The program aims to develop pragmatic common denominators that can create consensus across subsectors and professional affiliations. And most important, the objective is to get agreed solutions implemented in the sector's every day life. Before the Demands by Client scheme enters into effect, it will be modified based on experience gained from specific tests and from hearings and workshops held with the construction sector. Digital Construction has chosen to establish a learning network as a core activity in the program to secure a dialogue that crosses trade barriers, sub-sectors and fields of activities, and goes on between consortiums and staff in drawing offices, enterprises or on construction sites. An Advisory Board advises the National Agency for Enterprise and Construction. EBST, on the overall direction and progress of the development project. EBST also forms secretariat for the project, http://www.naec.dk/.

Four projects were launched in 2003 within client requirements formulation, (1) Digital tender, (2) 3D models, (3) Digital handover (Digital aflevering), DACaPo, and (4) Projectweb together with a project on Foundation for Digital Construction (classification and standardization issues). In 2005 the final project was launched namely, Best Practice - or in Danish 'Bedst i Byggeriet' - with a compilation of specific best-practice examples from real life, documenting how digital solutions in the different processes of the construction project can promote efficiency in the working process. See also http://www.detdigitalebyggeri.dk/english/0/10.

5 DIGITAL HANDOVER

The DACaPo project partners COWI (http://www.cowi.dk/ engineers, project leader), Pihl (http://www.pihl-as.dk/ building contractor), Denmark Radio (http://www.dr.dk/ facility manager) and Aalborg University (http://it.bt.aau.dk/) published in December 2004 the first version on a specification on requirements for digital handover. See also DACaPo workshop2 documentation at http://www.detdigitalebyggeri.dk/dacapo_ws2/0/10.

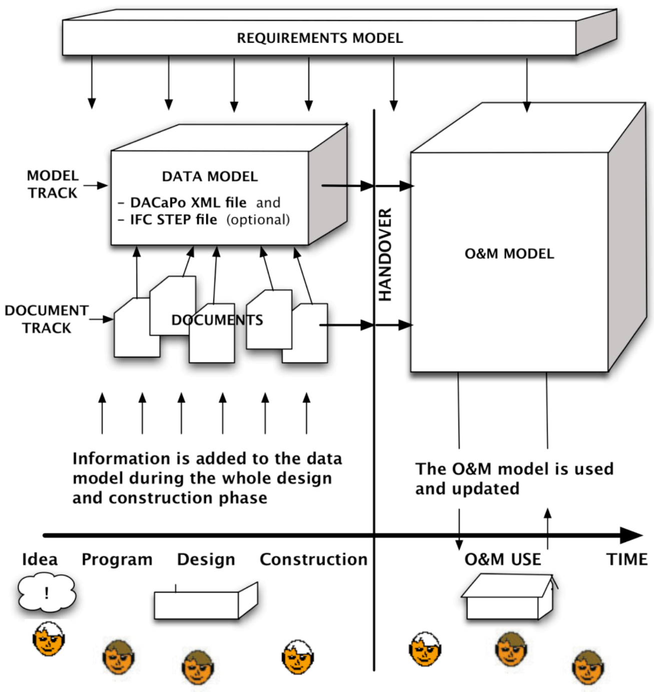


Figure 5. The first version of the Danish requirements for digital handover in 2005 is presently tried out at the Slots- og Ejendomsstyrelsen, Palaces and Property Agency, Ministry of Finance, http://www.ses.dk/.

The DACaPo consortium advocates a long term 2 track solution on data model development, ensuring a smooth transition towards a object oriented model, with possibilities to include traditional information containers (documents), see figure 5. A core meta data model must though be delivered in DACaPo XML format validated against DACaPo XML schemas (.XSD files).

6 DATA MODEL

The suggested Data Model is built around the building physical objects, see figure 6.

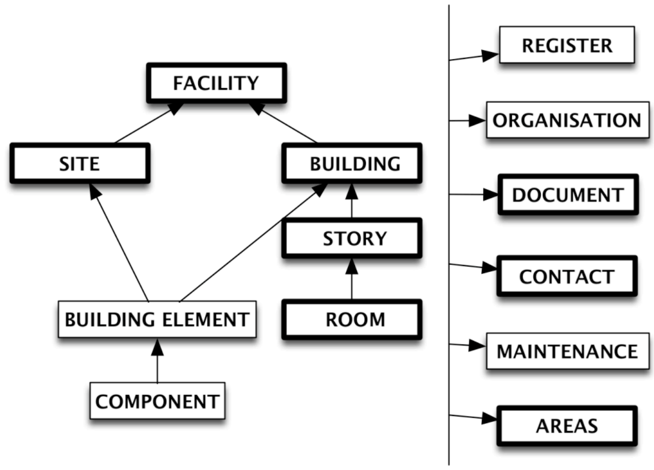


Figure 6. Required (bold) and optional objects of the DACaPo data model for digital handover.

The DACaPo meta data for marking documents is based on ISO 82045-5 (Application of metadata for construction and facility management), http://www.iso.org/. DACaPo XML is also harmonized with IFC XML and OIO XML (Offentlig Information Online http://www.oio.dk/) . (http://rep.oio.dk/ebxml/xml/schemas/dkcc/2003/02/13/.

The DACaPo XML structure is developed in close contact with the International Alliance for Interoperability, IAI, http://www.iai-international.org/index.html , to ensure harmonization with IFC.

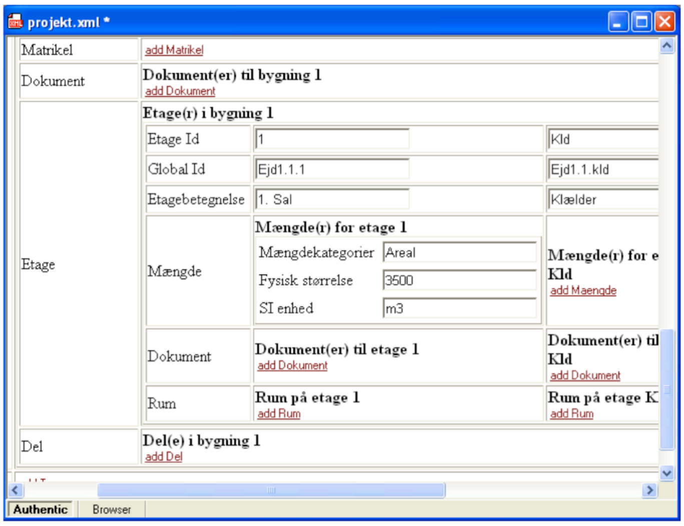
Three DACaPo XML schemas are defined (model, document, type). Document classes are Site, Building, O&M, and Economy. Within document classes documents are defined with label document type (kind) according to representation form (degree of structure such as locked/unlocked, editable, file/object) and file format (TIF, PDF, DOC, XLS, RTF, XML, DWG, DGN, and IFC).

7 SUPPORT TOOL

The support tool can be downloaded as a file from a local AAU DACaPo project site and opened in Altova Authentic 2005 SP1 Desktop edition (free download at http://www.altova.com/download.html). By using the support tool DACaPo XML files can easily be created and validated against web stored DACaPo scheme files (.XSD). The tool establishes references to external document such as text, photos, and drawings.

If there are client requirements on delivery of Building Element extension objects in large projects, the support tool will not be adequate to use due to extensive manual data input. In that case it is better to expand existing modeling tools, such as CAD systems, so they themselves output DACaPo XML files.

The support tools graphic user interface has two main input areas, (a) Project information such as contact, date, and (b) O&M data based on the hierarchy Facility, Building/Site, Story, Room, Building Element, and Component as well as metadata and document references. Figure 7 shows an example on the support tool user interface.



DACaPo Support tool example.
(Etage=story, Mængde=quantity, Rum=room, Del=part)

Figure 7. DACaPo Support Tool user interface.

8 CONCLUSIONS

The suggested data model from the national Danish digital handover project, DACaPo, is now under test in real projects and will be updated based on captured experiences and further development of the Danish building classification and ongoing IFC advancement. The model is designed to handle mixed representations with focus on central meta data definitions and future more object oriented representations with possibilities to efficient handling of loosely coupled building systems models and descriptions using meta data information containers.

There is a great need for end user learning of new model based ICT tools and object oriented representations as a complement to traditional document handling approaches. The universities plays a central role in educating engineers in these domains, also in the perspective of life long learning and attracting students from industry. See also Christiansson 2004a) and (Christiansson 2004b).

A very positive bi-effect of more building process participants with high ICT competence is that we hopefully better can involve the building industry in specification of extensions of the existing modeling and analyses tools, to handle domain specific XML information also in a distributed semantic web environment with semantically coupled information containers.

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