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FUTURE INTEGRATED DESIGN ENVIRONMENTS

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EDITORS: Kazi A S, Aouad G, Baldwin A

Professor Per Christiansson, Civil Engineering, Aalborg University, Denmark
Prof., Dr.Tech. Aalborg University, Department of Civil Engineering
pc@civil.aau.dk

Assoc. professor Kjeld Svidt, Civil Engineering, Aalborg University, Denmark
Prof., Dr.Tech. Aalborg University, Department of Civil Engineering
pc@civil.aau.dk

Industrial PhD student Kristian Birch Sørensen, Rambøll A/S, Denmark
M.Sc. (Civ. eng), Master of IT, Ramboll Denmark and Aalborg University, Denmark,
ksb@ramboll.dk

SUMMARY: *We are facing a probable great change in the way we carry through design in future ICT supported environments. The main driving forces are the digitalization of information handling leading to a paramount paradigm shift when information storage and access media are separated, building process and product systems are formalized in digital models, user environments are provided with rich adaptable multimedia access to virtual models, virtual collaboration rooms established, and new efficient and effective ICT tools defined and implemented.*

There are though some barriers putting strains on the development. Among the most important are missing ontologies both on business and Web/Internet service levels as well as their interrelations, poor user involvement in needs and requirements formulations on new ICT tools as well as in continuous user involvement in design and evaluation of new user environments, lack of interoperability within building process/product models, and the effects of local community behavior on global scale. The general competence level and preparedness for organizational and work change due to globalization and development of new common grounds for building design needs to be increased.

The paper presents a roadmap for development of future Integrated Building Design Systems (IBDS) with end-user participation. Methods for development of tools supporting creative and innovative building design with end-user participation is taking into account, including methods for capture and modeling of explicit and implicit end-user needs and requirements on both the building to be designed and the supporting design tools.

The paper provides grounds to higher success rate in capture of explicit and implicit end user needs and requirements on functional performance in use and re-use of buildings, taking into account effective tools for creative and innovative design. Providing a common ground for successful building design system development and meta-level agreements on open design systems supporting different design contexts and end user needs and values. The roadmap timeframe is 3-10 years.

KEYWORDS: *Future integrated building design systems, system development tools, ontologies, user driven innovation, functional building systems, end user needs, requirements modeling, innovative building design tools.*

REFERENCE: *Christiansson P, Svidt K, Sørensen B (2009) Future integrated design environments, Journal of Information Technology in Construction (ITcon), Vol. 14, Special Issue Next Generation Construction IT: Technology Foresight, Future Studies, Roadmapping, and Scenario Planning, pg. 445-460, http://www.itcon.org/2009/29*

1. INTRODUCTION

We are facing a probable great change in the way we carry through building design in future ICT supported environments. The main driving forces are the digitalization of information handling leading to a paramount paradigm shift when information storage and access media are separated, building process and product systems are formalized in digital models, user environments are provided with rich multimedia access to virtual models, virtual collaboration rooms established, and new efficient and effective ICT tools defined and implemented.

There are though some barriers putting strains on the development. Among the most important are missing ontologies both on business and Web/Internet services levels as well as their interrelations, poor user involvement in needs and requirements formulations on new ICT tools as well as continuous user involvement in design and evaluation of new user environments and ICT tools, lack of interoperability within building process/product models, and the effects of local community behavior on global scale. The general competence level and preparedness for organizational and work change due to global paradigm shift needs to be increased, as we are going from the art of writing (2500 b.c.) via art of printing (1450 b.c.) to the art of communication (with global information containers available for immediate access) (2000 a.c.), There is also a need for better methods and environments to establish a more user driven innovation process and capture of user needs and requirements on future building functional systems.

We are entering a very complex society where competences typically are distributed among people in problem solving efforts. For example the old Building Master is now a team of collaborating building design specialists and more often in virtual spaces. We need partly new fundamental human values, tools, and methods to effectively and efficiently act in these complex settings. A general competence level raise and preparedness for organizational and work change due to global communication paradigm shift is also needed.

The paper presents a system development approach to future development of Integrated Building Design Systems (IBDS) with efforts to specify needs and wishes on future system and resources to support system development. We enlighten the expected development with historic retrospection. Examples are picked from ongoing global efforts as well as finished and ongoing research at Building Informatics, Aalborg University. Most research results are achieved in beneficial collaboration with building industry companies.

2. HISTORIC DEVELOPMENT AND ENABLING ICT

Information and Communication Technology (ICT) tools have been a powerful driving force in development of the way we work and handle information. During 1950-60 large computers were used typically for batch processing over night in custom made applications, and the results presented on heavy-duty line printers. Classification systems were used to structure documents. During the 1970s building models with abstraction hierarchies were introduced as well calculations on 3D models. The relational databases were introduced, CAD(/CAM) systems were deployed on main frame or mini-computers, and the time sharing operating systems were implemented. During the 1980s the personal computer was launched (1981) and the terminal rooms were slowly substituted with desktop accessible (not portable) computers. We got high-resolution raster graphics and windows in operating systems. Object oriented building modeling systems (mid 1980s) became available as well as the Internet and practical use of email. It became popular to develop Knowledge Based Systems. As a follow-up to the Initial Graphics specification (IGES, 1979) the Product Data Exchange Specification/Standard for Exchange of Product Model Data (PDES/STEP) work commenced in 1983, see also (NBS-DATA, 1988). In 1989 the first version of a global operating systems, namely the World Wide Web (WWW), was formulated.

During the early 1990 we could efficiently share applications on personal computers over the Internet, and video communication over the Internet was also possible, Figure 1. The first demonstrations was made already 20 years before when Doug Engelbart 1968 demonstrated distant collaboration over the net with document sharing and video communication, http://sloan.stanford.edu/MouseSite/1968Demo.html, Biographical Sketch. Douglas C. Engelbart. Bootstrap Institute.

FIG. 1: Left; Experimental set-up at KBS-Media Lab, Lund University, 1991, with video communication and screen sharing using Timbuktu from Farallon. Right; A hypermedia workstation developed 1988 at KBS-Media Lab, Lund University with video display of images and films stored on video disk integrated with the hypertext based program HyperCard from Apple computer. From (Christiansson 2001b).

In the 1990s it started to be meaningful to talk about virtual workspaces as complement to meetings performed in physical rooms. Virtual Workspace is defined in (Christiansson, 2001b); "The Virtual Workspace, VW, is actually the new design room designed to fit new and existing design routines. VW may well be a mixed reality environment. The VW will host all design partners from project start with different access and visibility (for persons and groups) in space and time to the project, and will promote building up shared values in projects. The VW thus acts as a communication space with project information support in adapted appearances. VW gives access to general and specific ICT-tools". A Virtual Space (VS) in general may also be characterized as a mixed reality environment optionally involving many physical spaces and many virtual spaces. A VS may be set-up within one building or many buildings placed in the local community or on the other side of the world. A VS does not have to be stationary but can e.g. follow a person defined as the immediate surrounding of that person. Figure 2 shows an early example of setting up a virtual workspace.

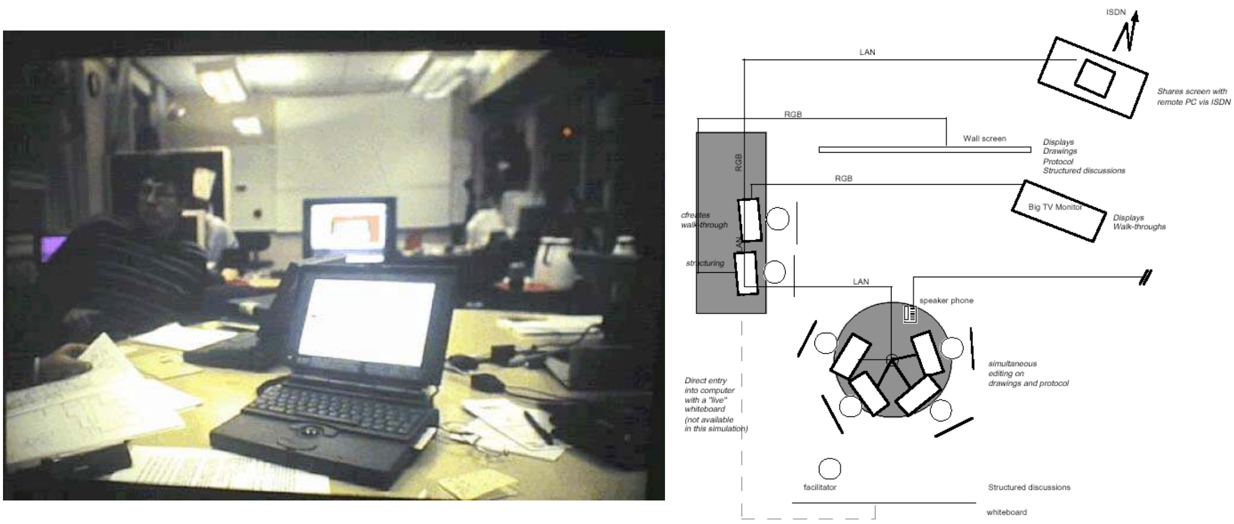


FIG. 2: In the COOCOM project (Cooperation and Communication in the Building Process), 1993, industry participants (SKANSKA, FFNS Architects, and LKF facility managers) performed local and distributed ICT supported collaboration (local joint document editing, remote screen sharing using ISDN connection with support group at SKANSKA, and structured discussions using MacEuclid for action-goal and structured augmentation diagrams). Walk-throughs of the design object were also available using the Virtus Walk-through system. (Modin, 1995).

Today we can decide on how close we want the connection between the physical and virtual world to be. Real and virtual worlds can be merged to a Mixed Reality. We can augment the reality (Augmented Reality) or augment the Virtual Reality (Augmented Virtuality) (Milgram et al., 1994) depending on service relevance and surrounding constraints. See also Figure 3.

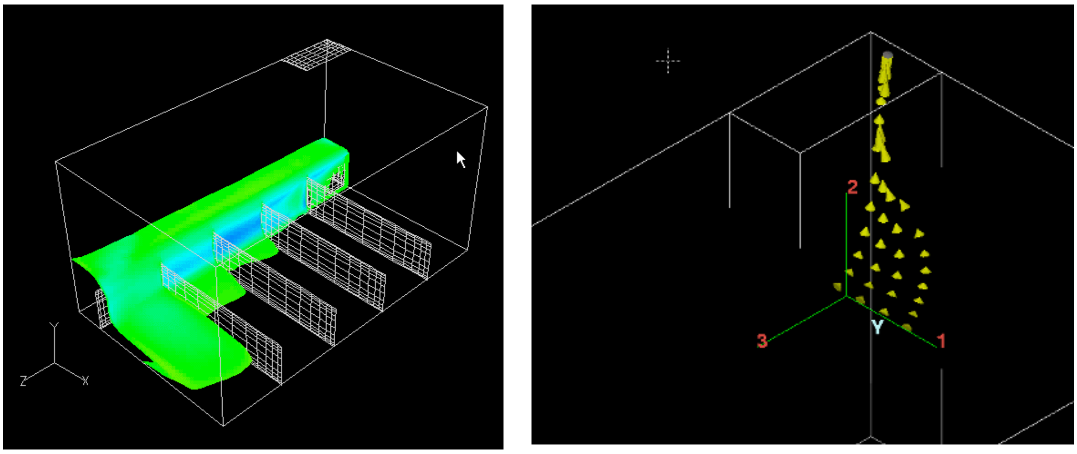


FIG. 3: Dynamic interactive 3D visualization of airflow in a livestock building. The CFD (Computational Fluid Dynamics) simulation results were displayed and analyzed with the visualization software VU (Pic and Ozell) in a panorama and a six-sided CAVE environment at VR Media Lab, Aalborg University. (The VU system was launched in 1993 and adapted for VR environments 1998.) From (Svidt et al., 2001)

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 for more than 40 years been engaged in building formalized digital descriptions (models) of the building process and particularly of the building itself in different stages of development and abstraction levels . 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 2001 and cloud computing. The Resource Description Framework (RDF) from 1997 paved the way for handling metadata on the WWW and The Semantic Web, see (Christiansson, 2003). See also (Eastman et.al. 2008) for a review of Building Information Modelling (BIM).

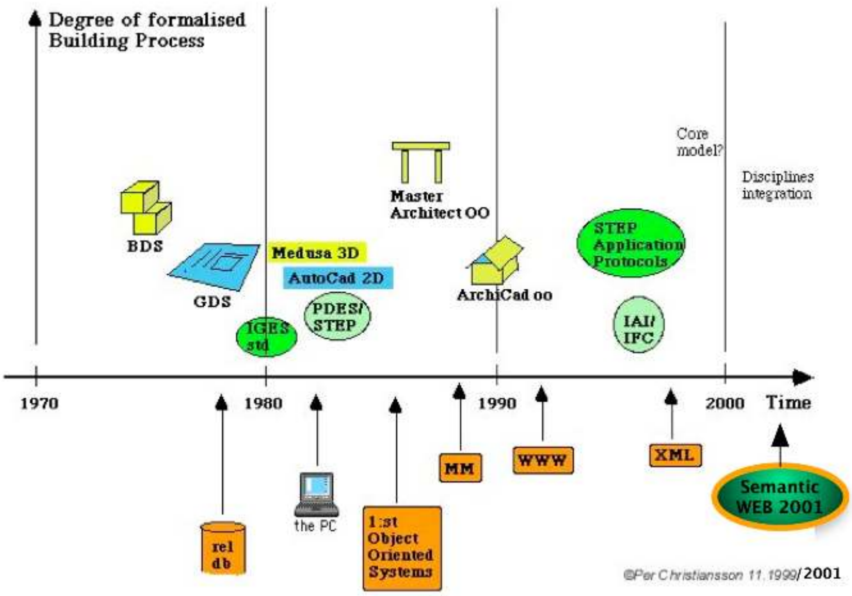


FIG 4: Building Product models development have during the latest decades had periodic focus on achieving a highly formalized non-redundant building product model (Virtual Building, VB). From (Christiansson & Carlsen, 2005).

3. GLOBAL TRENDS AND PARADIGMSHIFTS

The globalization leads to fewer nation related and more region related borders surrounding dynamically changing groups of people. A region may be defined by long-term project belonging (like a company), community of interest, and geographic properties.

Our society is getting more and more complex as well as the buildings we are producing and the building process itself. The old information storage and access paper based medium is substituted with digital information containers where storage and access media are separated. Information is stored and quality filtering is displaced to more frequently take place during information search than during augmentation of containers. This will also lead to storage of more information and digitally stored knowledge, which content for different users will be regarded as both good and bad. Information will be meta-marked to make search more effective (for example in the semantic web) and in the long run we will see more dynamic pattern oriented linking of information in a Dynamic Knowledge Net (DKN) se (Christiansson, 1993). In addition to this also physical things will be hooked up to the DKN forming the 'Internet of things' supported by the next generation Internet protocol IPv6 and Radio Frequency Identification (RFID) technology, (Sørensen et.al., 2008).

The old building master with all essential building project data in his head is in many cases replaced by teams with distributed and hopefully co-operating competences. We will build and use models of building products and processes in more effective ways through multimedia interfaces providing realistic access to digital models during for example simulations and analyses of use of buildings. We will overlay our reality with digital objects representing both existing and virtual things and persons i.e. augmented reality. Our working routines will partly change offering reduced information request-response latency efficient knowledge networking (Chachere et.al., 2003).

Building process and product models will be dependent on high-level (upper/meta) ontologies to tie them together to provide ICT supported interoperability. This also means that that we not are forced to create ONE non-redundant model to support our building projects.

The buildings themselves will be more adaptive to different uses and responsive the end user needs through embedded ICT supported systems. (Christiansson, 2007).

The user perspective will be much more in focus with higher user participation in needs and requirements formulations on building functionality and form as well as in design of human computer interfaces and user environments. We can thus expect more focus on early and late phases of the building process in the time to come.

4. SCENARIO AND VISION

In the following a short scenario is sketched describing a future Integrated Building Design Environment (IBDE) from the user perspective: "A client contacts a client advisory system on the WWW to learn more about the prospects on a new office building he is going to build. He contacts an architectural-engineering company and starts the project. The client involves a group of building end-user representatives in an early user-driven innovative and creative design process. He also includes the contractor in the early decision process to secure constructability."

Alternative building solutions, expressed as Component Building Systems (CBS) and Functional Building Models (FBS) are then evaluated by end users against needs and external requirements. A FBS may for example be a comfort system to provide personal living and working quality, a personal movement system, a load carrying building system, an escape system, or a communication system (for personal/team collaboration, knowledge transfer, mediation, virtual meeting). Functional building systems may be improved through embedded ICT-systems to help in making the building more intelligent and responsive to end user needs, usage context and surrounding constraints, see also (Christiansson, 2007). Before a client end-up with a requirements specification on a building and its services, the design team has to recurrently go through the end user needs capture and consolidation process. The end-users of a building are typically building inhabitants, external service providers, operations & maintenance (O&M) personnel, and building administration. They may in many cases have conflicting wishes and expectations on building performance optimizing from their world of discourse. Wishes and needs on the functionality of the final building have to be formulated with common mutual understanding in a collaborative process we can call co-creation, see (Prahalad &Ramaswamy, 2001) and (Christiansson et al., 2008).

The design process is then partly carried through in virtual spaces with access to the building product model on different detailing levels (volume, space, building element etc.) with possibilities to be browsed in geometric and time coordinates (4D).

The client early specifies representation, content and functionality of the building model to be delivered after the construction is completed. He also demands to get a model where he can acquire design rationale on different alternative solutions and rich multimedia access to as-built documentation on component building systems.

5. NEEDS ANALYSES

We are now prepared to start formulating needs on the future Integrated Building Design Environments (IBDE). The IBDE should be able to provide new functionalities, services, ontologies, human computer interaction environments, and be useful in different business environments supporting new business models, collaboration forms and less dependence on today's often phase locked process.

Practical experiences on how to organize and carry through collaboration on digital building models (Virtual Building, VB) should be (publicly) accumulated and contribute to the future implementation of tools for collaborative design using digital models of buildings and associated processes (BIM, Building information modeling).

What important development trends can we observe today?

- Local businesses is becoming *global local-like businesses* i.e. with greater needs for harmonization of cultural vaues on all levels.
- Lack of formal *Business models*. We have today business models very much based on locally optimizing value chains, see also Figure 5.
- *Innovation* in construction is a challenge (fax and mobile phones were real hitters).
- *Virtual Organizations* will be more often brought into play implying organisations sharing common resources during a project.
- *Moore's law* will be valid for at least another 20 years (memory, speed, ubiquitous computing).
- Extended development and use of *meta-data* marked www-accessible information (e.g. semantic web based solutions). See also (Lai, 2006).
- *Internet* based *services* on business application and technical service levels are developed, see also (Christiansson, 1993) "The so called *Dynamic Knowledge Nets*, DKN, are defined and used to explain changes for the next generation of computerized communication and knowledge handling systems"
- Clients get instruments to formulate better *requirements* on buildings, see also Figure 6.
- We are introducing, also in practice, the *time dimension* (4D) in Virtual Building models, see e.g. (Fischer & Kam, 2002).
- Virtual building (VB) models *access and exchange* is getting more standardized through use of the IFC standard, http://www.iai-international.org/.
- Efforts are under way to create *International Framework for Dictionaries* (and Ontologies) (IFD), http://dev.ifd-library.org/
- Information Delivery Manual (IDM) supporting information exchange for business processes in the building and construction industry. http://www.iai.no/idm/, http://idm.buildingsmart.no/confluence/display/IDM/Home
- *Intelligent products and buildings* with embedded sensors and actuators are again in focus.
- *Energy* optimization and *ecological and sustainable* building is gaining importance.
- We should be in a continuing *reflective* development process aiming at moving goals.

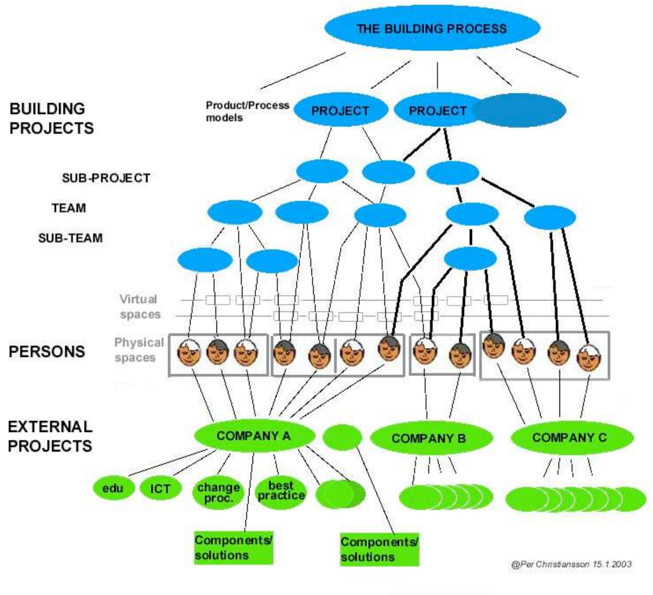


FIG. 5: Organizational view on internal and external building project actors, activities and attached information containers. (Christiansson, 2003).

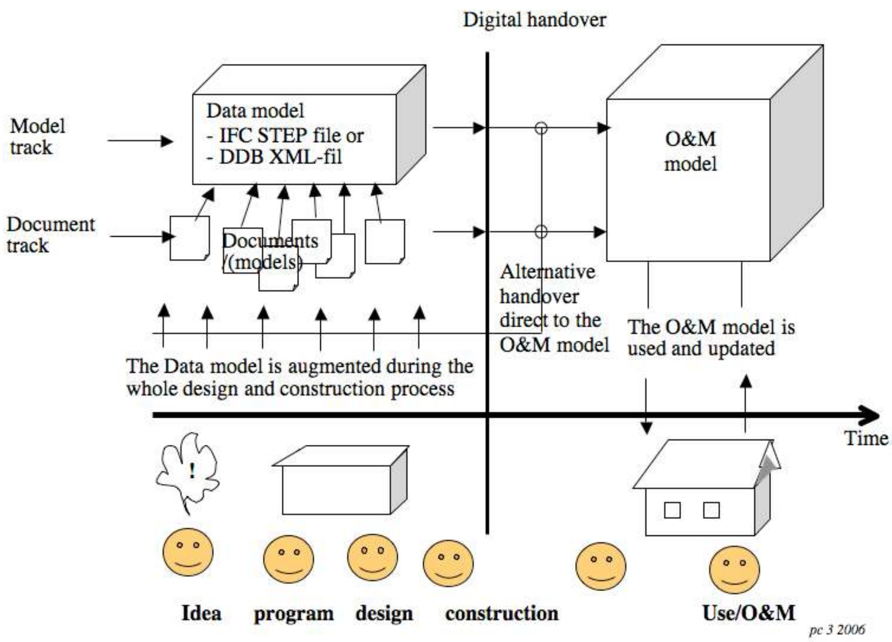


FIG. 6: The newly released, January 2007, Danish digital construction requirements let public clients put requirements on the content of the digital models of the building. After finalised construction the model is handed over to the client for use in operation and maintenance. (DDB, 2006). From (Christiansson, 2007)

Needs list on IBDE systems (that could and should be revised and extended)

- Better *Quality Assurance* (QA) on building process to minimize errors and improve documentation of the final product.
- Important decisions to be taken *at the right time (often early)* in the process.
- Better interactive *process models* for simulations with automatic update possibilities of VB.
- More user-friendly *design tools* also supporting use of thin flexible screens, haptic feed-back, ubiquitous access).
- Efficient *distributed collaboration* on Virtual Building models in virtual spaces.
- Common *ontologies* at least on *business meta-level*, see also Figure 7.

- Ontologies for *functional building systems* (FBS) such as comfort and personal security systems, see also Figure 8.
- Motivations and tools for *open* ontologies and open business models development.
- *Landmarks* (on high business and ICT levels) to aim at during long-term research, development, and organizational and work method change.
- Increase in *general competence level* and preparedness for organizational and work change due to global paradigm shift, going from the art of writing via art of printing to the art of communication.
- Increased possibilities for *user driven innovation and co-creation* in the design process.
- More *building informatics* related *education* on university level and ICT supported learning, see (Christiansson, 2004)

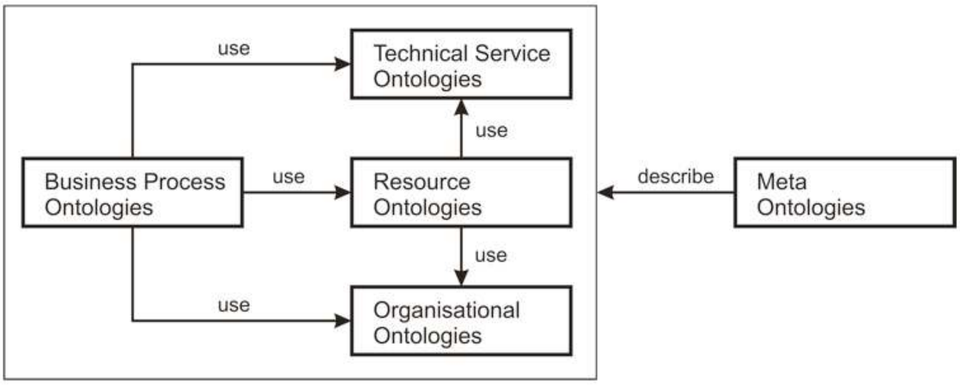


FIG. 7: Overview of meta building ontology domains and their relations. From (Sørensen et al., 2008)

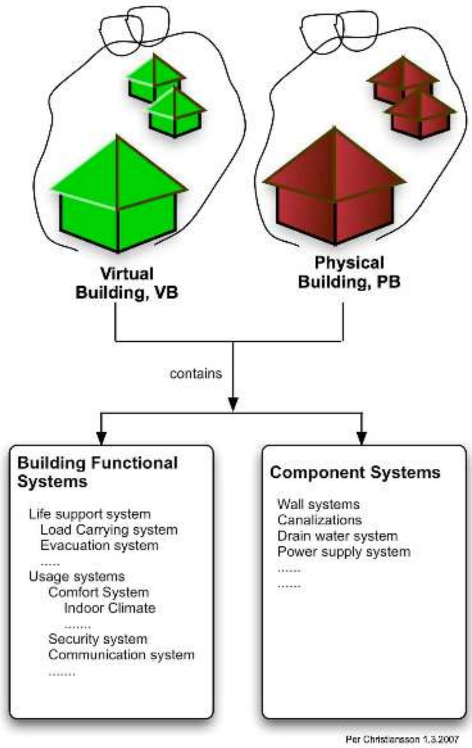


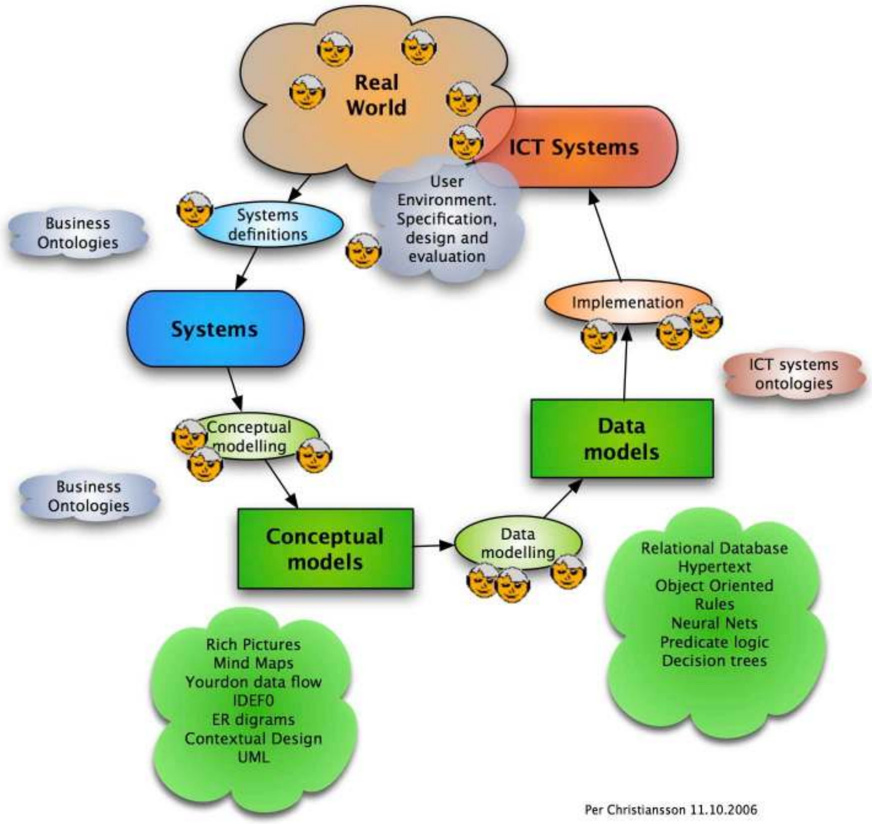
FIG. 8: The Virtual Building (VB) model should be a digital representation of the real building, the physical building (PB), even before it is built. (Christiansson, 2007). In (Christiansson & Svidt, 2006) the relation between functional building systems (FBS), and Component Building Systems (CBS) and detail levels of VB descriptions is further described.

6. SYSTEM DEVELOPMENT

6.1 Integrated design system

In the real world, see Figure 9, we identify activities, things, processes, context, and persons. The real world building can be described as (interrelated) building systems (FBS) (no de-facto structure is available today) to accomplish different functions e.g. a comfort system to provide personal living and working quality, and load carrying building system. The functional systems are modelled in context and more or less formal conceptual models, and later data models in formal representations, are designed. The data models are implemented in computerized information handling systems, and the ICT systems performance is (continuously) evaluated and usability tested, (Christiansson, 2007).

FIG. 9: Real world systems supported by ICT systems. The Systems may in connection with Integrated Building



Design Environments (IBDE) characterize a building or the design process.

Needs and requirements formulation from client and end users leads to specific requirements on the building functional systems and their implementation as a physical building. The traditional functional building systems may be improved to help in making the building more intelligent and responsive to end user needs, usage context and surrounding constraints, from (Christiansson, 2007).

6.2 Ambition, resources and time

During the last century the so-called 'industrialism' has been the ruling paradigm. We are now in the phase of changing to something new, which we could call 'globalism' ('the global village') or 'organizm' (from organization and organic). During the industrialism there was a need for man skill in the realm of logics to make known processes more effective. Today we need more non-parametric studies and creative thinking to formulate and try out sometimes totally new processes on all level in our society, (Christiansson, 1993). We have also passed the stages from 'art of writing' via 'art of printing' (1450 a.c.) to the 'art of communication' with global information containers available for immediate access (2000 a.c.) with changed demands on information quality assurance methods and separation of information storage and access media, from (Christiansson, 2004)

The higher the degree of formalization the more effective and efficient the computerized models of building product and processes will be and less flexible to changes, see Figure 10. It is of course a question about optimizing in a set of constraints, (Christiansson, 1993). These constraints may be dictated from external needs and access to resources (such as workforce, material, money resources) and available time as well as type of building product. During the 1960s there was (probably) another set of constraints than today.

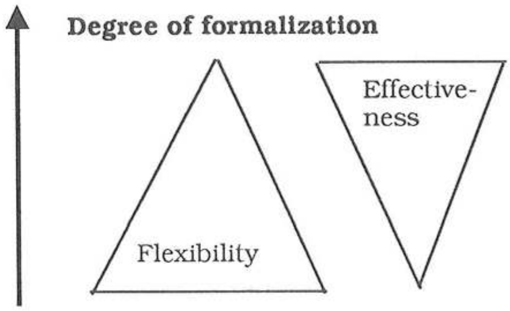


Figure 10: There might be a negative correlation between effectiveness and flexibility for different representations. From (Christiansson, 1993). Modern ICT tools may though lessen the gap.

7. BUILDING PRODUCT MODEL ACCESS

Figure 4 shows how building product models can be stored shared and distributed in ICT supported environments. The *flow* marked A) shows a representative situation of today where building models are developed and stored in CAD systems, and transferred between CAD systems, which are typically used by different disciplines. A more ideal situation is sketched in flow B) where discipline models can be merged into the shared IFC Building Model (see also http://www.iai-international.org/ for IFC descriptions) either direct (simultaneous work on the building model) or via a model file transfer. A more realistic situation of today is shown in flow C) where building sub-models are extracted from the model server, checked and stored locally using another system e.g. Solibri modelchecker, http://www.solibri.com/. Computer power and bandwidth limitations put constraints on handling large digital building models for example for access in a virtual reality (VR) environments. Flow D) shows a rare situation of today, where changes on simplified VR-models (often in the form of surface models) can be directly transferred back to discipline models in CAD systems and further to a IFC Model server for merging. Simplified VR models are made due to lack of computer resources and low network bandwidth to allow direct interactive work on large building models. These VR-models may typically be used for design brief and design review. Flow E) is the same as D) but updates on the VR-model has to be manually transferred from VR-model to discipline models.

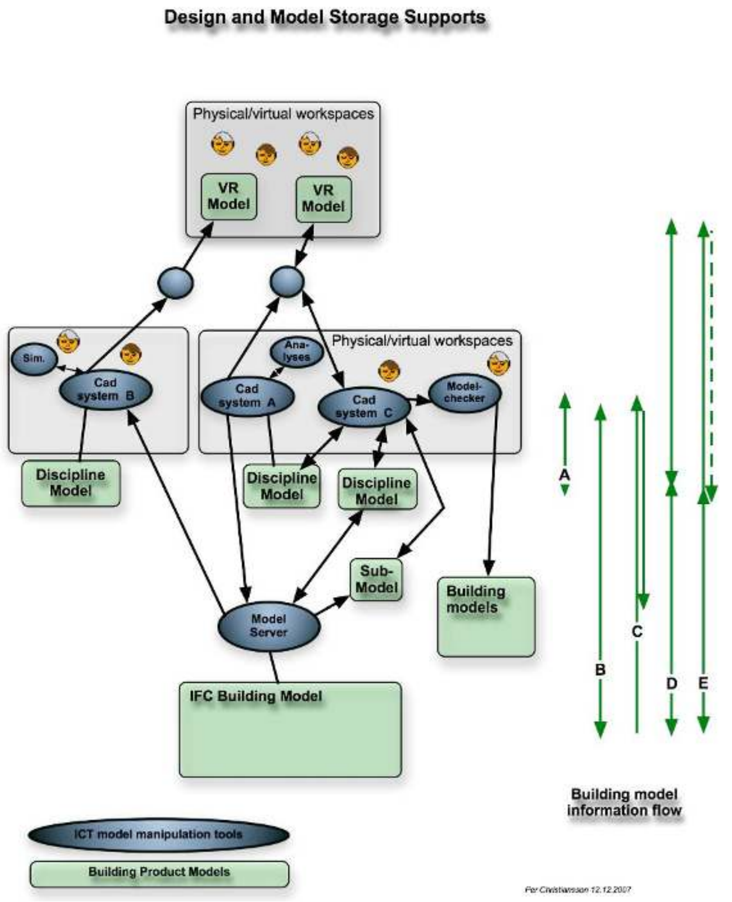


FIG. 11: Building product models can today be stored, shared, distributed, and used in more or less mixed reality environments with access to synthesis and analyses tools. (Flows A to E are explained in he text).

8. FUNCTIONAL AND COMPONENT BUILDING SYSTEMS

A building may be regarded as a system with sub-systems. The basic driving force for developing building systems are to fulfil end-users/buyers more or less formulated and revealed needs. There are no significant efforts done in formalising the early end user needs capture and describing corresponding Building Functional Systems (FBS). We exemplify FBS with Comfort system with sub-systems such as indoor climate, lighting, air-quality, acoustics, Collaboration system with sub-systems such as virtual meeting space, augmented reality model access, and transport systems such as personal evacuation system, and goods transportation system. Figure 12 gives an overview of functional and component systems relations in a formalisation of the building design process.

Merriam-Webster defines 'function 2: the action for which a person or thing is specially fitted or used or for which a thing exists'. System is defined as 'system 1: a regularly interacting or interdependent group of items forming a unified whole (a1) a group of interacting bodies under the influence of related forces, (d) a group of devices or artificial objects or an organization forming a network especially for distributing something or serving a common purpose <a telephone system> <a heating system>.. '. It is further stated in (Ekholm, 1996) "To adopt a view on a system is to observe a specific set of properties. A functional view on a system focuses on some of its bonding relations to the environment while a compositional view on a system is directed towards its composition and internal relations."

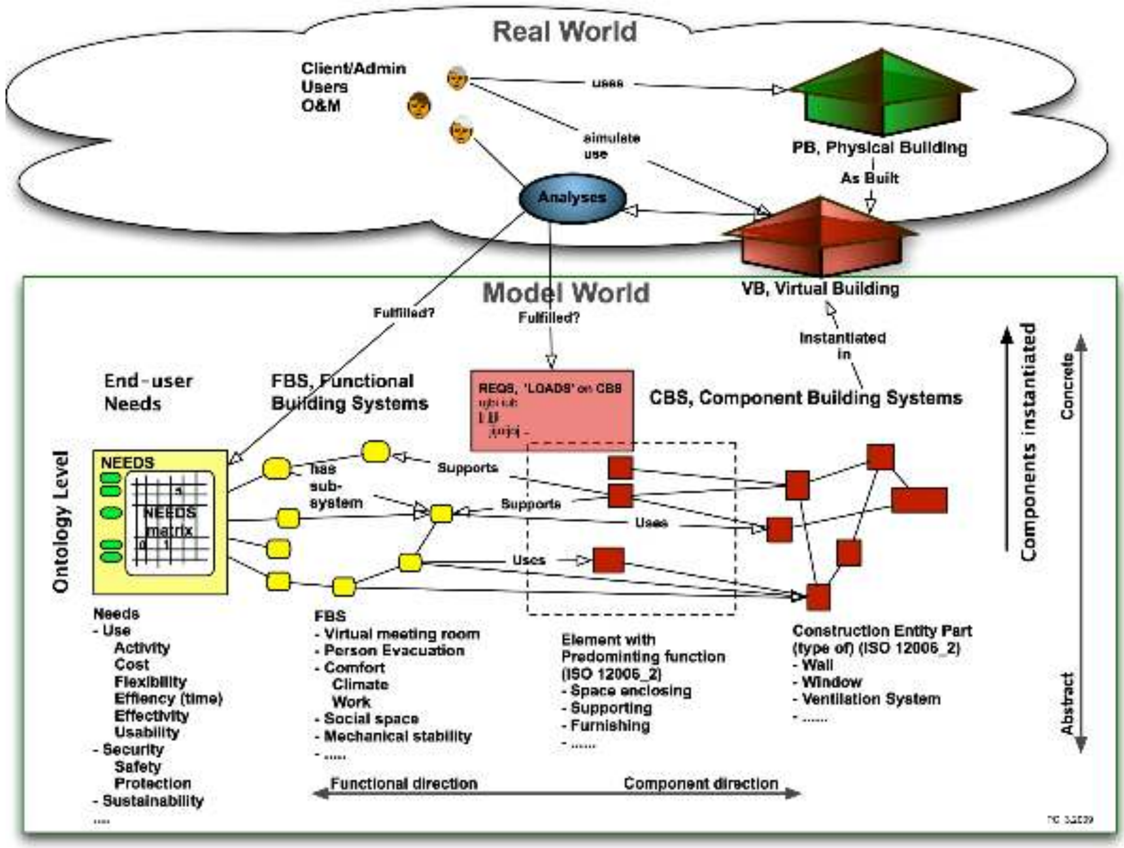


FIG. 12: Formalisation of the building design process. References are made to (ISO 12006-2, 1001).

Turner (1988) propose a 'AEC Building Systems Model "which divides a building project into a single site and building, each having a collection of systems (and other non-system components). Most of the physical elements of an AEC project are components of systems." The systems can further be active (communication, lighting etc,) and passive (structural, acoustic, spatial etc.). These systems are similar to CBS.

There are several functional representation schemes currently in the field of engineering systems with common features but different ontologies, (Goel et.al., 2009), see also (Borgo et.al., 2009). We here mention Functional Representations (Chandrasekaran, 2005), Function-Behaviour-Structure (FBS) (Gero, 1990), Structure-Behaviour-Function (SBF) (Goel et.al., 2009), and Requirements-Function-Form-Content-Behavior-Perfomance (Christiansson, 1995). See also (Erden et.al., 2007) for a review on function modelling.

We conclude that there is a need to develop the Functional Building Systems (FBS) on high ontological level to open up for a more formalised handling of end-user needs on buildings and how these can be linked to detailed design of Component Building Systems (CBS)

9. END USER DRIVEN INNOVATIVE DESIGN

In an ongoing project Virtual Innovation in Construction (VIC) we follow a scheme for creative/innovative design with user participation according to figure 11.

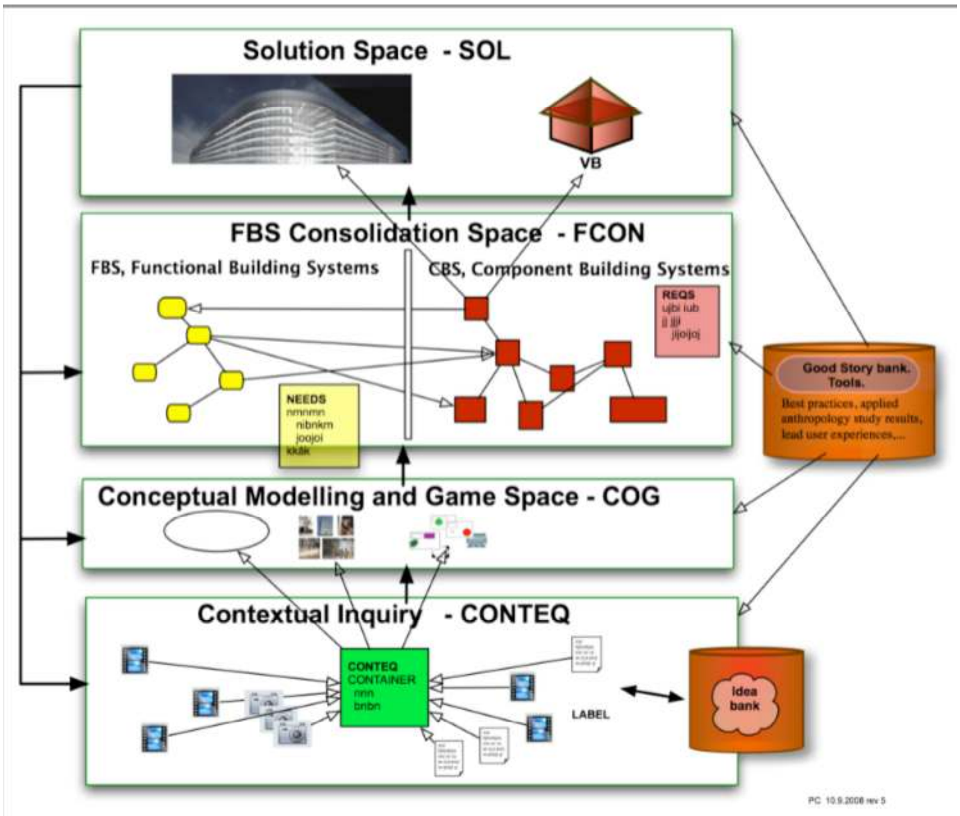


FIG. 11: From presentation Christianson P, et.al. "User Driven Innovation in the Building Process". 12th International Conference on Computing in Civil and Building Engineering. 2008 International Conference on Information Technology in Construction Beijing, (ICCCBE-XII & INCITE2008) China, October 16-18, 2008.

The innovative/creative design process is driven from user needs (more or less discovered, formulated, and augmented during design) translated into functional building systems (FBSs), which are instantiated in Component Building Systems (CBSs). The CBSs intended behaviours that can be reviewed in a performance test/evaluation against requirements derived from needs. In short we go through a process

1) Formulate design/innovation domain
2) Set up design theme. Invent resources available (such as contextual inquiry banks, Idea bank, Virtual Building models).
3) Contextual inquiry. Methods used for self observations, anthropological studies etc. Further inquiries needed? These activities take place in the Contextual Inquiry - CONTEQ domain, figure 11.
4) Conceptual modelling of building. Needs capture, collaborative story telling, design games, value formulations. Needs weighing, ordering and consolidation. These activities take place in the Concepual Modelling and Game Space - COG, see figure 11.
5) Functional Building Systems (FBS) formulations.
6) FBSs *functions* and CBSs *form*/structure mapping (on high conceptual level, static and dynamic). Requirements on CBS. These activities take place in the FBS Consolidation Space - FCON, see figure 11.
7) CBSs instantiations giving them *content* (in FCON)
8) predicted FBSs check through *performance* check of CBS *behavior* and *requirments fullfilment* . (Design solutions evaluations). These activities take place in the Solution Space - SOL domain, see figure 11.
9) go to 3), 4), 5) or 6).

The relations between FBSs and CBSs becomes very intricate when applied on big complex things as buildings. For example a room-separating wall can be removable or permanent in case it is a component in a load carrying FBS. The CBS may also house openings that are part of indoor comfort subsystems and evacuation systems. Trade offs between conflicting needs/requirements have to be done as part of reaching a balance between ambitions-time-resources (what-when-how). Typically there will be better or worse solutions rather than right or wrong, i.e. we are in reality dealing with wicked or ill-defined problems when optimally designing buildings.

Ideas and design-rationales in context from different design processes should be stored and made publicly available. In parallel ontologies and folksonomies (Porter, 2005) must be used and collected to describe especially the Functional Building Systems in order to support the crucial early formulation of requirements on a building and its expected life time performance.

Figure 12 shows the basic layout for a the user driven innovation and design VIC Method under development by the two main engineering and architecture companies in Denmark , Rambøll A/S and Arkitema A/S, and Aalborg University, Civil Engineering department. See also (Christiansson et al., 2008) and figure 11. The project goal of the Virtual Innovation in Construction (VIC) project is to create an ICT supported methodology VICMET to involve building end user in a creative innovation process together with building designers, to capture and formulate end-user needs and requirements on buildings and their functionality. An open dynamic innovation space VIC-SPACE is created with access from WWW.

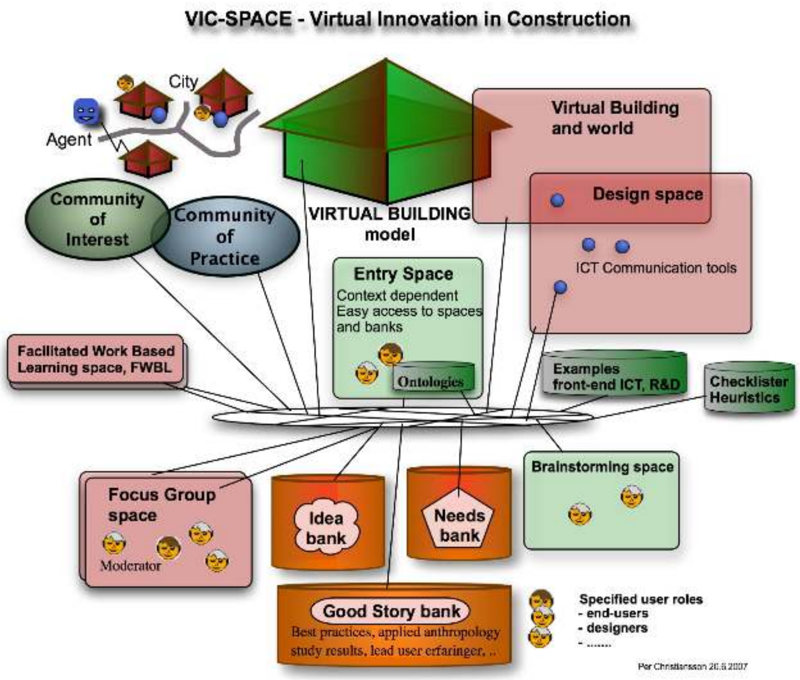


FIG. 11: The Virtual Innovation in Construction methodology, VICMET, will house a number of spaces suited for different activities. From (Christiansson et al., 2008).

10. CONCLUSIONS

We are in the middle of a great change process concerning development of Integrated Building Design Environments. Design activities and design competences collaboration are increasingly carried through in a global context in more or less virtual spaces using rich multimedia interfaces, and digital virtual building and process models. We are in fact accomplishing an innovative creative design of future design tools and buildings, requiring significant end-user involvement and usability engineering. Ontologies and dictionaries have to be further developed especially on business and meta-levels to secure effective systems interoperability, and information handling. Functional Building Systems have to be categorized and the client needs capture and requirements formulation and modelling be further advanced. There is a great need for increased efforts within building informatics education to secure needed competences for leading and carrying through the future research, development and innovation activities.

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