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USER PARTICIPATION IN THE BUILDING PROCESS

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SUMMARY: *Virtual Innovation in Construction (VIC) is a project aiming to develop an Information and Communication Technology (ICT) supported methodology VIC-MET, to involve building end-users in a creative innovation process together with building designers, and to capture and formulate end-user needs and requirements on buildings and their functionality. The method gives advisors and clients a set of tools to capture the required knowledge in a creative and innovative design process with end-users, and thus to incorporate user needs in the building. VIC-MET includes four design spaces that support different functions in the user involvement process. In space (1) 'Contextual Inquiry', the end-users are given tools and motivation to deliver their wishes, needs and views on suggested solutions. Individual views of end-users have to be expressed and consolidated into more general needs, common values must be established and conceptual building designs be illustrated. This is done in (2) 'Conceptual modelling space'. Here the VIC-MET proposes different tools and processes to build up a common understanding of end-user needs and values. In (3) 'Functional consolidation space', needs are linked to functional building systems (FBS), which are realized as component building systems (CBS), which will form parts in the total building solution. The formulated needs provide input to specific requirements in order to assure expected performance of the building components. The final virtual building model or part of it is evaluated by the end-users in the (4) 'Solution space'. Three on-going construction projects were used as cases in the development and in the testing of VICMET. Collaborative Virtual Reality environments were tested in order to present and discuss the suggested solutions with users. The virtual environments included CAVE and Panorama, a game console based solution and a virtual world in Second Life.*

KEYWORDS: *User driven Innovation, Functional building systems, Virtual Buildings, collaborative virtual environments.*

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1. INTRODUCTION

Successful construction projects are designed, built and equipped to meet users' needs. Whether it concerns the function and expression of an entire building or the design of a single space, users hold a unique knowledge, which should be integrated properly in the design to ensure a successful building project.

To extract this knowledge and translate it into a consistent design requires a systematic and coherent approach to user involvement. It is necessary to understand the user's background, surroundings and future use of the building and to organize a design process where the user needs are included at the right times in the design and construction process.

We see successful examples of user involvement in other industries. These include the Lego Digital Designer where users build their own model in a web interface, where after it is sent into production and delivered to the user. We also see attempts in some areas of the construction industry, e.g. suppliers of kitchens, who put users in focus by offering tools where customers can design their own kitchens.

The construction industry has always, to some extent, been working with user involvement. We are now facing a number of promising new possibilities for using digital tools. 3D modelling and computer supported collaboration can for example be used to support designers and users in achieving a common understanding of how the buildings are being designed.

Virtual Innovation in Construction (VIC) is a project aiming to develop an ICT supported methodology VIC-MET to involve building end-users in a creative innovation process together with building designers, and to capture and formulate end-user needs and requirements on buildings and their functionality. The method gives the advisors and the client a set of tools to support the process. The method rests on the basic assumption that users have a unique knowledge – explicit or tacit – that can contribute to the construction project. The advisors' role is to create a design process where the user wishes, ideas and needs come forward, and to include them in line with all other requirements for the project. The method is holistic and aimed at all types of projects and all phases of construction.

It is envisaged that the VIC-MET will support:

- Motivation to deepen and disseminate knowledge within the domains necessary for ensuring high quality on long-term requirements and needs formulation on buildings.
- Collection of spontaneous, innovative and creative ideas.
- General and project specific requirements capture and formulation (particularly unforeseen needs).
- Exchange and evaluation of ideas, and assessment of needs.
- Break down of barriers caused by lack of competences/knowledge.
- A general methodology for user driven innovation
- Highlighting of the interdependence between technological possibilities and realistic needs formulations

VIC-MET is based on four fundamental design spaces that support different functions in the user involvement process and thereby helps the advisors and the users in the user involvement throughout the design process from the mapping of context to the final solution.

This paper reports the development and test of the VIC-method including ICT-tools supporting activities in the different design spaces. Three on-going construction projects were used as cases to support the development of VIC-MET. Experiences from the cases contributed with input to the development of the method and later, the projects served as a test bed for VIC-MET.

VIC-MET is developed in the project User Involvement in Construction - Virtual Innovation in Construction, VIC, which is financed by the Danish Enterprise and Construction Authority through the Programme for User Driven Innovation. It started August 2007 and finishes in June 2010. Project participants are two major engineering and architecture companies in Denmark: Arkitema Architects and Ramboll A/S, together with Aalborg University, Department of Civil Engineering.

2. METHODOLOGY

The VIC method (VIC-MET) was itself developed in an innovative/creative design process. The Contextual Design method (Beyer & Holtzblatt, 1998) gave inspiration to the development process. The development process has included:

- Literature studies on user involvement and user-driven innovation from other industries.
- Capturing of best practices for user-involvement from on-going building projects
- State-of-the-art for virtual building modelling and collaboration in the building design process including the needs for development of ontologies
- A survey of IT-tools capable of supporting the processes in the four design spaces of VIC-MET
- Testing selected tools with decision makers and end-users from on-going building projects

The Confluence 'enterprise wiki' from Atlassian, http://www.atlassian.com/, was chosen to serve as a hosted project web also housing the VIC Public Space. VIC Confluence was mainly used as a dynamic content management system and also used to take real time notes during physical and virtual meetings.

3. WHAT IS USER DRIVEN INNOVATION

The terms 'innovation' and 'user driven innovation' are widely used in different contexts. If we do a search on the Internet on "user-driven innovation" or "innovation", we get 1.8 million hits and 107 million hits, respectively. The authors' approach in the present work is described in this chapter. It is believed that users possess valuable competences and tools to improve the quality of a building design project supported by a range of ICT tools.

3.1 What is innovation

There are different possible definitions of the term 'innovation'.

"*Innovation is the process through which firms seek to acquire and build upon their distinctive technological competence, understood as the set of resources a firm possesses and the way in which these are transformed by innovative capabilities*" (Dodgson and Bessant, 1996).

"*Innovation means the application of new knowledge to industry, and includes new products, new processes, and social and organisational change*" (Firth and Mellor, 1999).

"*A technological product innovation is the implementation/commercialisation of a product with improved characteristics such as to deliver objectively new or improved services to the customer. A technological process innovation is the implementation/adoption of new and or significantly improved production or delivery methods. It may involve changes in equipment, human resources, working methods or a combination of these*" (OECD/Eurostat, 1997).

Innovation (according to Merriam-Webster):

1 : the introduction of something new 2 : a new idea, method, or device :

Invention: (according to Merriam-Webster):

1: discovery, finding. 2: productive imagination: inventiveness. 3 a: something invented: as (2): a device, contrivance [Oxford American Dictionaries: a thing that is created skilfully and inventively to serve a particular purpose], or process originated after study and experiment.

Innovation is change; it is change in the things delivered (product innovations) or change in the way they are produced or delivered (process innovations) (Tidd et al, 2001). Another way of categorising innovations is according to their effect, ranging from radical to incremental. Radical innovations are of the highest novelty value and often necessitate shifts in production capabilities, distribution means or customer relationships (Stringer, 2000). The opposite, incremental innovations, are small-step, high-frequency, short cycles of change (Gallagher et al., 1997). Each individual incremental innovation may not be of any particular value, but together they may pass as the value of a radical innovation (Utterback, 1994).

(Baldwin & Clark, 2006), comment on architectural innovation: *"The concept of architectural innovation was first proposed in the management literature by (Henderson and Clark, 1990). They define such innovations as follows: [Architectural] innovations ... change the way in which the components of a product are linked together, while leaving the core design concepts (and thus the basic knowledge underlying the components) untouched (p. 10). ---- In other words, architectural innovation involves rearranging known parts (components) into new patterns (architectures) to achieve higher levels of system performance on one or more dimensions"*

The innovation scene is changing as we apply more open business models, (Chesbrough, 2006), also entailing uncertainties of intellectual property establishment. Innovation and development of new products is not taking place inside a single company and may require long term strategy development and implementation and return of investments. Innovation diffusion occurs within a social system or network (Rogers, 2003).

3.2 User driven innovation

In the VIC-MET project, we define user-driven innovation as a process towards development of a new product or service, where analyses and understanding of the end-users needs, preferences and expectations play a decisive role. More precisely, we describe user driven innovation as a '*systematic approach to develop new products and services, building on investigation or adoption of users life, identity, praxis, and needs including unrevealed needs*' (http:// www.ebst.dk/brugerdreveninnovation.dk/tilskud).

There are a number of methods that can be used to support user driven innovation. These methods are of an anthropological nature, and go under such terms as user-centred design, empathic research, and applied ethnography. A central issue is to capture and unveil both known and not yet formulated needs on functionality and form of new and refurbished buildings, (Christiansson et al, 2008).

User behaviour can be studied by using applied ethnographic methods like Contextual Design (Beyer & Holtzblatt, 1998). End-users can be involved indirectly by use of so-called personas. It is typically a representation of a real or potential user including invented details to make the person more real. From (Cooper, 2010) "*As we interview and observe users in their natural habitats, we look for patterns of behaviour and goals shared by multiple people. Each distinct behaviour pattern becomes the basis for a persona: a description of an archetypal user*".

The end-users can be more or less involved in the design of a product or part of it. In so-called participatory design, the end-users are directly involved in the design work. In VIC-MET, we differentiate between the terms *User Involvement* and *Co-Creation*. In the first case, the users are typically interviewed or observed first and later presented with alternative solutions to comment on and in the latter case they are deeply involved in the design activities.

There are several methods, supplementing the above mentioned Contextual Design, to capture user needs and creative ideas. Here we mention *interviews*, *questionnaires*, and *focus groups* where group interaction is the basis for knowledge capture, *self-observation* documented through text or speech commented digital photo and video shots, personal or collaborative *story-telling*, *scenario writing*, *lead user* involvement (Von Hippel, 2005), *behavioural mapping* with a systematic observation research that tracks user behaviour over space and time, *walk-throughs* in digital virtual building models or physical buildings, *appreciative inquiry*, and *design games* (Brandt et al, 2005) (Johansson, 2006).

3.3 User needs and requirements on buildings

Before a client end up with a requirements specification on a building, we have to recurrently traverse the end needs capturing, weighing and consolidation process. The end-users of a building are typically building inhabitants, external service providers, operation and maintenance personnel, and building administration. They may in many cases have conflicting wishes and expectations on building performance, optimizing from their world of discourse.

It is important to unveil the underlying, unrecognized desires, needs, expectations and longings that motivate people to act as they do. If, for example, you aim to develop a new type of meeting room for a knowledge enterprise, you should examine not just the meeting situation, but the entire organisational life of which the meeting room forms a part.

The end-user needs can be derived from persons, teams, organization/company and society. Needs are always associated with some context where they are to be met. End-users may be well specified for example in case of a company building a new office, but we can expect usage change and new needs arising in most cases during the life-time of a building.

4. THE FOUNDATION OF VIC-MET

A number of different research disciplines have been taken into account in the development of VIC-MET. Along with the development within these disciplines, new possibilities arise to make a fruitful user involvement in the building design process. The principles of building modelling are changing from representing the building model as a number of more or less independent documents including 2D and 3D drawings to representing the building as a system of closely connected sub models of building objects and their properties. The possibilities of interacting with the models are increasing with the development within virtual worlds and game spaces. New advanced building components give new possibilities to make intelligent and responsive buildings. This contributes to making the design process more complex and increases the need for testing the new services and designs with end-users in virtual environments to find the right solutions. The increasing requirements to integrated design environments also increase the need for development of ontologies, which is discussed at the end of this chapter.

4.1 Virtual buildings

The virtual building (VB) plays a central role when we simulate, test, evaluate and refine services during building design. A VB may be defined as "*a formalized digital description of an existing or planned building which can be used to fully simulate and communicate the behaviour of the real building in its expected contexts*" (Christiansson, 1999). The process of creating VBs is often termed Building Information Modelling (BIM), Se Eastman et al. (2008). The main driving forces for this development are access to the global Internet and its services, communications standards, building classifications, and new ICT tools and services.

VBs and BIM help us concretize the old dream of being able to design, build and test the building before it is built, in a progressing virtual version. It will also support a kind of revival of the pre-renaissance building master in the form of involvement of many competences, also in the early phases of a project. Up until now, the greatest focus on development of CAD tools has been on the late phases of a project. Greater emphasis should be made on the important information gathering and formulation of customer needs to ensure high building quality and low life cycle costs. Innovative design solutions should be made and alternative solutions tested. Integrated tools for decision support at this early stage are still at an early development stage.

4.2 Virtual worlds and game spaces

The developments in the gaming world have for some time given spin-offs to valuable technologies useful in collaborative building design. This is true especially in the populating virtual worlds with avatars that can represent users performing collaborative tasks in synchronous and asynchronous modes. In the VIC project, we used Second Life as a vehicle for creating a virtual world supporting building design. The world was useful for end-users to make walk-throughs, make annotations and give feed-back on solutions. The main barrier is the missing powerful in-built building design tools and limited possibilities to import building models created in external programs.

4.3 Future Advanced Building Components

Late development within information and communication technologies (ICT) supply us with possibilities to create new services to assist us in the user driven innovation process but also in introducing newly adapted services in the buildings. These new services must be designed to be effective, efficient and provide user satisfaction during use (Christiansson, 2007).

In the middle of the 1980s, development of so called intelligent building installations in intelligent and responsive buildings (IB) was starting in the USA.

During the latest 20 years and more, there has often been a mismatch between what users expected from an intelligent building or smart house and what the suppliers were able to deliver. Often the intelligent building services were defined based on the available technologies and systems, rather than in terms of the goals and needs for services defined by the occupants.

Today, we experience a renewed interest in the possibilities offered by the implementation of advanced ICT controlled processes and new services in buildings. These systems are part of the buildings Component Building Systems (CBS) and provide rich opportunities for innovative solutions to fulfil user needs and demands from the Functional Building Systems (FBS). This will be explained further in chapter 4.4. Traditionally, Intelligent Building (IB) systems have supported fire alarm energy control, heating control, ventilation control, indoor climate surveillance, electrical power supply, security, access control and automatic door functions. Through standardized communication protocols and ICT supported sensor and control components, it is easier today to develop and implement creative and innovative services in buildings. See also (Christiansson, 2007).

We also observe an interesting development of new materials that can change the properties of components in buildings. We already have self-cleaning windows, conductive fibres in textiles, nano robots, and Organic Light Emitting Diode (OLED) panels. Many of these advancements are due to the rapidly evolving nanotechnology.

In 2000, one of the authors made the following definition: "*Intelligent buildings are buildings that through their physical design and IT installations are responsive, flexible and adaptive to changing needs from its users and the organisations that inhabit the building during its life time. The building will supply services for its inhabitants, its administration and operation & maintenance. The intelligent building will accomplish transparent 'intelligent' behaviour, have state memory, support human and installation systems communication, and be equipped with sensors and actuators*."

From (Christiansson, 2000) "There have been many definitions of IB made during the last 20 years. The IB will possess some important characteristics

- be *flexible* and *responsive* to different usage and environmental contexts such as office, home, hotel, and industry invoking different kinds of loads from nature, people, and building systems,
- be able to *change states* (clearly defined) with respect to functions and user demands over time and building spaces (easy to program and re-program during use)
- support *human communication* (between individuals and groups)
- provide *transparent* intelligence, simple and understandable to the users (support ubiquitous computers and networks)
- have a distributed long term and short term *memory*
- contain tenant, O&M, and administration *service systems*
- *support introduction of new* (sometimes not yet defined) *services*
- be equipped with *sensors* for direct or indirect input and manipulation of signals from users, systems and the building structure
- be equipped with *actuators* for direct or indirect manipulation installations and the building structure
- accomplish *'intelligent' behaviour* (self diagnosis, trigger actions on certain events and even learn from use)
- *integrate* different IB systems to form complex systems
- contain IB life time *standardized* solutions as far as possible
- be well *documented* (in 3D with functional descriptions) available in Virtual Reality with physical structure overlay
- provide *canalization* (information roads) that shall house 'wires' carrying new services
- be able to handle *high band width* information transfer.
- provide *dynamic secure information domains*
- be open to efficient communication between *applications* based on for example XML implementations, and platform independent solutions"

The traditional physical building components are on all levels, from canalisation to walls separating virtual spaces, integral parts of the Intelligent Building ICT support systems. The IB response time to different service requests is an important design factor and can vary from milliseconds to years. The virtual building, see Fig. 1, can be used as interactive documentation of the final building to support different services such as O&M activities, location of resources and persons in the building, and simulation and design of new services and user environments. The building is more or less functionally integrated with other buildings, city areas, and optional global 'neighbourhoods'.

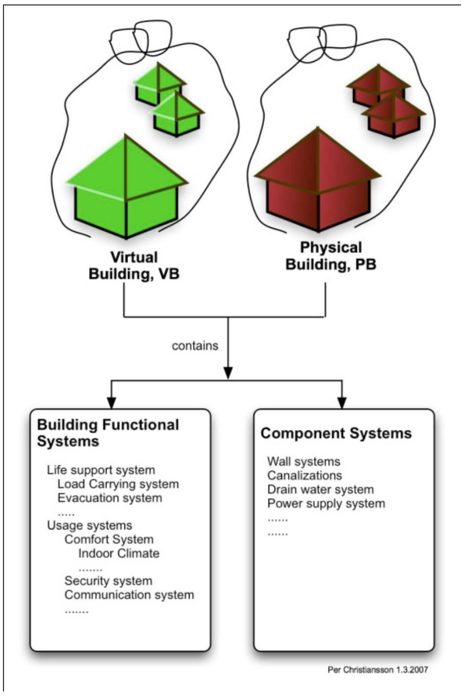

FIG. 1: The virtual Building (VB) model should be a digital copy of the real building, the physical building (PB), even before it is built. (Christiansson, 2007).

A Virtual Space (VS) may be defined as a mixed reality environment optionally involving many physical spaces and many virtual spaces. A Virtual Space may be set-up within one building or many buildings placed in the local community or on the other side of the world. The VS does not have to be stationary but can e.g. follow a person defined by the immediate surroundings of that person. In this latter case, wireless connection to the space is a necessity and maybe a complication in interaction with stationary spaces, (Christiansson, 2007).

There may be a close dependence between VSs and physical spaces that may put constraints on the design of Virtual Spaces. We notice the classical design dilemma, if form follows function or vice versa. In case of new constructions, it may be easier to fulfil form needs such as requirements on physical space layout and special requirements on communication spaces.

4.4 The building as a system

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.

In Merriam-Webster’s dictionary, a system is defined as *'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*."

In the VIC project, we regard the building as a system that can be viewed from a functional respective component perspective (Functional Building Systems, FBS, and Component Building Systems, CBS).

Fig. 2 schematically shows how a building's functional and component systems can be joined by process models. The process model describes for example how an analysis or simulation can be carried through (manually and/or automatically) where the loads, which the CBS shall be designed to withstand, are derived from, and the functional system's required performance.

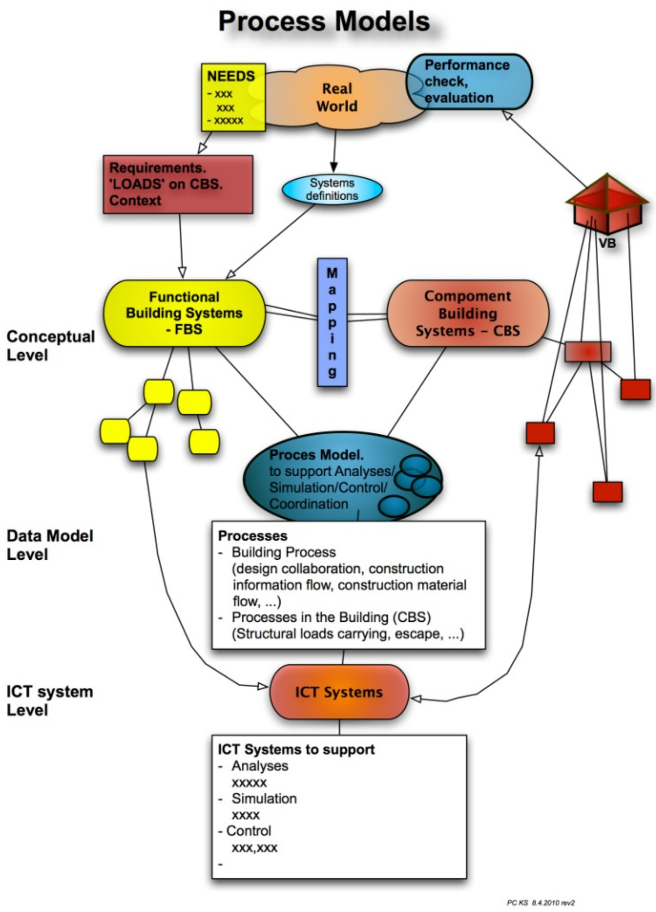

FIG. 2: The component systems of a building are designed for subjected loads. The loads are derived from needs and requirements analyses. The building system design starts by capture of user needs and requirements on the building, and formulation of high-level functional building systems to fulfil these needs. The requirements (such as load carrying capacities, area dimensions, mobility of building elements, sound insulation) forms the design loads on components. The components are put together to a complete building system that is stored in digital format as a data model. The data model is stored in an ICT system.

In designing a system, end-user needs and requirements together with societal requirements expressed in norms must be fulfilled. It is important during design to be able to check for well quantified requirements such as minimum distances and maximum stress levels but also to check the building functional performance against more qualitative requirements derived from end-user needs.

From (PeBBu, 2005, page 56) we cite: "*The simplest and most widely cited definition of the Performance Concept in Building has been given some twenty years ago by CIB W060 by the phrase 'the practice of thinking and working in terms of ends rather than means'* " /W060 - CIB Working Commission on Performance Concept in Building/.

It is further stated that *"It should be noted that the W060 definition focused mainly on ends relevant to the building's direct users (occupants) and the general public, whereas, according to some of the PeBBu Tasks [Barret 2005a, Gray 2005, Foliente 2005c, Fenn 2005] PBB /Performance Based Building/ should address a much wider range of end targets, including also ends related to the overall built environment and the building process itself, as well as ends relevant for other stakeholders, such as the contractor, building owner, investors and insurers, facility managers, and the organisation occupying the building*."

In Fig. 3, it is indicated (through the 'Fulfilled?' arrows from the 'Analyses' box) how design solutions can be evaluated/checked for both quantifiable technical performance (to the right) and in a more qualitative non-prescriptive way (to the left). In the VIC-MET, the later evaluation can be supported by end-users access to analyses in 3D virtual building models. This could for example apply to how well the building appearance/personality reflects company profile, flexibility in usage of spaces, and room colour profiles. These evaluations or performance based assessments will probably require higher competence of the professional design team as we do not deal with routine check of design requirements here. At the same time, it will give greater possibilities to create innovative, creative and non-routine design solutions.

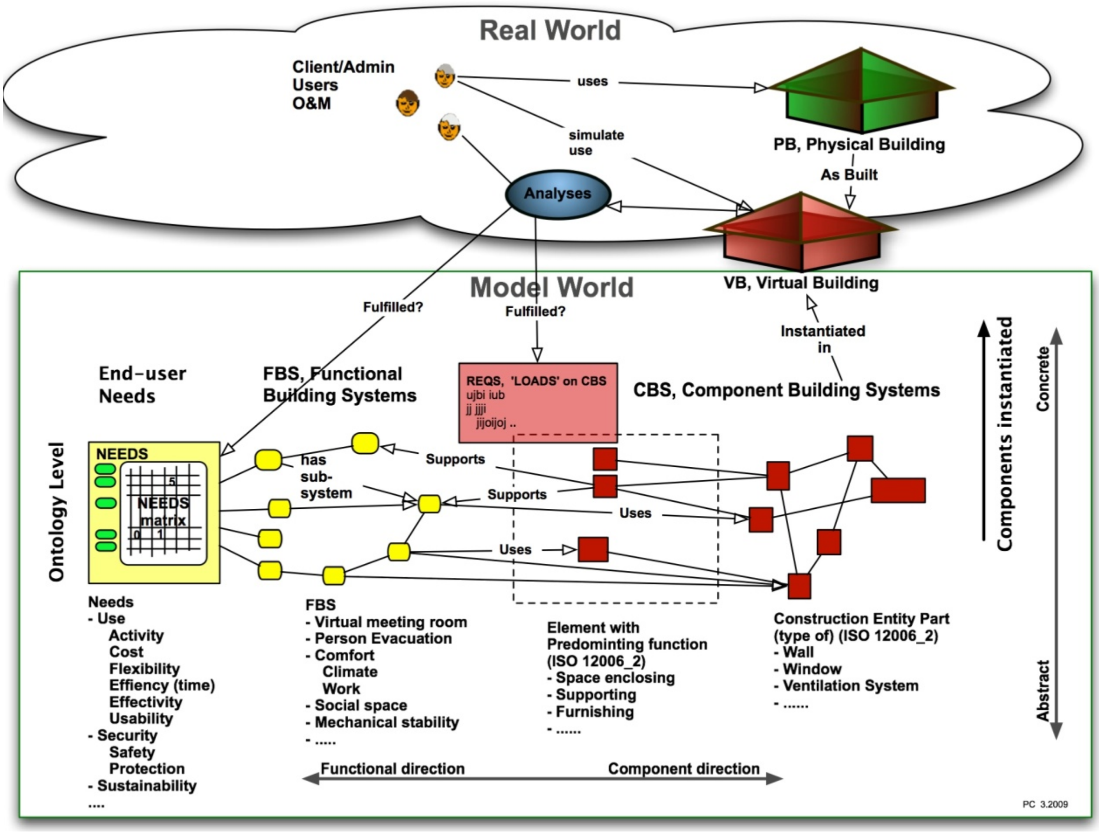

FIG. 3: Formalisation of the building design process. References are made to (ISO 12006-2, 1001) from (Christiansson et al, 2009b). Performance check and evaluation of solutions (the analyses round box) are made on both qualitative and quantitative performance criteria.

4.5 Ontologies

The probability for a successful system development is highly increased if we can agree on concepts and their relations, that is, if we have a common linguistic reference frame. We call such a description an ontology. Within knowledge engineering, the term has been widely discussed in the 1990s (Guarino, 1996). Guarino argues that Tom Gruber's definition is the best known (Gruber, 1993): "*An ontology is an explicit specification of a conceptualization*." For use within IT in construction, the similar but more detailed definition by (DLI Glossary, 1998) is also a good definition: "*An ontology is an explicit formal specification of how to represent the objects,* *concepts, and other entities that are assumed to exist in some area of interest and the relationships that hold among them".*

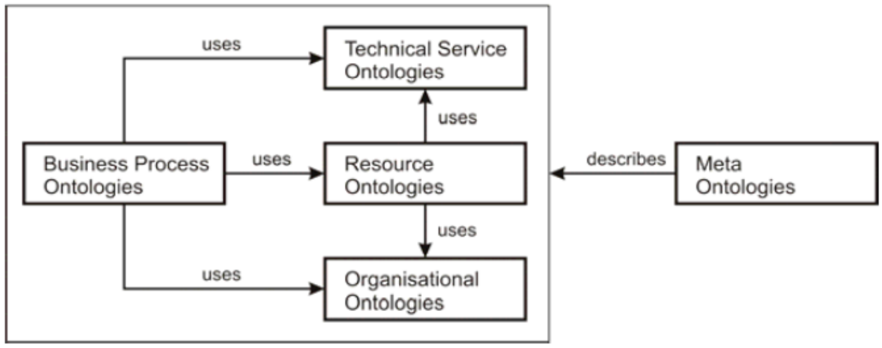

FIG. 4: Overview of ontology domains and their relations (Sørensen et al, 2009).

Below, examples of possible sub-ontologies are given. It can be concluded that collected efforts are needed to collect and publish ontologies that for example cover user needs and Functional Building Systems (FBS). See also Fig. 4. and Fig. 3.

Organisational

- Context
- Roles, competences
- User needs (person, team, organisation, society)
- Co-operation (type, form, language)
- Activity

Resources

- Models (Virtual Building, processes, project external, representations, level)
- Functional Building Systems (FBS)
- Component Building Systems (CBS)
- Building classifications
- Communication standards and formats
- Tools (modelling, cooperation, analyses, learning,...)
- Building system components (virtual, physical)

Technical Service

- I/O devices
- Communication channels
- Web services
- ....

Business processes

- Working tasks
- Building design
- Building creation
- Negotiation
- Procurement

- Transportation
- Storage
- .....

For example, we require some kind of metrics to describe our needs. Needs-requirements metrics with special regard to workspaces are exemplified below, from (AWA, 2002): *adaptability* (to suit different building users changing needs), *capability* (providing the potential to introduce, replace and change building elements, services and systems), *compatibility* (ensuring that all aspects of the building are wholly coordinated and integrated and can be none selected without influences from other elements), *controllability* (providing users with the means to maximise their use and operation of the workspace, its services and facilities), and *sustainability* (ensure that the workspace and its facilities are operated and maintained to enhance individual and corporate productivity, and their health and wellbeing at all times).

Further development of ontologies is important for the future collaboration between actors in the design process and interaction between IT systems supporting the process. Early in the project, a top level ontology was formulated (Christiansson, 2008).

5. VIC-MET OVERVIEW

VIC-MET is a methodological framework for supporting user driven innovative and creative building design. The method supports user involvement in every phase of the design and construction process and with an individual setup depending on the design context.

5.1 VIC-MET spaces

Four spaces to support the innovative/creative design process have been identified based on previous experiences from the project participants: The Contextual Inquiry Space, the Conceptual Modelling and Game Space, the Functional Building Systems and Consolidation Space, and the Solution Space. See Fig. 5.

VIC-MET provides a vehicle to understand, document and evaluate non-routine design solutions through mapping between user needs, functional building systems (FBS), and technical solutions documented as Component Building Systems (CBS). Solutions can be evaluated and assessed on different abstraction levels covering both qualitative and quantitative building performance criteria. It is, for example, possible to assess solutions regarding virtual meeting rooms and their properties (such as size, type of physical room connections, communication support, and room adaptability) and suitability for different kind of activities on an abstract conceptual functional layout or in a 3D Virtual Building with different more or less realistic artefacts. The top level evaluation domains are effectiveness, efficiency, and user satisfaction.

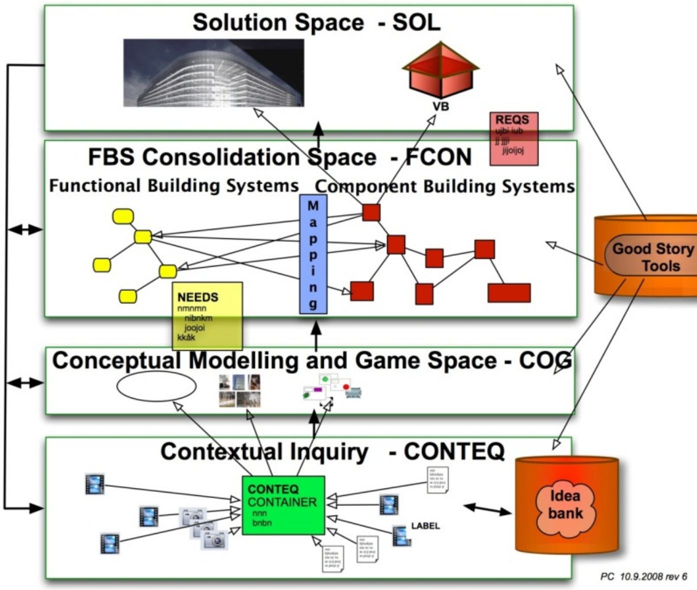

FIG. 5: The four design spaces in the Virtual Innovation in Construction Method, VIC-MET. From (Christiansson et al, 2009a)

5.2 Using VIC-MET

The following activities in VIC-MET spaces can be distinguished; see Table 1.

TABLE 1 Activities in the different VIC-MET spaces

The 4 Design Spaces	Activities
Contextual Inquiry space (CONTEQ)	• Formulate Design/Innovation domain. • Set up design team including proper end-users groups. • Plan the whole design process. • Identify/allocate resources such as Idea bank, Best practice, Contextual Inquiry Bank. • Allocate tools from the ICT Tools Bank. • Perform contextual inquiry including needs capture.
Conceptual Modelling and Gaming space (COG)	• Develop conceptual models (e.g. using Contextual design methodology). • Listening to needs. • Common values development. • Functional Building Systems specification. • Creative/Innovative design. • Allocate tools from the ICT tools bank.
Functional Building Systems Consolidation space (FCON)	• Needs consolidation, weighing and listing. • Project vision formulation. • Prioritizing needs. • Mapping of Functional Building Systems (FBS) and Component Building Systems (CBS).

Solution space (SOL)	• Listing of requirements on Component Building systems. • Component Building System modelling. • Allocate tools from the ICT tools bank. • 3D virtual building modelling of (alternative) solutions. • End-user evaluation of solutions. • Documentation of end-user feed-back. • Allocate tools from the ICT tools bank. • Choose solution(s) or return to the FCON, COG or CONTEQ space.

During the project, 10 good advices in connection with using VIC-MET were extracted:

1) End-users are the primary *needs formulators*. Needs can be revised during the innovative/creative design process due to deeper understanding of the needs. Part of the VIC-MET is to document the process that unveils needs in a natural way.
2) End -users should be *motivated* to participate. What's in it for me? Why should I bother? I will not do it for free. Calculate on a degree of risk (risk money for developers). Establish sense of ownership of both quantitative and qualitative values.
3) Ensure *broad backing* in participating companies of end-user involvement in the creative/innovative design through funded and organised participation, access to idea banks (in/out), mediation of success, long term financing plan and ownership of a new innovative service or product.
4) Ensure that end-users have possibilities to *express ideas easily* and have access to a bank of ideas explained in context.
5) End-users should be familiar with *available methods and tools* or have guidance in choosing tools.
6) End-users should be supported in *expressing* themselves effectively in the design space.
7) Define *end-user roles profiles* such as end-user experiences, degree of involvement, competence profile. List reasons for the end-users involvement (why).
8) Explain the *new service/product* in context of existing solutions. It may be new use of existing components/systems or functional services or completely new systems or services. (This information is part of the design/innovation rationale)
9) How will building operation and maintenance (O&M) support be *affected* (what, who, when, where, why, how) by implementation of innovative designs.
10) Not all good ideas input can be developed. Therefore *store* the ideas and the rationales behind (and why some ideas are not good).

5.3 VIC-MET tool box

The selection of ICT tools to support user involvement in the construction process has increased significantly in recent years and is now very extensive. Several of the methods described in the preceding chapters have previously been used without the support of IT, but the focus of the present work has been to investigate and develop an IT-supported method for user involvement.

The identified ICT tools have been divided into categories as shown in table 2, and for each category, it is explained how they can support the process. The capabilities and complexity of the individual tools vary in a wide range from simple charting tools to large multi-functional knowledge management systems that can be used for projects as well as entire organizations. Some of the tools are freely available, others are commercial.

Data collection and modelling: IT systems are powerful for collecting, managing and analysing data and information. This can also be utilized in connection with user involvement processes. It has been identified how this can be done from the first interviews and the data is analysed and provides the basis for decisions about the impending construction.

Communication and collaboration: User involvement is very much about good communication and good cooperation on construction projects to achieve the solution which best supports the user needs. For many years, collaboration and communication have been carried out with limited use of ICT, but the World Wide Web (WWW) has paved the way for several new technologies that can support the user involvement.

Visualization and interaction: To illustrate solutions for users and partners, visualizations based on 3D building models can act as a powerful tool. Particularly across disciplines or when users are laymen who are not accustomed to reading 2D planes, sections and elevations, digital 3D models contribute to the common understanding of the building. The authors identified examples of practical applications of visualization and interaction with 3D building models for user involvement and communication between client and advisers.

Fig. 6, Fig. 7 and Fig. 8 give examples on VIC-MET tools used in the VIC project.

TABLE 2 VIC-MET tools overview (around 90 tools are listed). References to applicable tools are made in the VIC-MET description manual.

VIC-MET tools categories	Tools to support the VIC-MET
Data collection and modelling	• Interviews and user investigations.
	• Conceptual modelling.
	• Scanning and surveying.
	• 3D modelling.
	• Registering and measurements.
	• Analyses and prioritizing functional requirements
Communication and collaboration	• Communication.
	• Information and knowledge sharing.
	• Relationship and competence handling.
Visualization and interaction	• Still renderings.
	• Animation.
	• Interactive visualization.
	• Virtual reality.
	• Virtual 3D communities.
	• Rapid prototyping.

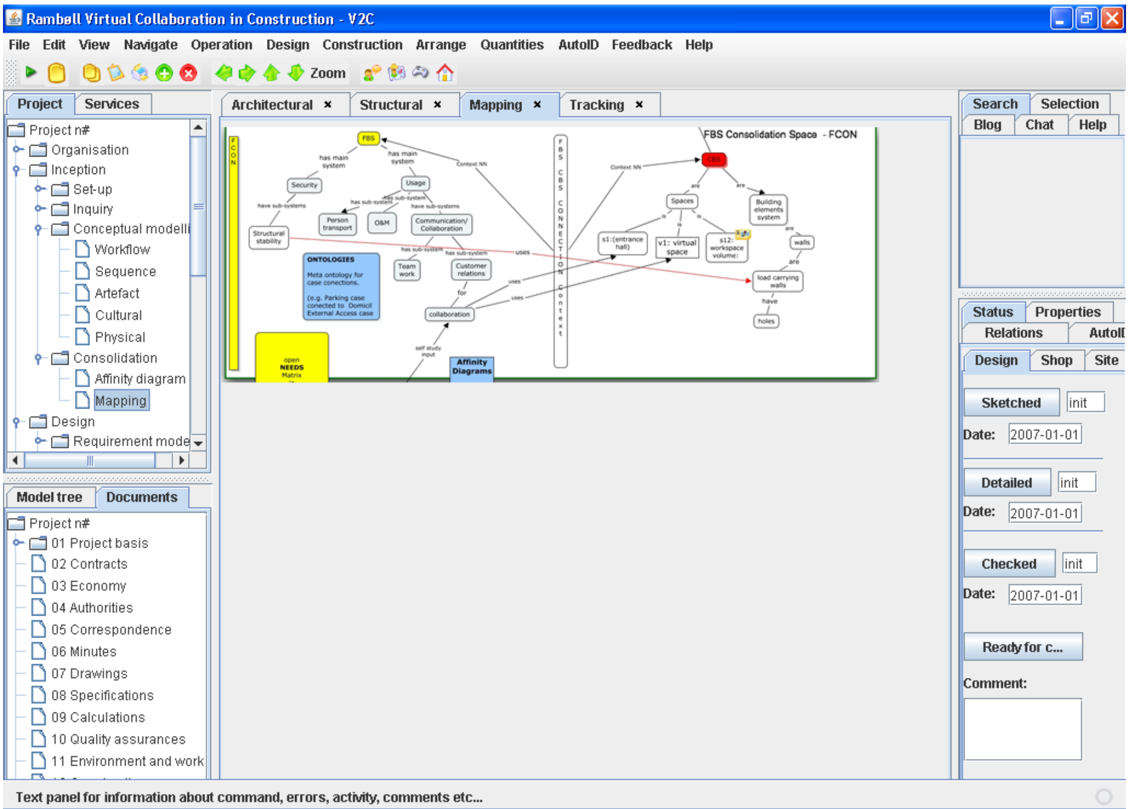

FIG. 6: Prototype from the VIC-MET project, where the mapping functionality from the Functional Building System to the Component Building System is illustrated in a virtual collaboration tool for construction. The prototype illustrates an implementation in a desktop application. (Christiansson et al, 2009a).

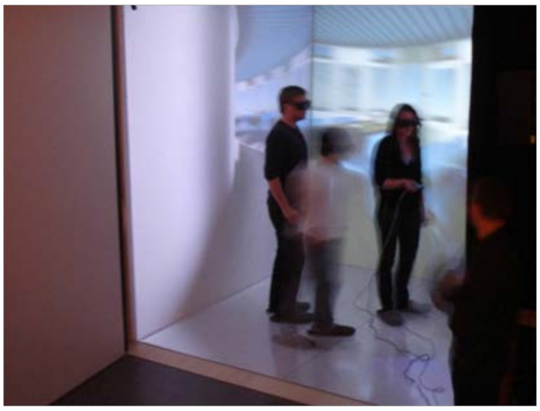

FIG. 7: Exploring solutions in the 6-sided Cave at Aalborg University

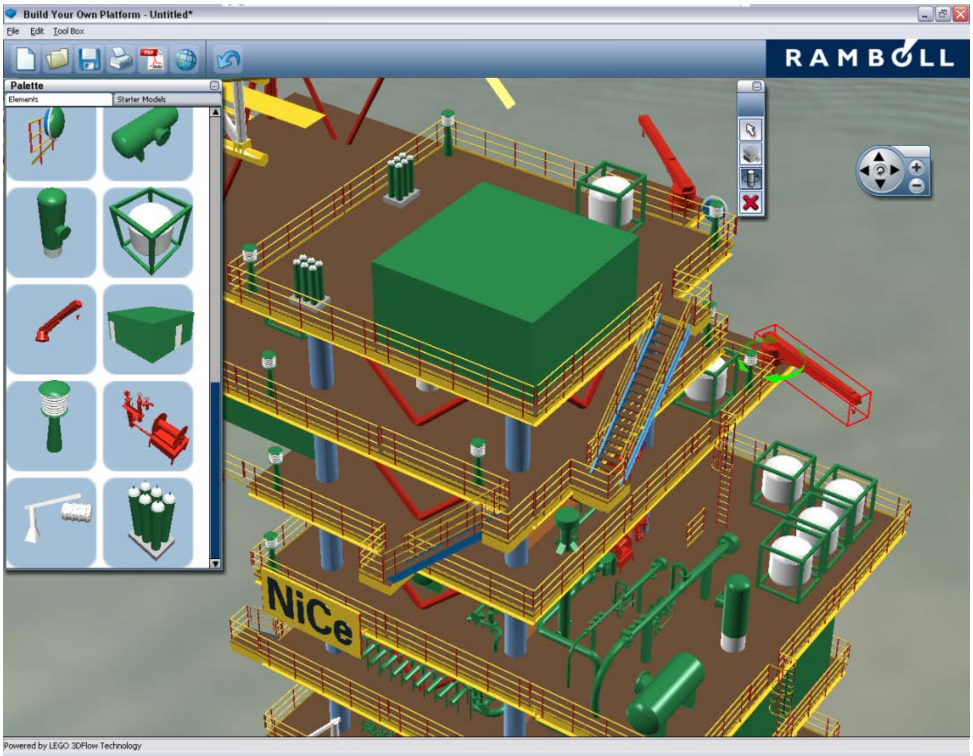

FIG. 8: Lego Digital Designer with Ramboll extension Build Your Own Platform

5.4 Cases for evaluation and development support

Three on-going construction projects were used as cases to support the development of VIC-MET. Experiences from the cases contributed with input to the development of the method and later, the projects served as a test bed for VIC-MET. The projects were the new Ramboll Head Office (RHO) and the new Arkitema office (Mikado House), both situated in Copenhagen, Denmark, and the third project was a centre for brain injured persons situated in Frederikshavn, Denmark. The three cases are described below. See also (Christiansson et al., 2010).

5.4.1 Ramboll Head Office

Three tests were carried through in the RHO case.

1) Colour selection
2) Placement of reception desk
3) Interiors of meeting spaces

End-users from the interior and identity groups were involved in the process. The user participation was mainly of the type User Involvement rather than Co-creation. The users took stands on principles of colour distribution and range in the building, as well as general views on the artist’s colour composition. See Fig. 9.

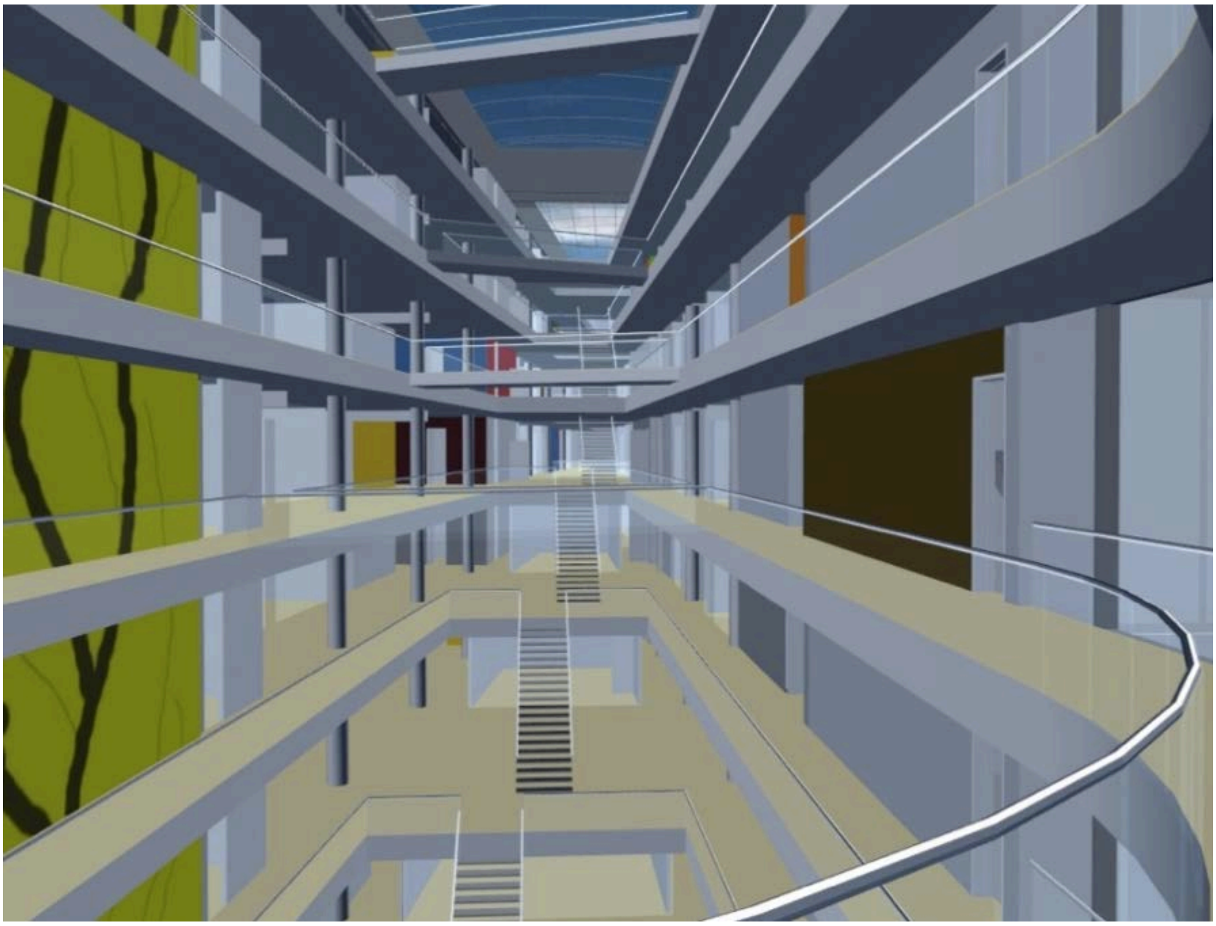

FIG. 9: Colouring the new Ramboll Head Office

The following conclusions were drawn from the colour selection case. The interior colour selection process requires models on appropriate detailing level. In this case, the artist found the original digital model too detailed to work with. It is also very important to do a proper calibration of the displays used in the colouring and evaluation process and to keep in mind that lighting conditions in the model greatly influences the impressions.

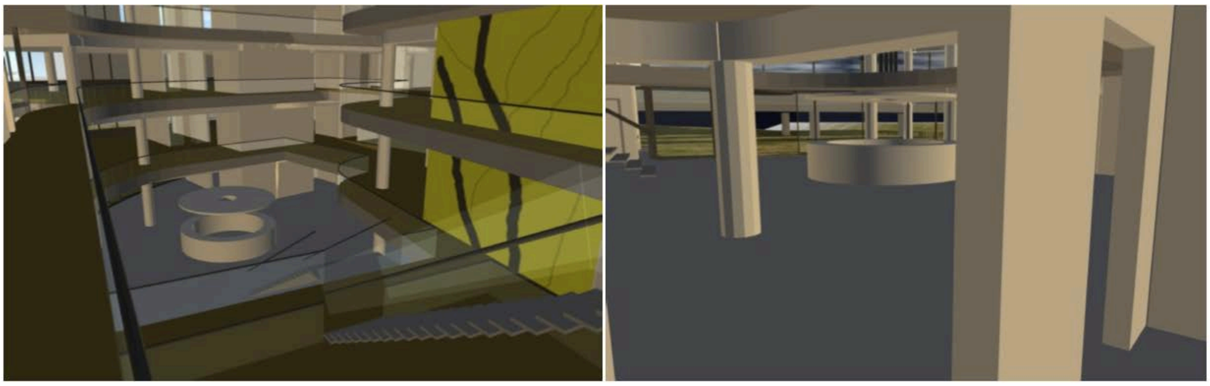

FIG. 10: Entrance alternative 1 in the new Ramboll Head Office.

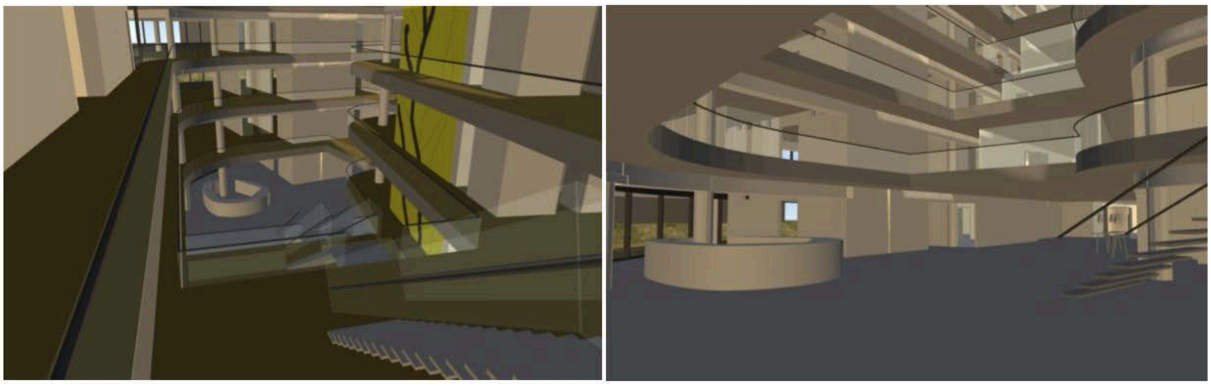

FIG. 11: Entrance alternative 2 in the new Ramboll Head Office.

In the 3D model, the users could experience the size of the coloured areas, distance colour visibility, and colour compositions. The first evaluation on high level took place in the Solution (SOL) space and the feed-back was introduced by the artist in the subsequent return to the Conceptual Modelling and Game (COG) space. Here the end-users agreed on for example nice vs. ugly colouring, correlation with the personality of the building, and the amount of complement colours and contrasts. The user needs and views were included in a not very formal way to the Functional Building Systems and via colour attributes of components in the Component Building Systems, which were later realized in new solutions in the SOL space. See also Figure 9.

Another test in the Ramboll Head Office case was reception placement in the entrance hall. See also Fig. 10 and Fig. 11. The activities in the Contextual Inquiry (CONTEQ) space, invoked mainly the executive level in Ramboll. These end-users expressed a lot of needs and requirements with, at first glance, contradictory functional and visual challenges. Four initial proposals were presented to the end-users in the solution (SOL) space, to support the following discussions in the Conceptual Modelling and Gaming (COG) space. It was, for example, discovered that there were different requirements on the reception placement depending on if it was seen from the entrance or from the inside of the entrance hall. The experience was that such evaluations worked very intuitively for the users compared with traditional drawings.

FIG. 12: A special Virtual Reality solution based on Nintendo Wii Remote equipment was developed at Ramboll.

The function of the reception related to present and expected future functionality was further discussed in the Functional Building Systems Consolidation (FCON) space. Revised solutions were evaluated and discussed in the SOL space.

A special Virtual Reality solution based on Nintendo Wii Remote equipment was developed at Ramboll providing the users with a simple and cost efficient way to navigate in the virtual building solutions in the SOL space. See Fig. 12.

A particular user group was established early to take care of end-user needs in connection with interiors and facilities in meeting spaces and common locations. In this case, VIC-MET was used late in the process involving choice of specific furniture and its placement. Solutions were presented in both virtual and real settings in the existing office. The main activities took place in the FCON and SOL spaces. Special regards to possibilities for housing both social and more private meetings were studied in the café space. See Fig. 13.

FIG. 13: The combined café and meeting space at the new Ramboll Head Office

The café space was also used as a case in initial studies of the virtual world “Second Life” (http://secondlife.com/), see Fig. 14. Second Life is a virtual 3D community where users can navigate from their own computer. They are represented by an avatar, and they can communicate by chat, message boards or voice through their headset. Parts of the Ramboll Head Office including the entrance and the café space were built in the Second Life environment with the purpose to let users navigate on their own in the planned facilities. However, the project team soon realized that there were limited possibilities to transfer building models from the construction industry’s traditional design tools to the 3D representation of Second Life. This proved to be a significant barrier for an efficient use of the tool, and it was decided not to use it for further studies of the user involvement.

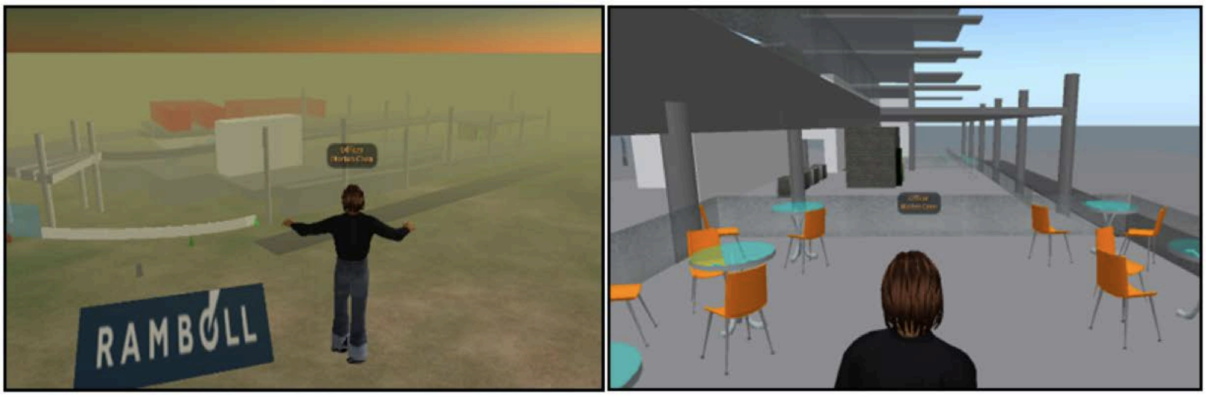

FIG. 14: Initial studies of the possibilities to use Second Life for user involvement in the design of entrance and café space of the Ramboll Head Office.

5.4.2 Arkitema headquarter

The Arkitema office project started in 2005. The kick-off procedure and early workshops from this work gave fruitful input to the VIC-MET development. An intentional focus in the office design was to keep the design activities on a high abstraction level with focus on common values, needs and functional building performance. The integration of the company's vision and strategy in the design process should have a positive influence on employees and managers’ behaviour. They wanted to strengthen the professional identity and create a platform where to work more process and value oriented.

Initially, a four-day workshop for all Arkitema’s employees and partners was held as a kick-off for the project, where knowledge should be shared, as well as joint ownership and the first ideas were generated. After this, several shorter workshops were held for smaller groups of stakeholders. To conclude this course of workshops, an architect and an anthropologist developed a card game. The cards depicted various facilities that throughout the game were prioritized by the participants. This activity provided an overview of how differently employees looked at their ways of working.

After these thorough initial processes, a number of solutions were proposed. The ability to test VICMET on the Arkitema case was then investigated. The proposed solution was made available through 3D tools in the "Panorama" and "Cave" at Aalborg University. In preparation for this test, Arkitema designed a workshop in Aalborg with the participation of the design team and user group.

FIG. 15: Video documentation of design, evaluation activities in the SOL space at the Panorama VR Media Lab at Aalborg University.

The idea was that the contents of the workshop should be:

- Introduction to 3D tools and the ability of users to navigate in them.
- Virtual examination of the building in the "Panorama".
- Definition of the project area.
- Presentation of 2-3 design suggestions in the "Panorama", respectively placement of furniture, respectively, the choice of surfaces including colours.
- Individual (two and two) walks in the "Cave".
- Conclusion and redesigning.
- Presentation of the redesigned layout proposals in the "Panorama".

It was also investigated how participants could comment digitally and change colours, materials and placement of furniture, and how much this could be done simultaneously in a workshop process. Furthermore, it was discussed what level of abstraction that would best support the focus on relevant issues.

It was concluded that:

- It is possible to move and change the layout simultaneously and save the proposal.
- You can to some extent annotate directly in the model, but that part of the software can be developed.
- The abstraction level must be carefully assessed from time to time depending on users' skills and what you want them to decide.
- The users in the Arkitema case were used to assess both 2D and 3D, and therefore it is vital for them that the abstraction level is uniform for all the listed parts, so nothing unintentionally is given more attention than other.

Alternative solutions were partly changed and evaluated in the Panorama and Cave at the VR Media Lab at Aalborg University. The conclusion was that it was feasible to make real time changes, annotations, and to store different solutions. It was also concluded that is very important to work on a uniform abstraction level, dependent on design context and user skills. See Fig. 15 and Fig. 16.

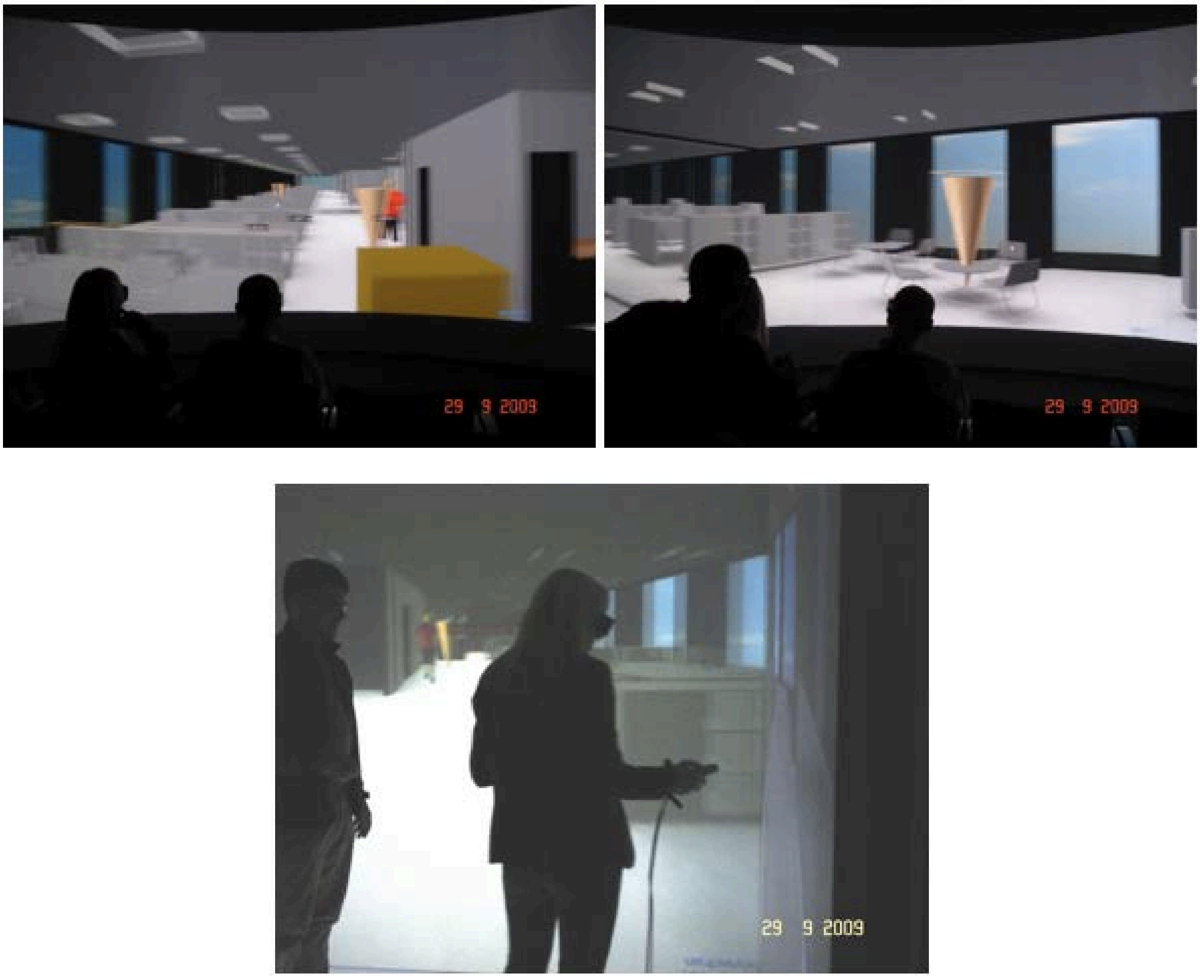

FIG. 16: Use of symbols in the virtual building office space to evaluate placements of privileged meeting places in the Panorama respectively Cave at the Aalborg University.

5.4.3 Brain Injury Centre

Finally, VIC-MET was assessed in connection with design of a Late Brain Injury Centre including patient housing, training facilities and Living Lab facilities for Aalborg University. See Fig. 17. In this case, the architect for a first alternative presentation compiled the end-users needs and wishes. The architect leads the walk-through for a broad (15 persons) end-user representation of clients, patient relatives, AE design team, nurses, and university Living Lab researchers. Feed-back from evaluations in the SOL space were used as input to the architect for further iteration and alternatives evaluations.

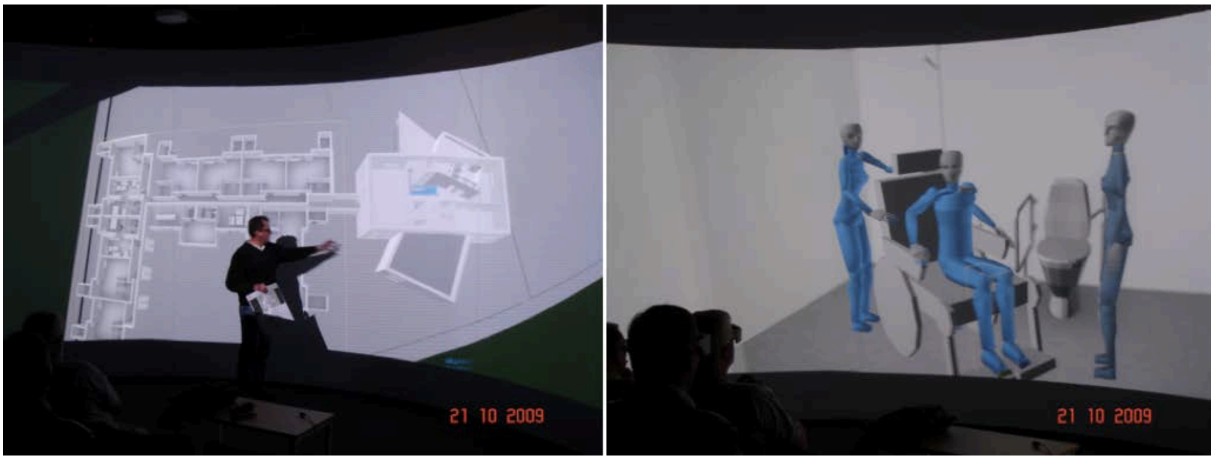

FIG. 17: User Involvement in the design of The Late Brain Injury Centre Frederikshavn Denmark.

6. THE FUTURE

We are in the middle of a great change process concerning the development of Integrated Building Design Environments. Design activities performed as a close collaboration between a number of specialist design competences are increasingly carried through in a global context in more or less virtual spaces using rich multimedia interfaces, and digital virtual building models 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 (Christiansson et al, 2009b). VIC-MET is an example of such a tool or method that is developed in close collaboration between practicing engineers and university.

We can expect more tools to be developed that will support performance-based design with broad competences collaboration in the early phases of building projects. These changes will influence project organization, information ownership, trust among project participants, work content and roles in projects (like model manager), and building up of new competence profiles.

Ontologies and dictionaries have to be developed further 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 further advanced. We should see more public ontology containers used by an international community as a vehicle for global public ontology development.

We will see companies with new business ideas as for example client advisors that can provide information and knowledge in very early project phases. Development of semantic web applications and containers has potential of further supporting effective, efficient and user-friendly search and management of knowledge on the WWW. We can, for example, more easily put up public idea banks where we can share experiences for free.

Advances in ICT and nanotechnology will be a seedbed for building components with new and/or improved properties. There will be greater demand on component system interoperability and connectivity on all levels from nano units to industrially produced large building parts. We will see a closer linkage between the physical building and its components with its corresponding digital virtual models (Sørensen, 2009).

There will also be a great need for increased efforts within building informatics education to secure needed competences for leading and carrying through the future research, development, innovation activities and company internal competence development.

7. CONCLUSIONS

VIC-MET defines four different design spaces in the user driven innovative/creative design process where it is possible to enter in optional space. In space (1) 'Contextual Inquiry' the end-users are given tools and motivation to deliver their wishes, needs and views on good and bad solutions. The individual views of end-users have to be expressed and consolidated into more general needs, common values established and conceptual building designs established. This is done in (2) 'Conceptual modelling space'. Here, the VIC-MET proposes different tools and processes to build up a common understanding of central end-user needs and values for the building under design. In the (3) 'Functional consolidation space', needs are linked to functional building systems (FBS), which are realized as component building systems (CBS), which will form parts in the total building solution. The formulated needs provide input to specific requirements to assure expected performance of components. It was clear early on in the project that it was important to be able to express needs in terms of functional building systems to be able to stay at a high abstraction level in the early design phases. There are, however, no agreed ways to describe FBSs neither on national or international level. It was also concluded that it was a too ambitious endeavour to formulate an ontology for FBS in the VIC project. A many to many relation exists between FBSs and CBSs, this relations can be expressed and documented in conceptual maps. The final virtual building model or part of it is evaluated by the end-users in (4) the 'Solution space'. Through access to 3D solutions, in the ultimate case in virtual reality environment, end-users get intuitive possibilities to investigate and evaluate solutions and even make real time adjustments and changes of solutions. The end-user input is captured and used in the design process that continue in spaces (3), (2) or (1).

Early in the project it was confirmed that a method to support end-user participation in innovative and creative building design was both needed and necessary. It should be possible to formalize some of the experiences made at the participating companies and develop a method that was flexible, and easy to use and learn. The design of a building can be seen as a system development process. New advanced ICT tools give opportunities to involve end-users and clients from early on in the design process. In this way, it can to a higher degree than before be ensured that user needs can be captured, also those not yet discovered by the users. VIC-MET can be used in all phases of design at all levels of building solution detailing from abstract to concrete solutions.

VIC-MET offers; a method that supports the end-user needs capture process, early involvement of motivated end-users in the innovative/creative design process, collection of experiences for later use in other projects, achievements of common values and needs prioritizations, possibilities for end-users to participate in the design process with varying degree of participation and to express their ideas and needs as well as to simply understand and evaluate solution proposals in 3D virtual building environments, support to choose appropriate ICT design tools, optimal design team configuration with regard to competences and roles, and establishment of an effective, efficient and user friendly ICT supported collaboration environment.

VIC-MET supports the important early conceptual design phases. The method supports performance based design with focus on end-user needs, expected functionality of the building and possibilities for qualitative and quantitative evaluation of solutions.

The project has confirmed the very beneficial effect of combining university and companies efforts in the project. Both long and short-term effects can be taken into account as well as practical experiences and theories can be mixed all phases of the VIC-MET development from initial ideas to evaluation of derived solutions in real settings. This is especially important in these times where we are finding new ways and tools to carry out design, to build and access building models, to establish new ways to collaborate and not the least to come up with innovative solutions to functionalities, services and layout of buildings.

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