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Christiansson, Per

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ICT Enhanced Buildings Potentials

Prof. Dr.Tech. Per Christiansson
Aalborg University
Denmark

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Abstract

The paper describes and gives example on how Information and Communication, ICT, can and will enhance and support the building functional systems defined from client and end-user needs and requirements. The building systems may be derived from functional requirements on buildings such as usability and security on highest level with sub-systems definitions on lever levels. Building functional sub-systems may be defined for user comfort, indoor-climate, evacuation, space configuration, aesthetics, O&M etc. These building systems are supported by Information and Communication Technology, ICT, and building component systems that are accessed and integrated in the real world of building use in different contexts. The ICT systems may be physically or virtually embedded in the building.

Already in 1982 AT&T established the 'intelligent buildings', IB, concept due to marketing reasons and the Informart building was established in Dallas as a showplace for IB installations. The interest in IB has fluctuated since then.

There may be a fruitful interaction between user needs pull and ICT break-through push for creative and innovative development of ICT enhanced buildings. The paper explains the Intelligent Building concept with focus on virtual building models support, new services and user environment definitions and development, virtual spaces and augmented reality, intelligent building components, application ontologies, and ICT systems integration to illustrate ICT enhanced buildings potentials and R&D needs.

Introduction

The concept of intelligent buildings, IB, was due to marketing reasons established 1982 by AT&T to demonstrate how advanced IT from different suppliers could be used in the Intelligent Building (IB). Through the latest more than 20 years there has often been a mismatch between what users expect 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. The paper explains the Intelligent Building concept, future avenues of R&D and influences on the building construction industry.

History of Intelligent Building

In 1982 AT&T establishes the concept "INTELLIGENT BUILDINGS" due to marketing reasons. The INFORMART building is erected in Dallas containing latest IB systems on display. In 1984-85 The Smart House Development USA (National Association of Home Builders, NAHB) starts and we talk about 'Automated Buildings', 'High Tech. Buildings', and 'Smart Houses'. STS, Shared Tenants Services, companies are started with minor success. There are today many Smart House systems available for the family villa. (Christiansson, 2000).

In 1986 we arranged a national Intelligent Office workshop at Lund University Sweden, where some still valid conclusions were drawn - man/machine environment important, lack of knowledge, information vulnerability, flexibility requirements not fulfilled, too little holistic problem views, new building construction coordination and procurement forms needed, and lack of standards. N.Y. Times writes 1987 "I.B. is a dumb idea".

Services announced around year 2000 by IB-system companies were typically - fire alarm, energy control, heating control, telephony/computer net, ventilation control, climate, surveillance, lightning, power, security, passage control, and automatic door functions. Intelligent Building services may be directed towards 3 groups of people 1) residents/end users including end user external service providers, 2) operation & maintenance personnel, and 3) building/facility administration personnel. See also figure 1.

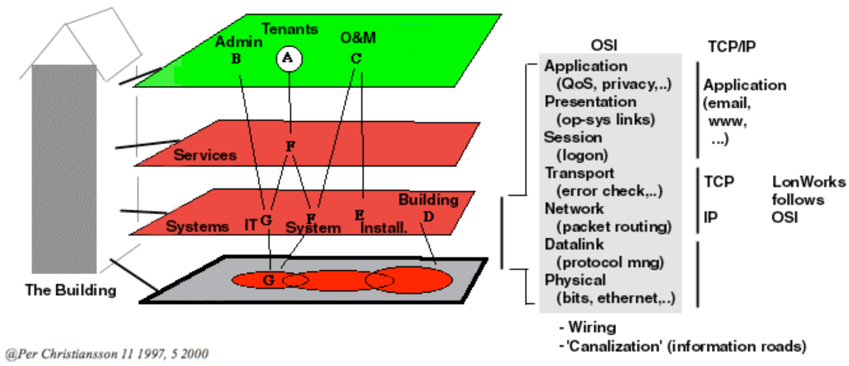

Figure 2 The IB integrates Internet, intranets, IB systems, and the physical building. Canalization may be canals, wireless carrier frequencies, existing wires, overhead lines or other reserved space. from (Christiansson, 2000)

(Weiser, 1996)" 'Smart House': Does this mean any more than a house with a computer in it? Does it mean anything like "Better House"? Do we really think that everything in the world would be better if it were smarter? Smart Cappuccino? Smart Park? The "Smart House" of 1935 had an electric light in every room. The "Smart House" of 1955 dared to put a TV and a telephone in every room. And the "Smart House" of 2005 will have computers in every room. But what will they do?"

Around 10 years ago there started to be more focus on broader social and life-quality end-user aspects on services in the Intelligent Building/Smart House domain, for example elderly/handicap living support, home health care, and home distant working.

The Gator Tech Smart House project (Helal et.al., 2005) looks at context descriptions and how for example a space can adjust to a certain context by using a set of sensors, actuators , and objects/devices engaged in different services.
"..the University of Florida's Mobile and Pervasive Computing Laboratory is developing *programmable pervasive spaces* in which a smart space exists as both a runtime environment and a software library. Service discovery and gateway protocols automatically integrate system components using generic middleware.."
"The project's goal is to create assistive environments such as homes that can sense themselves and their residents and enact mappings between the physical world and remote monitoring and intervention services."
"We have implemented most of the reference architecture, though much work remains to be done at the knowledge layer." " Ultimately, our goal is to create a "smart house in a box": off-the-shelf assistive technology for the home that the average user can buy, install, and monitor without the aid of engineers". (Helal et.al., 2005)

A number of protocols and network solutions to integrate more or less intelligent sensor/actuator control units have been developed. 1990 LonWorks technology work starts (LON), Local Operating Network for IB systems, developed by Ecehelon Inc. http://www.echelon.com/, EIB, European Installation Bus, and later KNX (ISO/IEC 14543) http://www.konnex.org/, BACnet, a Data Communication Protocol for Building Automation and Control Networks, developed under the auspices of the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE), http://www.bacnet.org/. OSGi, Open Service Gateway Initiative, http://www.osgi.org/, is an industry plan for a standard way to connect devices such as home appliances and security systems to the Internet, a kind of Universal Middleware. Wireless sensors and control networks are delivered today based on for example ZigBee (Kinney, 2003) and Z-Wave (Jorgensen & Johansen, 2005). The proposed Near-Field Communication standard (Want, 2006) is now implemented in some mobile phones enabling communication with a RFID (Radio-frequency identification) tags within maximum 20 cm distance (important security aspect).

Driving forces and trends

The technology driving force has been significant in development of the Intelligent and Responsive Buildings and Intelligent Cities. The main technological factors have been Moore's law predicting doubling of Information and Communication Technology, ICT, performance/price in 18 months, spread and standardisation of Internet, increased bandwidth within Internet, communication standards development, new sensors with standardised connection properties and inbuilt intelligence (now also applied to RFID), embedded intelligence, flat panel screens, and wireless communication standards. We can slowly, enforced by the progress of cheap RFID technology, imaging an Internet of things (ITU, 2005).

New network services and service-oriented architectures have been developed e.g. SOAP web services - Simple Object Access Protocol, UDDI - Universal Description Discovery and Integration, WSDL - Web Services Description Language, WSRF - Web Service Resource Framework), OGSA - Open Grid Services Architecture. See also the above-mentioned specific IB networks. A future improved interoperability between technical support systems can be expected.

We will see an increasing focus on ontology development as a necessary pre-requisite for services and ICT systems inter-operability. The Semantic Web has set new focus on ontology development. Ontologies can be machine readable represented in e.g. RDFS (Resource Description Framework Schemas) (http://www.w3.org/RDF/), OWL (Web Ontology Language) (http://www.w3.org/2004/OWL/), and OWL-S an OWL-based Web service ontology http://www.w3.org/Submission/OWL-S/.

Ontologies in general today mainly support the technical service layers and to a lesser extent the business application layers. There are though efforts to fill in this gap. See for example the Inteligrid project (Interoperability of Virtual Organizations on a Complex Semantic Grid, http://www.inteligrid.com), Amigo (Ambient intelligence for the networked home environment http://www.hitech-projects.com/euprojects/amigo/), and Service Oriented Business Architecture (SOBA) and Service Oriented Technology Architecture (SOTA), (Doucet, 2006)

Virtual building (VB) models access is getting more standardised through use of the IFC standard, http://www.iai-international.org/, and will thereby be easier to integrate as a resource in IB service systems. VBs can be used to augment the real world and to simulate different processes and actions. Figure 2 illustrates how the new Danish public client requirements norm enhances possibilities to obtain a VB that can be used as a resource in the IB services systems. See also (Christiansson & Carlsen, 2005).

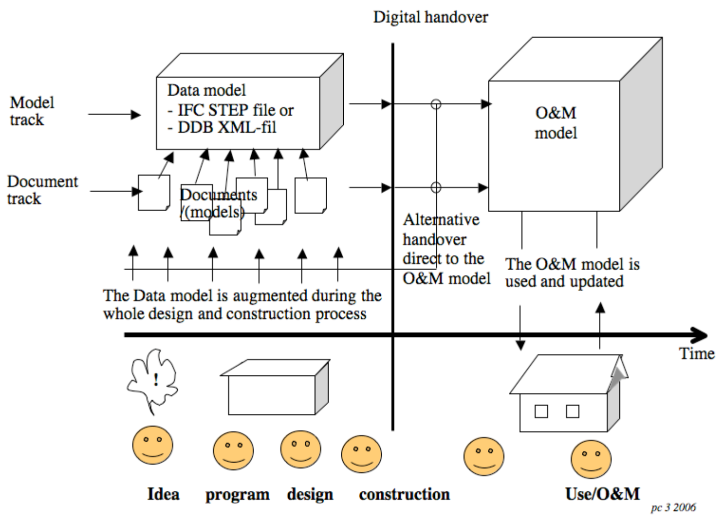

Figure 2 The newly released, January 2007, Danish digital construction requirements lets public clients put requirements on the content of the digital models of the building handed over to the client after finalised construction. (DDB, 2006)

We have in late years outside the research community seen a dramatic growth of interest in virtual worlds. This is caused by more powerful graphic processing power in personal computers, and widespread availability of high bandwidth on the Internet. We can more easily augment our physical world with for example overlaid models of invisible building parts, create virtual spaces as a combination of different scattered physical surroundings, simulate and try out design ideas in virtual building models for example alternative building layouts as well as new end user services not yet implemented and interaction/dependencies between different services.

We experience a growing focus on design of end-user environments with early involvement of end-users and formal methods to capture end-user needs and requirements on systems, as well as continuous evaluations. This processes can and shall be integrated with the more traditional technical system development. These activities may also involve user driven innovation.

Intelligent Building definition

In 2000 the author 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."

(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 *document* (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* (i.e not based on a non-routed Ethernet in a residential block)
- be open to efficient communication between *applications* based on for example XML implementations (Christiansson 1998), and platform independent solutions as Jini on Java Virtual Machines, (see http://www.sun.com/jini)"

Physical and virtual cities, buildings and spaces

The building systems view

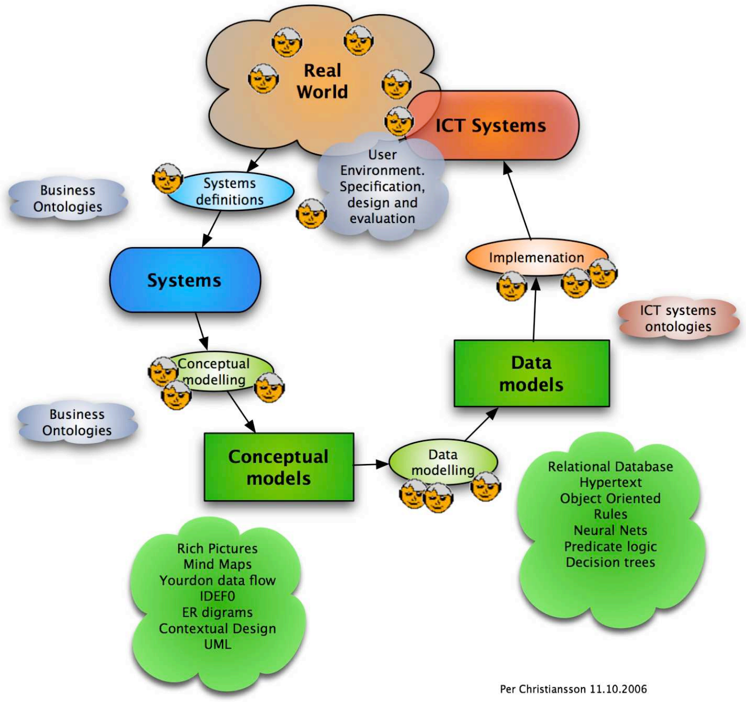

Figure 3 Real world systems supported by ICT systems

In the real world, see figure 3, we identify activities, things, processes, context, and persons. The real world can be described as (interrelated) systems (no de-facto structure is available today) to accomplish different functions e.g. a comfort system to provide personal living and working quality, personal transport system, load carrying building system, escape system, and communication systems (collaboration, knowledge transfer, mediation, virtual meeting). The 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 and physical component systems performance is (continuously) evaluated and usability tested.

Needs and requirements formulation from 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.

The traditional physical building components are on all levels, from canalisation to walls separating virtual spaces, integral parts of the IB 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 figure 4, can be used as interactive documentation of the ready building to support different services such as O&M activities, location of resources and persons in the building, and for 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'.

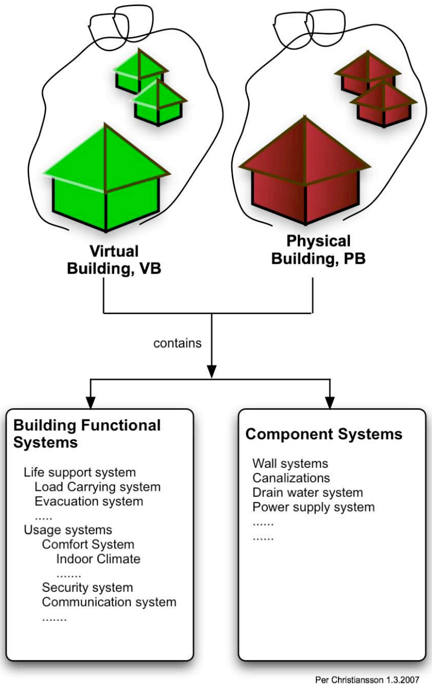

Figure 4 The Virtual Building (VB) model should be a digital copy of the real building, the physical building (PB), even before it is built.

Virtual Spaces

We can decide on how close we want the connection between the physical and virtual world to be. The virtual world is represented in models that we can use for different purposes like simulating activities, remote collaboration, hand over tasks to agents, link up physical objects (off all kinds from door to clothing to personal artefatcts/tools/objetcs), store historical data on activities and building systems performance etc. There are great room for innovations here. 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.

A Virtual Space (VS) may be defined 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 do not have to be stationary but can e.g. follow a person defined as the immediate surrounding of that person. In this latter case wireless connection to the space is a necessity and maybe a complication in interaction with stationary spaces.

A virtual space may provide service to support many kinds of activities. We may define virtual workspaces supporting collaboration, see (Christiansson, 2001) and (Lai, 2006) for semantic web supported collaboration, home health care space with access to distant doctors, different communities of interest or practice, virtual city space for service discovery and access etc. The impact on social behaviour, economics, and personal values due to virtual spaces introduction should continuously be monitored and taken into account.

There may be a close dependence between VSs and physical spaces that may put constraints on the design of VSs. 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.

Services ontologies

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. (http://www.doi.org/). Ontologies can be machine-readable represented in e.g. RDFS (Resource Description Framework Schemas) or OWL (Web Ontology Language).

Service ontologies should support service consumers and service providers on different service levels.

Ontologies provide end-user service and ICT support system developers a common base for efficient and effective services definitions as well as integration and utilization of ICT systems and resources.

What will trigger a service and how can it be discovered? Trigging may be done by context automatically measured somehow, special sensor trigging a service or a manual start. It may probably in many cases be favourable for end users to manually compose and set up a temporary service that also may be stored in e.g. a personal space specific memory (compare to personalized RSS feed news service). Mechanisms for end-user service discovery must be carefully designed and evaluated by the end users.

A service request may generate alternative support system actions depending on context and/or other parallel services requests. Worse case is that a critical service will invoke temporary close down of other services. E.g. establishment of escape ways in conflict with fire spread prevention, conflict between heating and lighting leading to different actuators activation pattern or care provider service in conflict with O&M service.

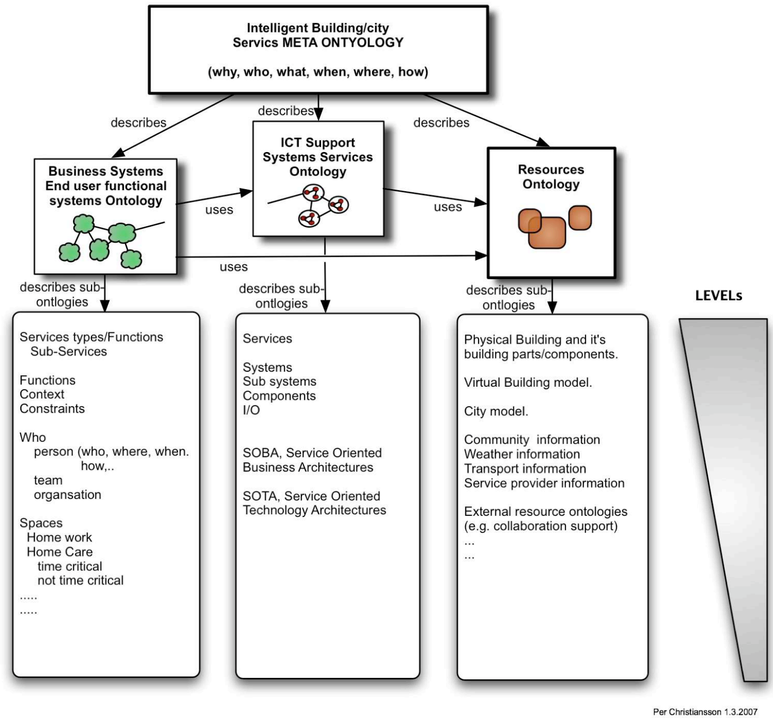

Figure 5 Possible outline of main ontologies to support IB services development, implementation, and use. Many IBs can interact during services supply.

Capture of end user needs and requirements

There is a great need today to secure development with below specified areas to secure smart buildings to meet future needs from end users and technology providers

- Systematic description of existing and future *application/business services needs* in terms of application domain, functionality, involved actors, organisation, and use contexts.
- Systematic description of existing and future available smart *building/smart city services* in terms of application domain, functionality, and use context.
- Systematic description of existing and future available *resources* that can support provided services.

This is a complex design endeavour that well could be supported by a platform as suggested below, bSB - building Smart Buildings platform.

The 'building Smart Buildings', bSB, platform can act as a vehicle for continuously generating and capturing creative ideas, needs and inventions on new products and services, and new business models within the IB/Intelligent City domain. bSB will also support subsequent product design, development, evaluation as well as high-tech products and business promotion (demonstration, test installations, training, feed-back capture). The platform can also provide a living environment and laboratory for end users, companies in particular SME´s, and university research groups with possible inclusion of real smart buildings and parts of smart cities. End-user, company and researcher should participate and innovate in all stages of the new product and business development.

bSB should embrace methods and tools to secure high motivation for platform participants. This is achieved through establishment of communities of interest and communities of practice where goals and rewards are formulated and revised both in a social and a business context.

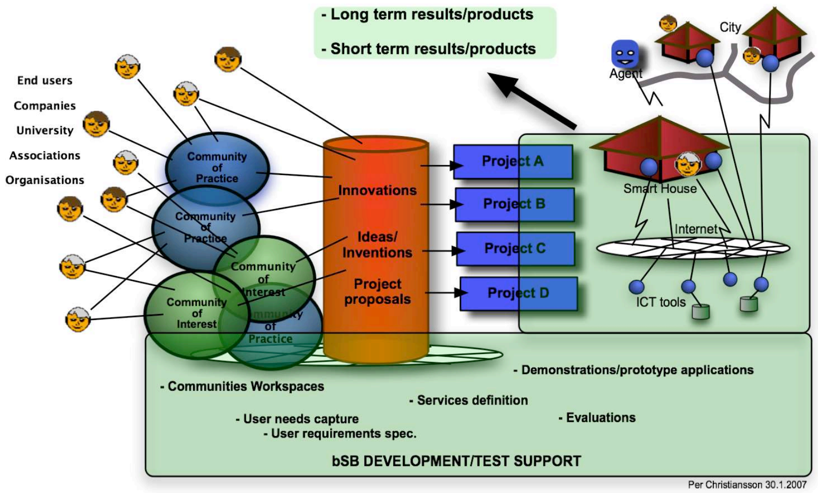

Figure 6 A bSB, building Smart Buildings, platform will actively contribute to the building of smart buildings by providing mechanisms for idea generation and product/services development beyond inventions in isolation.

A similar approach is reported in (Match 2007) "The overall aim is to develop a research base for advanced technologies in support of social and health care at home. This includes care at home of those with long-term illness, physical or mental impairment." with focus on four technology areas "home network services, lifestyle monitoring, speech communication and multimodal interfaces" (Helal et.al., 2005). See also (Wang, 2006).

Future directions

We can conclude to ascertain that we are facing some major challenges and possibilities to create user friendly and improved services in the IB/Intelligent City domain. We shall bear in mind that it is a slow process involving de-facto standards development very often driven by bottom-up processes. It is important to try to establish a sustainable top-level framework and meta-classification to ensure efficient services use of underlying resources, service definitions, and service interoperability.

Business level ontologies and Service Oriented Business Architecture must be subjected to increased development efforts. This will also require building sector persons to gain higher insight in areas presented in the paper. It is extremely important that the new civil engineers posses these competences.

End-users must be involved in service needs capture, service design, and evaluation. Platforms as described and 'Living Labs' can support development of efficient tools for design, simulation, and evaluation of services in realistic digitally supported settings. The impact on social behaviour, economics, and personal values should continuously be monitored and taken into account.

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We will soon broader realise the need for better descriptions and structuring of Building Functional Systems. These will in general support requirements set-up and modelling in connection with building design and end-user service ontologies specification as well as model-based control of technical building services. ICT and building system component providers will also use these requirements. Again we can expect slow development, which though could start in collecting relevant meta level information on global level. We will in this context with high certainty find deviations with tight dependences on living culture and social values.

We should also be very open for start-up of companies providing needs capture and try of new service as well as service provider companies.

An important effect of efficient IB energy systems is the possibilities to reduce energy consumption through more optimal energy use.

Questions concerning legal aspects on use of virtual worlds spaces should also be considered. A virtual world is vulnerable for information loss/theft/modification as well as illegal trespassing.

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