NEXT GENERATION KNOWLEDGE MANAGEMENT SYSTEMS FOR THE CONSTRUCTION INDUSTRY

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SUMMARY

We have for a few decades been changing paradigm with regard to information handling. The traditional paper based information storage and presentation medium is substituted and complemented with digital storage accessible for reading and updating at optional time and place. Digital models of our reality and also non-physical objects are accessed from adapted and advanced user environments (UE). The paper explains potentials of new advanced ICT and discusses how these tools will support and influence the building process models and its organisation. Recommendations are given on how we can handle and meaningfully contribute to the ongoing change process. Important advances in ICT tools development such as semantic web and temporal databases are explained and related to increased quality and change of the building process. It is stated that ICT must not be regarded as one of these tools that we only have to learn to use but as an integral part of the company and project knowledge management system. The formulation and refinement of digital models of the building process must be driven by the end users preferably in collaboration between industry and university.

INTRODUCTION

It has been said before, but can well be repeated. We have for a few decades been changing paradigm with regard to information handling. The traditional paper based information storage and presentation medium is substituted and complemented with digital storage accessible for reading and updating at optional time and place. Digital models of our reality and also non-physical objects are accessed from adapted and advanced user environments (UE).

HTML (hypertext markup language) based documents has been stored on the World Wide Web since the early 1990s. Now the web documents may be separated into a content and presentation part through use of the XML (Extended Markup Language) and XSL (Extended Style Sheet) languages. Increasing number of resources on the Internet, labelled by their Uniform Resource Identifier (URI), can be described and reached through a common syntax and structure such as RDF, Resource Description Framework. The web content is given meaning through introduction of standardised name spaces and schemas such as XML Schema (specifying structure and data types) and RDF Schema that give meaning to the web based information containers. Efficient tools for improvement and development of new services are now tried out in the research communities. These services are based on ontologies that will provide a shared understanding of knowledge domains that can thus be communicated across persons and applications in what is called the semantic web (Berners-Lee et.al., 2001). In addition to the development of the semantic web our possibility to formally handle temporal data in building process models will increase through integration of temporal databases.

The paper explains the potential of new advanced ICT and discusses how these tools will support and influence the building process models and its organisation. Recommendations are given on how we can handle and meaningfully contribute to the ongoing change process caused by ICT (Information and Communication Technology) tool development.

EXISTING AND EMERGING ICT TOOLS

Basic XML

We can easily export XML (Extensible Markup Language), formatted data from a database. In the

example found at
http://it.civil.auc.dk/it/education/sem7_2002_vb_it_mngmnt/knowledge_representations_7_8/
(from a modelling course given by our group) we convert the web accessed database SQL response (Structured Query Language) to an XML file and reference one of several XSL (stylesheet) files to present the result on a web browser in a format adapted to the user. The following sequence describes the main elements in the application example:

- A relational database describing a building is produced (entities are among others 'building_id', 'floor_number', and 'space_id').
- The database is accessed from a web browser through call of server side ASP (Active Server Page). The imbedded scripts make SQL calls to the database and convert the database output to XML format.
- The XML file is now either sent to the client (web browser) with a reference imbedded to an XSL file or, alternatively, the XML file is processed on the server using the XSL file and then sent to the client as an HTML file.

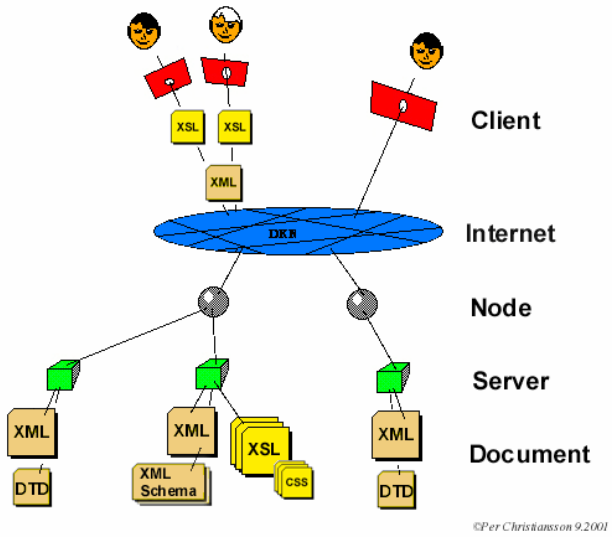

Figure 1 Differentiation between content and presentation using XML (Extensible Markup Language) and XSL (Extensible Stylesheet Language) files.

The XML files produced as extracts from databases or other applications can be used to transfer data between building applications (databases, CAD programs, simulation programs, etc.). In the EU project DIVERCITY mentioned later we have used the Simple Object Access Protocol (SOAP) to handle communication between applications in different computer systems running under different operating systems. SOAP uses the World Wide Web's Hypertext Transfer Protocol (HTTP) and XML as the mechanisms for information exchange.

Exstensible Style Sheet Language (XSL) is a language for creating a style sheet (the older Cascading Style Sheets, CSS, covers some of the XSL functionality) that describes how XML is to be presented to the user on the web browser. XSL has also been extended (XSL Transformations, XSLT) to cover transformations of XML document structures.

XSD (XML Schema Definition), is a Recommendation of the World Wide Web Consortium (W3C, http://www.w3.org/XML/Schema), that specifies how to formally describe the elements in an XML document. They provide a means for defining the structure, contents and semantics of XML documents (shared vocabularies). (The older document type definition, DTD, covers some of the XSD functionality). This description can be used to verify that the XML document is 'valid' by a receiving system. See also figure 1.

XML namespace is a collection of names, identified by a URI (Uniform Resource Identifier) which is used in XML documents for element types and attribute names. (An URL, Uniform Resource Locator, is the address to a web page and a subset to URI that can point to any information container). The goal of the Web Services Activity is to develop a set of technologies in order to bring Web services to

their full potential (http://www.w3.org/2002/ws/). We see now an increasing number of applications on the Internet taking advantage of XML and SOAP for secure standardised interoperability.

Temporal databases

From (Christiansson, 1999)
With temporal data introduced into the Virtual Building (VB) new opportunities arise:

- we can store snapshots of different building processes (e.g. alternative designs) and *backtrack* to make a re-design or re-simulation with changed requirements (regeneration of the VB);
- it should be easier to document and retrieve *causal connections* over *time* and *space* in the VB;
- storage of *lines of reasoning* and possibilities for analyses of their relations;
- improved possibilities for efficient updating of VB model with *as-built data;*
- effective use of the time parameters in the *life-time documentation* of building behaviour;

Temporal extension to traditional relational database systems, see also (Snodgras, 1999) and (Böhlen & Jensen S., 1997), enables us to handle queries like 'what resources have we used during different time periods of the conceptual design of the building?', 'who and what competencies were engaged during different time periods of the Virtual Building design?', and 'how many resources have we used over different time periods at different building locations?'. These types of questions are very difficult to handle in conventional databases, but will help us to capture experiences for better planning of resource allocation and to make complex time dependent queries. We will be forced to handle both so-*called valid times* (times related to phases in virtual building evolution from idea to demolition) and so-called *transaction times,* i.e. when the supporting systems were actually augmented and updated in real time. These aspects can be handled separately or in a mixed mode in so-called bitemporal tables in the database. (Christiansson et al., 2002b), and (Christiansson, 1999).

The Semantic Web

From above it is clear that we can now build and make interoperable web based information containers by use of XML based web services. Through the introduction of the RDF (Resource Description Framework), (Lassila & Swick, 1997) and (RDF, 2002), an emerging standard for handling metadata on the World Wide Web was introduced. RDF will provide a framework for metadata interoperability across different Internet based resource description communities with focus on semantics rather than meta data syntax and structure. 'For the semantic web to function, computers must have access to structured collections of information and sets of inference rules that they can use to conduct automated reasoning' (Berners-Lee & Hendler & Lassila, 2001). The semantic web will use XML, RDF, and Ontologies (with taxonomy and a set of inference rules) as basic building substances.

"RDF is a way to express relations between objects, something XML does not allow you to do", "RDF provides a general model for describing resources. Resources in RDF are any objects that can be uniquely identified by a Uniform Resource Idendifier (URI). The objects can have properties, which then have values (which may be another resource, i.e., they are atomic, which means they are text strings (literals), numbers, etc.)", (Hjelm, 2001). See also (Christiansson, 1998). The property types as well the names of the properties are defined in a vocabulary. The RDF Schema defines the meaning, characteristics, and relationships for a set of properties. "The RDF schema language is a declarative representation language influenced by knowledge representation, database schemas, and graph data models" (Hjelm, 2001). The semantic web is in its infancy though. The 'RDF Vocabulary Description Language 1.0: RDF Schema' was presented as a W3C Working Draft 12 November 2002, http://www.w3.org/TR/rdf-schema/.

The semantic web will allow us to introduce new *services*, see figure 2, to handle unstructured and structured data accessed from the Internet. Our research group are currently implementing semantic web technology in two projects with focus on experience capture, quality assurance, and web accessibility and support, respectively, for early design collaboration (Lai et al., 2002). There is no limit on the kinds of (new) services that may be introduced

- link documents to other documents handling similar subjects/concepts;
- search specified and similar concepts in interaction with end user;
- annotate existing web contained documents;
- capture concepts in documents and create meta content descriptions;

- translate a document to a another 'language';
- combine low level concepts in different containers for idea generation.

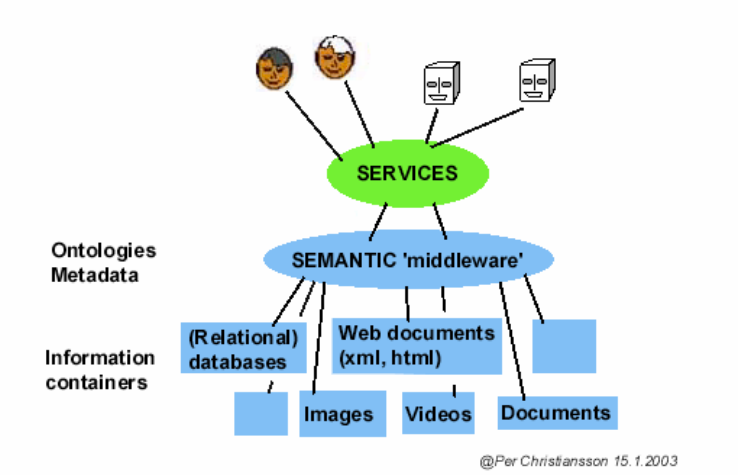

Figure 2 New services will be introduced in the Semantic Web.

Some of the existing tools we use are

- XMLSpy for XML editing and validation, Schema design (http://www.xmlspy.com/),
- SemTalk for graphic ontology modelling, http://www.xmlspy.com/,
- OntoEdit ontology engineering environment, http://www.ontoedit.com,
- Sesame an Open Source RDF Schema-based Repository and Querying facility, http://sesame.aidministrator.nl/,
- DCdot, Dublin Core metadata editor, http://www.ukoln.ac.uk/metadata/dcdot

VIRTUAL WORKSPACES

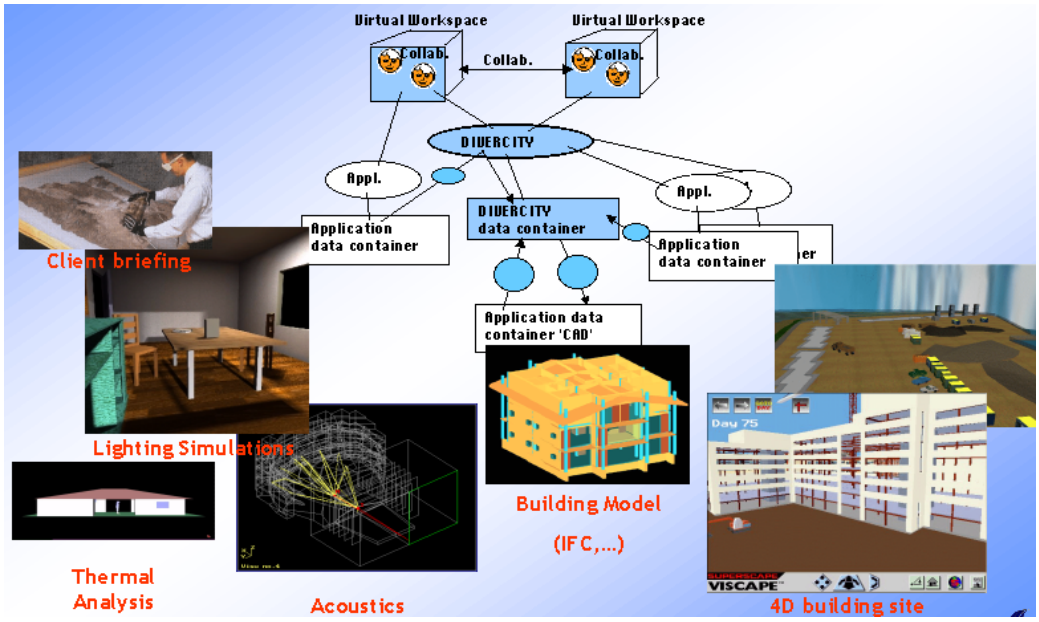

Figure 3 The DIVERCITY framework supporting client briefing, early design and construction in a virtual collaboration environment.

Figure 3 gives an overview of the DIVERCITY project (Distributed Virtual Workspace for enhancing Communication within the Construction Industry. EU IST-1999-13365, start April 2000 ending September 2002) where XML and SOAP were used in a framework to support communication between users, applications, and product models. Distributed and collaborative applications can be included through an open mechanism allowing any third party to use data controlled by the central

framework server. The distribution manager is the client (user) side of the communication layer of DIVERCITY. It can be included in an application or can be a stand-alone application, controlling data exchange between the client and the central server. The distribution manager has been released in JAVA and C++ and it is platform-independent. The project clearly demonstrated the importance of parallel innovative user environment design and user requirement capture, and technical implementation activities. More information and video clips from usage can be found at http://www.e-divercity.com/. See also (Christiansson et.al., 2002a), and (Christiansson et al., 2001).

ICT in the Building Process

Figure 4 puts the ICT tools described into a building process context. We envision greater emphasis in the near future on formalisation of building process components especially on the meta level. Formalised processes will more efficiently handle flexible user environments (UE) and project information containers accommodating partly redundant information.

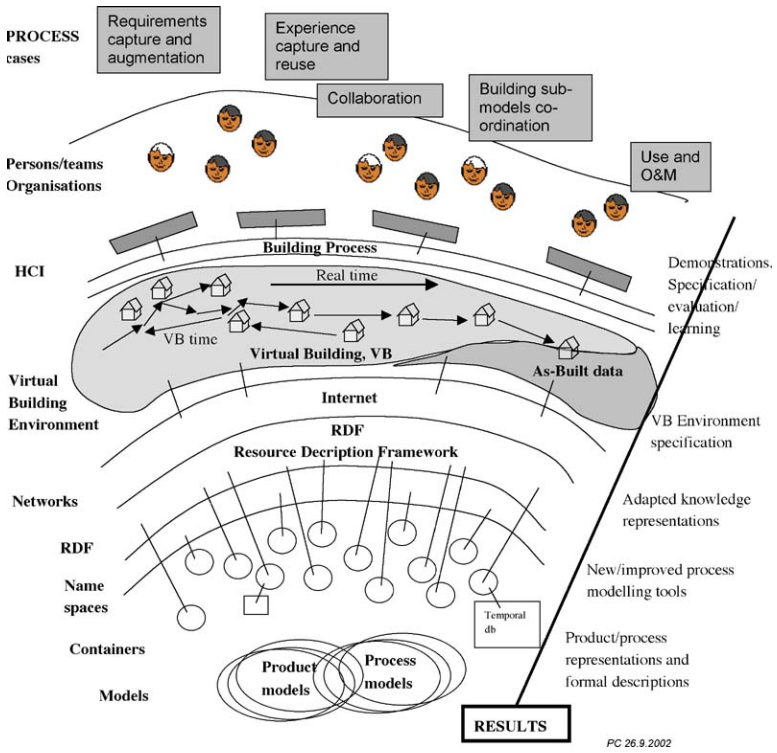

Figure 4 Overall map showing areas of interest in the PROMORE (Process Models and Representations for the Construction Industry) project proposed in Expression of Interest to EU FP6 (Christiansson & Karhu, 2002)

ORGANISATIONAL IMPACT

It is now a fact that the so-called global village is a reality. Projects are formed with participants from all over the world. Physical and digital resources are also flexibly purchased and handled on a global basis. This up-scaling of the traditional business arena together with implementation of efficient support for knowledge management and collaboration puts strains on existing organisational structures. We point at some of the expected changes, see also figure 5,

- Mix of physical and virtual workspaces (80/20 to 20/80, physical meetings will *remain* very important especially during non-routine activities).
- New procedures (new companies?) to provide knowledge management support (e.g. long-term project information storage end experience transfer, education services).
- Greater possibilities to back-up digital knowledge resources in the companies due to efficient capture and re-use of experiences and ideas.
- Efficient handling of unstructured and partly redundant information. (The building process will for

a foreseeable future contain semi-structured data together with information containers with highly formalised non-redundant data models).

- Meta data in models containing non-redundant data on high abstraction levels will glue together domain specific more specialised application models.
- Disconnection of building application semantics from underlying information containers will facilitate system interoperability and build-up of user specific search in and interrogation of underlying information containers.
- Higher flexibility in creating project teams composed of persons from different companies.
- Flexible collaboration patterns between and within teams.

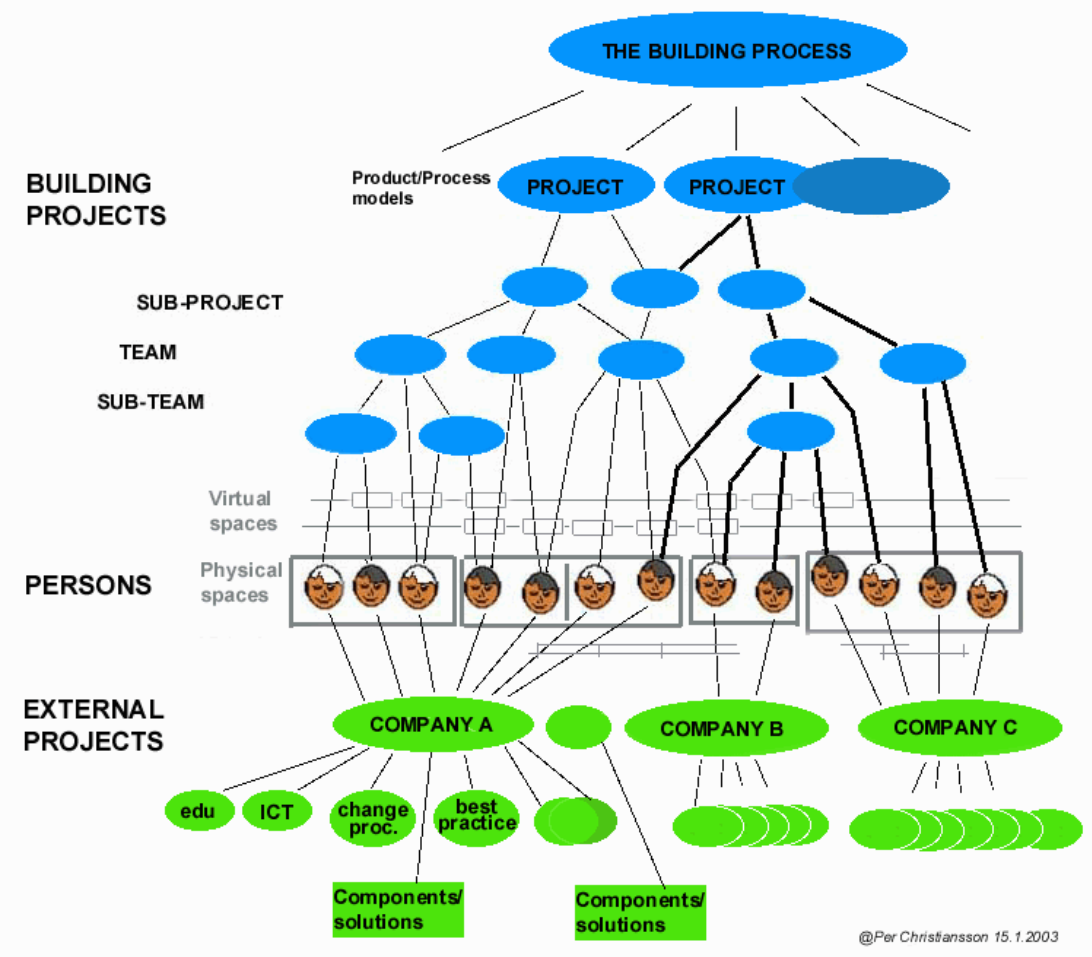

Figure 5 Organisational view on internal and external building project actors, activities and attached information containers.

We will get greater possibilities for transforming information to a suitable form for the human/artefact receiver. E.g. a person wants to use information from his/her personal information container to make it more comprehensible for a person using another 'language' or when a person or team shall convert information from 'team language' to project language' and vice versa. The likelihood to find and utilise adequate competencies in project collaboration should increase through access to company knowledge bases. Efficient collaboration tools in adaptive virtual workspaces and access to virtual building and analyses/synthesis tools provide a solid foundation for early design ICT support with all stakeholders involved including client (so-called partnering project organisation models are now also developed). Important decisions can be made in early design phases regarding alternative and optimum solutions also for complex designs. Design requirements, intent and rationale will be stored and form important ingredients in experience knowledge bases.

RECOMMENDATIONS FOR HANDLING CHANGE PROCESS

Based on 30 years' experience from use of ICT in construction and the later achievements in ICT development, the following recommendations will hopefully contribute to a more successful change of the building process yielding higher quality of end products and a more efficient building process, in all aspects. ICT must not be regarded as one of these tools that we only have to learn to use but as an integral part of the company and project knowledge management system.

The formulation and refinement of digital models of the building process must be driven by the end users. Models describing

- Building project processes and company specific processes.
- Building project products such as buildings (and all systems built into the building), virtual buildings (VB), and building components.
- Production systems.
- ICT tools.
- User/team ('languages', competencies, human computer interaction styles etc.).

Some crucial aspects in connection with development of next generation knowledge management systems for the construction industry are listed

- Participatory design (industry - university) of new tools and services that in many cases are not yet defined, see also (Christiansson et al. 2001).
- Development of scenarios (from idea to demolition of building) encompassing credible ICT tools.
- Deep understanding of ICT influence on organisation, work methods, user environments, and information handling.
- Agreements on vocabularies and concepts within and between stakeholders starting with meta project level and more detailed team and component supplier specifications.
- Introduction and use of tools for semi-automatic capture of vocabularies and concepts.
- Active propagation of captured and harmonised vocabularies to meta level project name spaces.
- Conscious formalisation and automation of design tasks to reduce risk of formalisation into non-flexible solutions.

We are *all* involved together in a continuous change process and *design of the future* (with constant re-assessments). There are great opportunities now to do some creative, bold, and holistic inceptions at both universities and industries and in collaboration.

REFERENCES

Berners-Lee T, Hendler J, Lassila O. (2001) *The Semantic Web. A new form of Web content that is meaningful to computers will unleash a revolution of new possibilities*. Scientific American, May 2001.

Böhlen M. H., Jensen C. S., (1997) *Seamless Integration of Time into SQL*. Department of Computer Science, Aalborg University. (54 pp).

Christiansson P., Karhu V. (2002) *Process Models and Representations for the Construction Industry*. Expression of interest to the EU FP6 program. Aalborg UIniversity Denamark and VTT Finland. (5 pp).

Christiansson P., Da Dalto Laurent, Skjaerbaek J. O., Soubra S., Marache M. (2002a) *Virtual Environments for the AEC sector - The Divercity experience*. ECPPM 2002 Proceedings European Conference of Product and Process Modelling. eWork and eBusiness in AEC. (Editors: Ziga Turk, Raimar Scherer). Swtes & Zeitlinger Publishers, Lisse The Netherlands. ISBN 90 5809 507 X. 9-11 September 2002, Portoroz, Slovenia. (pp. 49-55)
< http://it.civil.auc.dk/it/reports/ecppm_slovenia_9_2002.pdf>

Christiansson P., Dawood N. N., Svidt K. (2002b) *Virtual Buildings (VB) and Tools to Manage Construction Process Operations*. CIB W78 Conference on 'Distributing Knowledge In Building', Aarhus, Denmark. June 12-14, 2002. Proceedings Volume 1. (Editors: Kristian Agger, Per Christiansson, Rob Howard). CIB International Council for Research and Innovation in Building Construction. ISBN87-90078-34-9. (pp. 132-139)

<http://it.civil.auc.dk/it/reports/w78_denmark_6_2002.pdf>

Christiansson P, Svidt K, Skjærbæk J O, Aaholm R. (2001) *User requirements modelling in design of collaborative virtual reality design systems*. International Conference on Construction Information Technology. Mpumalanga, South Africa, 30 May - 1 June 2001. (pp. 40/1 - 40/12) <http://it.civil.auc.dk/it/reports/r_africa_2001.pdf>

Christiansson P. (1999) *Properties of the Virtual Building*. Proc. of the 8th International Conference on Durability of Building Materials and Components. Information Technology in Construction. (ed. M. A. Lacasse, D. J. Vanier). NRC Research Press, Ottawa, 1999., May 30 - June 3, 1999 Vancouver, Canada. ISBN: 0-660-17743-9. (pp. 2909-2919). <http://it.civil.auc.dk/it/reports/r_cib_vancouver_1999.pdf>

Christiansson P. (1998) *Using Knowledge Nodes for Knowledge Discovery and Data Mining*. Lecture Notes in Artificial Intelligence 1454, Artificial Intelligence in Structural Engineering. Information Technology for Design, Collaboration, Maintenance, and Monitoring. Ian Smith (Ed.). Springer-Verlag Berlin Heidelberg 1998. ISBN: 3-540-64806-2 (pp. 48-59). <http://www.it.civil.auc.dk/it/reports/ascona_98/ascona98.html>

Hjelm J. (2001) *Creating the Semantic Web with RDF*. John Wiley & Sons, Inc. (277 pp)

Lai Y-C, Christiansson P, Svidt K. (2002) *IT in Collaborative Building Design (IT-CODE).* Proceedings of the European Conference on Information and Communication Technology Advances and Innovation in the Knowledge Society. eSM@RT 2002 in collaboration with CISEMIC 2002. (Editors: Yacine Rezgui, Bingunath Ingirige, Ghassan Aouad). University of Salford, U.K November 2002. ISBN 0902896415. (pp. 323 - 331, Part A)
<http://it.civil.auc.dk/it/reports/ycl_itcode_esmart_11_2002.pdf>

Lassila O., Swick O. R. (1997). *Resource Description Framework (RDF) Model and Syntax*. Working Draft, World Wide Web Consortium.
<http://www.w3.org/TR/WD-rdf-syntax/>

RDF Vocabulary Description Language 1.0: RDF Schema
W3C Working Draft 30 April 2002
<http://www.w3.org/1999/02/22-rdf-syntax-ns#>

Snodgrass R. (1999) *Developing Time-Oriented Database Applications in SQL*. Morgan Kaufmann USA (504 pp.)