REQUIREMENTS ON 3D BUILDING INFORMATION MODELS AND ELECTRONIC COMMUNICATION – EXPERIENCES FROM AN ARCHITECTURAL COMPETITION

Kjeld Svidt, Per Christiansson
Aalborg University
Denmark

ABSTRACT

In 2007 the public clients in Denmark started implementing new requirements on information handling in their construction projects. In the full implementation they will demand that all construction data on public construction projects are digitally managed and interchanged. Tendering shall be effected electronically over the Internet. Design will be based on 3D building models, which are gradually specified to reach different levels of detail. The parties involved in a specific construction project must share and interchange data and documents about the construction project on a common document management system accessed through the Internet. When a construction project is finished, the parties will hand over relevant operation and maintenance data electronically to the client. Detailed requirements have been developed on behalf of the public clients within four main areas: 3D models, Digital Tendering, Project Webs and Digital Handover. Within each of these areas, initial requirements have been tested in specific construction projects. This paper describes experiences from the test of the suggested requirements on 3D models. The requirements were used in an architectural competition on modernizing a cluster of university buildings. Four selected architects were invited to the competition. The proposals from the architects should be prepared as a 3D model in IFC format supplemented with a number of 3D visualizations chosen by the individual architects.

KEYWORDS

3D building models, BIM, electronic communication, requirements, architectural competition.

1. INTRODUCTION

The Danish government has decided that construction data on public construction projects must be digitally managed and interchanged beginning in 2007 with a set of requirements regarding electronic communication and tendering through a web based document management system, use of 3D building models and digital handover of operation and maintenance related information to the client. The extent of the new rules depends on type and size of the construction project. Details of the rules are given in an executive order from the National Agency for Enterprise and Construction, (Erhvervs- og Byggestyrelsen, 2006) in Danish. Information in English is available at Danish Enterprise and Construction Authority (2008) and (Implementeringsnetværket, 2008).

To prepare the public clients and the industry for the new requirements, a development project called 'Digital Construction' was carried through from 2003 to 2006. The project was divided into six major work packages:

−   The foundation for digital construction
−   Client demands on electronic tender
−   Client demands on 3D models
−   Client demands on project webs (web based document management systems)
−   Client demands on electronic hand-over
−   Best practice

The structure of the Digital Construction programme is illustrated in figure 1. A short introduction to the programme is given in the publication "Digital Construction" by the National Agency for Enterprise and Construction (2005).
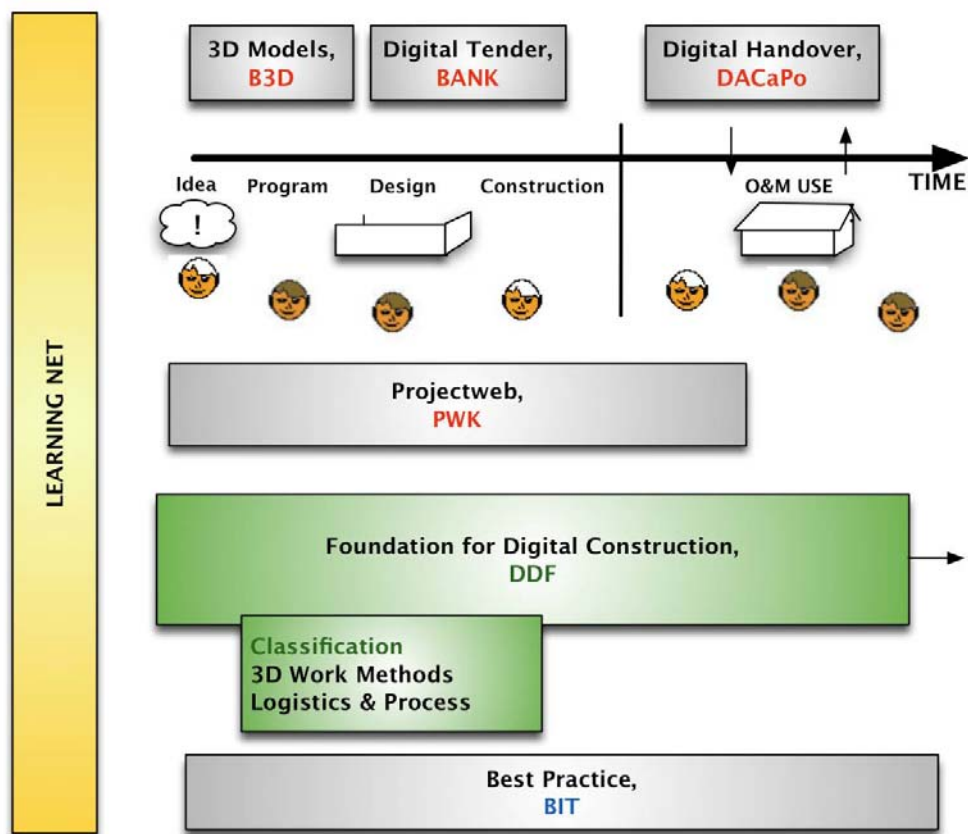
Figure 1. Structure of the Digital Construction project. From Christiansson (2005).

Six different consortiums were commissioned, through a public tender, to carry through the individual work packages. Each consortium had a number of partners typically including major consulting engineers and architects, contractors as well as university departments.

As a part of the development process, the four consortiums, that developed the client demands, were expected to test preliminary versions of the developed requirements in current construction projects managed by the public clients. The first version of the requirements regarding 3D-models is expressed in two publications (Karlshøj et al, 2004a and 2004b) describing the requirements and guidelines for using them. These publications are in Danish. For English information on related topics of the Danish Digital Contruction project, please see bips (2007)

The two requirements publications describe modelling concepts and recommendations regarding agreements between the client and advisors. Modelling concepts are described to give the client and advisors common terms for describing the content and level of detail of the required models. The described modelling concepts are based on guidelines from Finland developed in the ProIT project (Niemioja, 2003). The Danish requirements publications further give a survey of data requirements for a number of simulation and visualisation possibilities which can be based on 3D models. It is suggested that building models are exchanged in the IFC format specified by the International Alliance of Interoperability, http://www.iai-international.org/.

Similar requirements are in recent years being introduced in other countries. In January 2008 the U.S. General Services Administration and similar organisations in Denmark, Finland and Norway announced a "Statement of intention to support building information modeling with open standards" (U.S. General Services Administration et al, 2008). Senate Properties in Finland announced new BIM requirements (Senate Properties, 2007) and there are other initiatives going on in Norway and the United States (Kiviniemi et al, 2007).

The case, that was chosen to test the first version of the Danish requirements on 3D models, was an architectural competition on an overall plan for modernizing a cluster of university buildings (fig. 2). The

buildings were 30 years old, and the university wanted proposals to modernize the buildings so they could meet new requirements from students and employees of a modern university. Some of the wishes were:
- more daylight in the corridors, especially by roof light
- incorporation of social rooms near entrances of the buildings
- more or less covering of outdoor areas between buildings
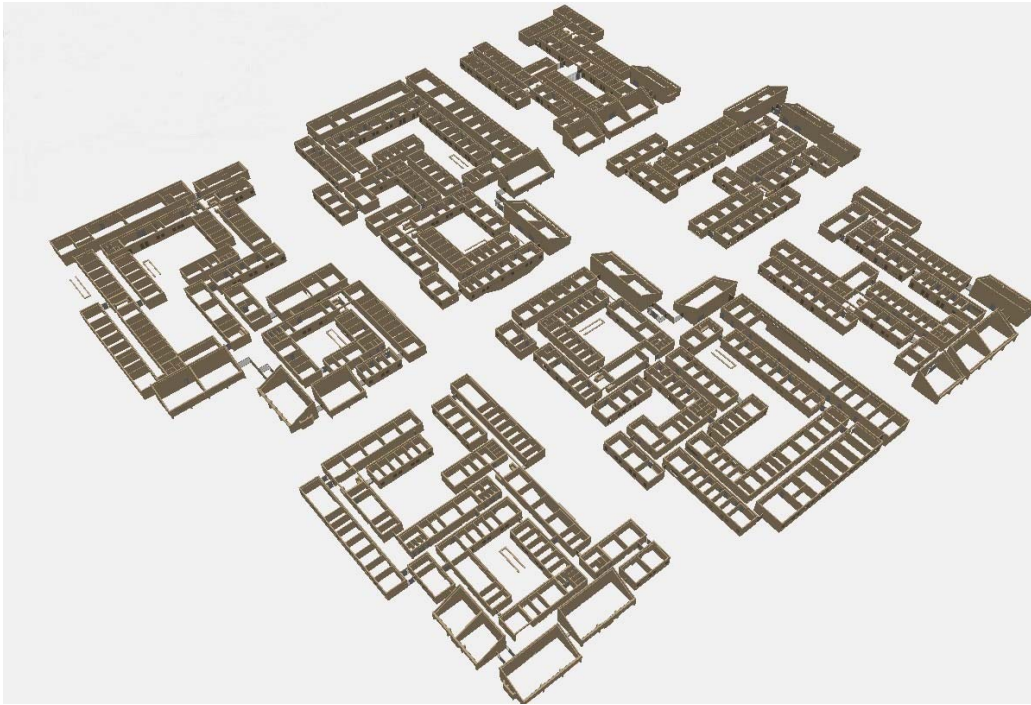- establishing a covered square at the main entrance of one of the departments

Figure 2. The test case was an architectural competition on an overall plan for modernizing a cluster of university buildings.

The client, who was the public owner of Danish university buildings, invited four selected architects to participate in the competition. The proposals from the architects should be prepared as a 3D model in IFC format supplemented with a number of 3D visualizations chosen by the individual architects.

The client had existing 3D object based models of the individual buildings for operation and maintenance purposes, and the client decided to use these models as a basis for the competition. The models had a high level of detail reflecting many construction details of the real buildings (an example of a complex wall object is shown in figure 3). The models were merged into one model including all buildings of the site, and then exported to the IFC format. This model was used as a major basis for the competition together with a sketch map of the area in the form of a 3D IFC model of the surrounding terrain and photos of selected details of the existing buildings.

In addition to the requirements on 3D models, which should be tested, the client decided to avoid any paper based communication. All information on the competition including sketch maps and photos was delivered electronically to the architects via a web based document management system, and the architects were required to hand in the entire proposal electronically to the same document management system. The proposal should include an IFC model of the modified cluster of buildings as well as traditional descriptions and visualisations of selected parts of the site. The assessment committee was given electronic access to the proposals, and the committee also decided to present all the proposals electronically with a computer projector at the assessment meetings, i.e. no traditional posters were printed to present the proposals.

2. METHOD

The developing consortium monitored the entire process of the competition including the client's preparation of the basis material, the architects' production of the proposals and the meetings of the assessment committee, in order to capture experiences with the use of the 3D client requirements

Two persons from the developing consortium assisted the client in the preparation of the material for the competition and they participated in all meetings with the client and architects as well as the jury meetings.

After the competition, representatives of the university operation and maintenance organisation as well as the participating architects were interviewed individually to collect their experiences. The interviews were based on the following main questions:

- *Did you experience problems in communicating the requirements to the employees who must meet the requirements?*
    - *requirements in the specific project*
    - *the requirements in general*
    - *form and extent of the publications*
    - *content and language*
- *Assuming that the requirements have been understood correctly; did you meet any problems in fulfilling the requirements with regard to*
    - *Technological, software, hardware*
    - *User competences*
    - *Organisational, commercial aspects*
- *What is the profile of the target group facing the requirements in your organisation?*
    - *role in the organisation*
    - *competences*
    - *existing tools*

3. RESULTS

The major experiences captured from interviews with the architects, the client and the jury are presented below. Further details can be found in a Danish report by (Svidt & Karlshøj, 2005).

3.1 ARCHITECTS EXPERIENCES

All of the involved architects had chosen to use Autodesk Architectural Desktop for the import and export of IFC files. For the visualisations, they used a range of tools for 3D modelling and image editing as they were used to in traditional projects.

A collection of statements from the interviews are presented in the following sections focusing on:
- The requirements in general
- The IFC requirement
- Competences and technology
- Working methods
- Digital information exchange
- Digital presentation

Some of the statements may be contradictory, since they originate from different persons.

3.1.1 THE REQUIREMENTS IN GENERAL

- Specific requirements on visualisations may be a limitation, since architects prefer to have their own graphic profile.
- Architects will feel limited by requirements on too accurate models in the competition phase.
- The requirements publications contain too many pages, we would prefer a shorter introduction
- In fact we only needed a few pages from the requirements publications.
- The 3D building model from the client gave us a good overview of the project.

- The 3D terrain model did not help us, we would prefer a traditional map with contour lines.
- The 3D model from the client had a higher level of detail than we were supposed to deliver back to the client. This fact caused us some problems (e.g. complex wall objects as the one shown in fig. 3 made it complicated to manage simple operations as inserting windows and doors)
- The complex wall constructions in the original model made it complicated to insert new doors and windows in the model.
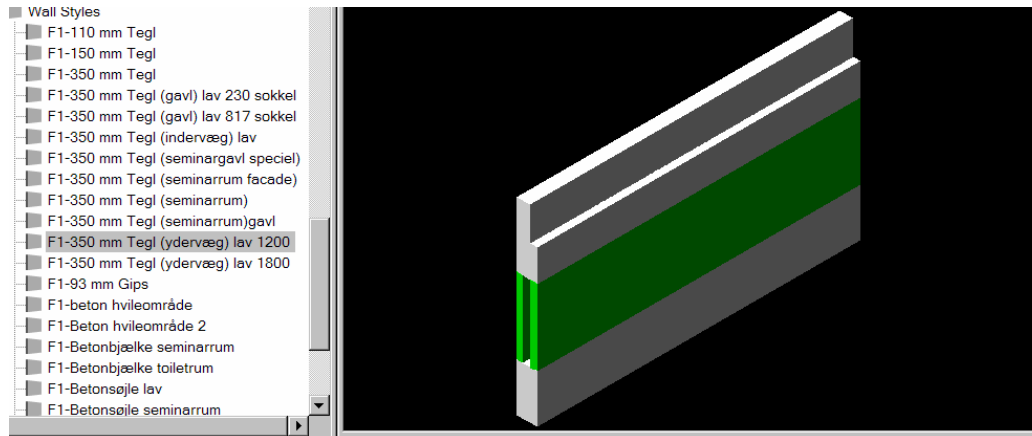- We found a lot of errors in the model from the client, which disturbed our further work.

Figure 3. The model of the existing buildings included many construction types at a high level of detail. Walls with different layers at different heights caused problems for the architects modification of the model.

3.1.2 THE IFC REQUIREMENT

- We had never heard of IFC before.
- We had some trouble in the beginning, but now we don't see any problems in delivering IFC files.
- Other clients, e.g. hospitals owners already require object based models, normally in a specific CAD format.
- We see some immediate advantages in these models, e.g. the possibility for quantity take off.
- We had some problems with 3D objects imported from another software.
- The IFC format in itself is not a problem, but using this type of models in general would require a big educational effort to spread the necessary competences in our organisation.

3.1.3 COMPETENCES AND TECHNOLOGY

- Some of our employees have used object based CAD for the last three years.
- For many purposes this is faster than traditional CAD.
- One third of our CAD licenses are on object based systems.
- We need further education to have sufficient competences in the company to meet such requirements in general
- We used to work with 3D digital building models, but had never heard of IFC and the Danish Digital Construction project.
- We had problems to get teachers for an internal course, because they were employed in competing companies.

3.1.4 WORKING METHODS

- We made the 3D visualisations in a pure visualisation tool and built the object-based models from scratch in Architectural Desktop, no reuse of models.
- Working with 3D models in the sketching phase was more challenging than traditional 2D, but forced us (i.e. helped us) to solve some issues, which wouldn't have been solved by traditional sketching.

- We normally don't use this type of models in the initial sketching phase.
- We plan to use 3D in the detail design phase, but our engineers still prefer traditional 2D drawings.
- We did the architectural part of this proposal with our traditional tools and made the required 3D model in the last minutes before delivery.
- We didn't find that we could present our ideas through the required 3D model.
- We had some problems with the high level of details in the delivered model, and therefore decided to build a new model from scratch.
- We worked in parallel with hand sketches, object based CAD and a 3D visualisation tool.

3.1.5 DIGITAL INFORMATION EXCHANGE

- We experienced no problems in the electronic communication.
- This is the first time we try a pure digital delivery.
- We find this working method interesting and would like a faster progress towards 3D models and electronic communication.

3.1.6 DIGITAL PRESENTATION

- We see some interesting possibilities in making more dynamic presentations
- Presentation on a computer screen or projector give some limitations regarding a general overview of the proposal, it is often necessary to zoom in and out.
- We had to consider if the user should be allowed to navigate freely in the model or he should follow a predefined route.
- Traditionally we are supposed to present proposals on posters or other printed material and thus we are not used to make animations.
- It reduced our workload in that we should not print and send anything
- We considered several times to build physical models to support our internal design process.
- We chose to deliver the proposal as a pdf file in print quality.
- We planned, but due to limited time and ressources we didn't fulfil to make an interactive model where the user could choose a number of predefined fly-through tours.

3.2 CLIENTS EXPERIENCES

- The electronic presentation (projector) of the proposals was not successful in all cases since some of the received proposals were more suitable for high resolution printing than for a low resolution projector.
- It was found positive that the entire jury was focused on the same picture during presentations and discussions.
- It was concluded that the use of IFC models required special competences.
- Some uncertainty on the role of the IFC-models compared with traditional visualisations was expressed.
- Using the 3D requirements requires new competences in the clients organisation.
- The jury would have benefited from a "3D pilot" to support the navigation in the delivered 3D models.

3.3 THE JURY'S EXPERIENCES

It was new to the jury members that all communication was electronic and that traditional proposals based on posters and books were replaced by a projector. The individual jury members experienced some technical problems in handling the electronically delivered materials. However, the jury emphasises the good possibilities achieved to study the proposals before the first jury meeting. Only one member of the jury brought a laptop computer to the meetings, so he could browse the proposals individually during the meetings.

4. DISCUSSION AND CONSCLUSIONS

A proposal for requirements on 3D models was tested in an architectural competition by the public owner of Danish university buildings. In addition to the 3D requirements, the client decided in the project to

avoid any paper based communication and thus all information exchange and presentation was based on electronic media.

It was found that the new requirements on 3D models were received positively from all parties of the project, and that the architects only had minor problems in fulfilling the requirements. All participating architects managed to use the electronically delivered material as intended to identify the buildings' mutual position on the site and their internal structure. The main part of the architects have used the required 3D models directly in presentation of their proposals. However, none of the architects have chosen to give the jury the possibility to navigate freely in a visualisation model.

In this case, there were no requirements to specific 3D visualisations or animations and there was thus a large variation in the material that the different architects had decided to deliver for presentation of their proposals. It would probably be easier for the jury members to navigate in the proposals if there had been certain minimum requirements such as specific viewpoints or specific informations to be presented in the proposals. It would also be relevant to require that the delivered documents are suitable for projector presentation if this is planned to be the main presentation medium.

The client didn't carry out any further treatment of the delivered IFC models, but chose to show the 'raw' models directly in an IFC viewer during the assessment committee meetings. By the largest models this procedure caused some viewing problems due to insufficient capacity of the computer in use. This raises some questions regarding the choice of tools for a certain visualisation purpose and the possibilities (or missing possibilities) to handle different information levels of large and complex building models.

The succeeding interviews with the architects showed a generally positive attitude to the 3D requirements and the selected structure of the competition. One of the participants expressed that the requirements forced the architects to solve some problems in the early phase, which could have caused greater problems later in the project. However, the competences to build object based models for such purposes are not always available in the team, who makes the competition proposals since these tools are more common in the detail design teams.

Experiences from the interviews and from discussions at the jury meetings show that it has been difficult for the involved parties to distinguish clearly between different parts of the requirements, e.g. 'visualisation', '3D-models', 'electronic communication' and 'electronic presentation'. Some of the participants have associated the 3D requirements with pure electronic communication and information transport over the Internet. And electronic storage and transport of the information has further been associated with presentation on a projector which has a very limited resolution compared with posters and other paper based presentations. This means that it has been difficult to keep the main focus on the 3D requirements, which was the main subject to be tested in the project.

ACKNOWLEDGEMENT

REFERENCES

bips (2007): 3D Working Method 2006, April 2007. http://www.detdigitalebyggeri.dk/ ('Material in English')
Christiansson, P (2005): Den digitale byggeproces, introduktion (Introduction to the digital construction process). Presentation at Life Long Learning, Aalborg University, August 2005. http://it.civil.aau.dk/it/education/livslang/8_2005/
Danish Enterprise and Construction Authority (2008): "Digital Construction". http://www.deaca.dk/Digital_Construction
Erhvervs- og Byggestyrelsen (2006): "Bekendtgørelse om krav til anvendelse af Informations- og Kommunikationsteknologi i byggeri". Retsinformation.dk, https://www.retsinformation.dk/Forms/R0710.aspx?id=27419&exp=1
Implementeringsnetværket (2008): "Det Digitale Byggeri (Digital Construction)" http://detdigitalebyggeri.dk

Karlshøj J, Nybo E, Bennetsen J, Kjems E, Svidt K (2004a): Bygherrekrav - 3D-modeller, Kravspecifikation version 1. Juli 2004. http://www.detdigitalebyggeri.dk. Erhvervs- og Byggestyrelsen, København, 2004. In Danish.

Karlshøj J, Nybo E, Bennetsen J, Kjems E, Svidt K (2004b): Bygherrekrav - 3D-modeller, Vejledning version 1. Juli 2004. http://www.detdigitalebyggeri.dk. Erhvervs- og Byggestyrelsen, København, 2004. In Danish.

Kiviniemi, Tarandi, Karlshøj, Bell, Karud (2007): "Review of the Development and Implementation of IFC compatible BIM" Erabuild Report available at http://www.ebst.dk/det_digitale_byggeri/0/7/0

National Agency for Enterprise and Construction (2005): "Digital Construction". http://detdigitalebyggeri.dk/component/option,com_docman/Itemid,110/task,doc_download/gid,408/

Niemioja (2003): "Design Guidelines 1.1, ProIT, Product model data in the construction process, Product models for architects, general basics and advice". Innovarch Oy.

Senate Properties (2007): "Senate Properties' BIM requirements 2007". http://www.senaatti.fi/document.asp?siteID=2&docID=517

Svidt K, Karlshøj J (2005) Bygherrekrav vedrørende 3D-modeller, visualisering og simulering : Erfaringer fra første afprøvningsprojekt, Idékonkurrence for Fibigerområdet. Aalborg Universitet. Det Digitale Byggeri. Erhvervs- og Byggestyrelsen, København, 2005.

U.S. General Services Administration, Danish Enterprise and Construction Authority, Senate Properties, Directorate of Public Construction and Property (2008): "Statement of intention to support building information modeling with open standards". http://www.gsa.gov/gsa/cm_attachments/GSA_DOCUMENT/Statement_of_Intention-BIM_R2-tPB-t_0Z5RDZ-i34K-pR.pdf