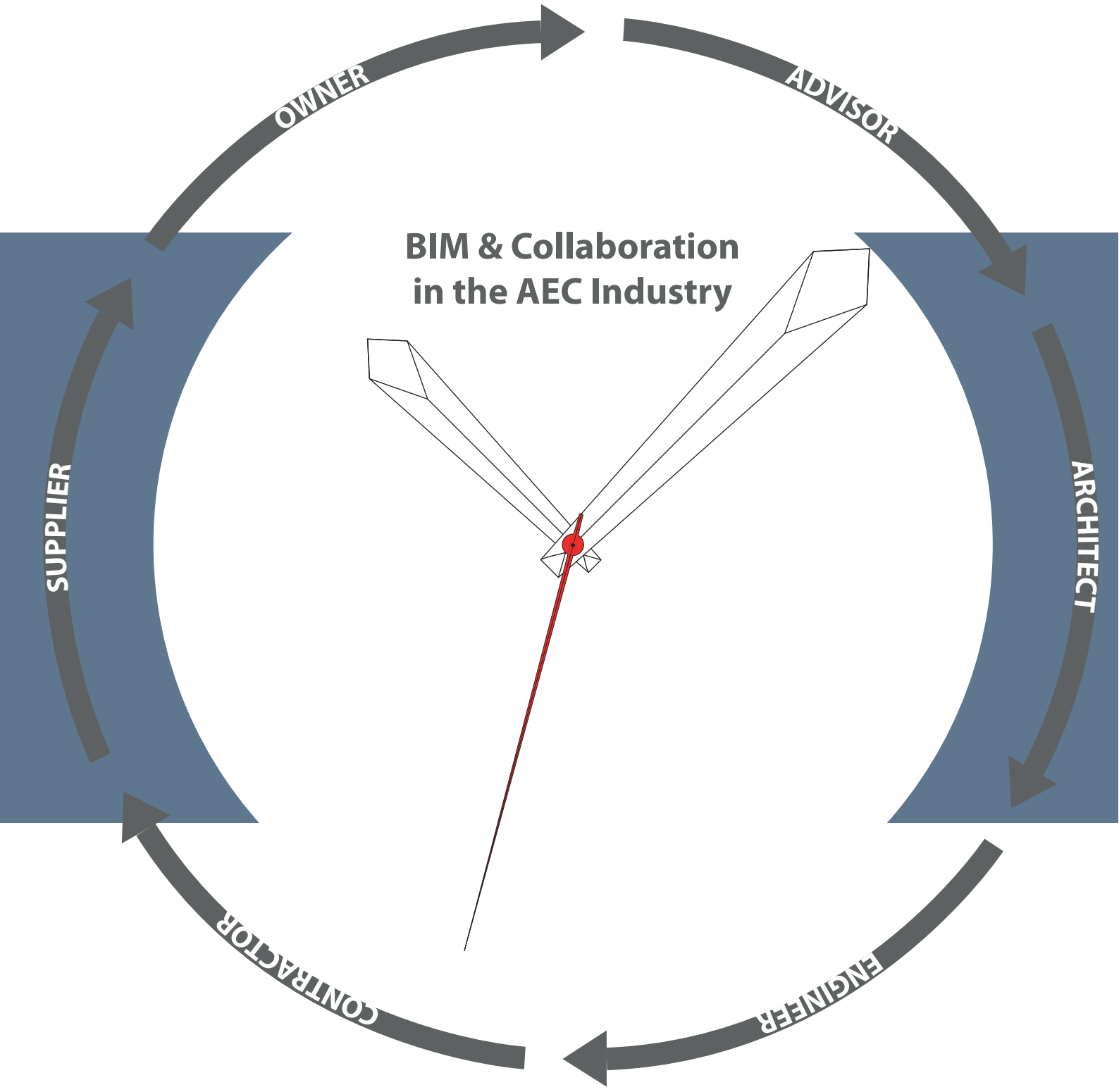
BIM & Collaboration in the AEC Industry



Master of Science in Engineering - Management in the Building Industry
4th Semester
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Thesis in
Master of Science in Engineering in Management in the Building Industry (Cand. Scient. Techn.), Department of Mechanical and Manufacturing Engineering, Aalborg University, Denmark.

Synopsis

This project deals with the current situation in the architect, engineering and construction industry, where use of virtual building modelling affects the way buildings are designed and produced. Building information modelling is a process which aims to control and utilise the potentials from using digital software tools for collaboration between every part of a design and construction team.

The present report analysis the current situation in the use of building information modelling in the industry, and reflects on the processes related to the use of these systems today. It evaluates the suitability of today's delivery process agreements, and how to be inspired from modern design/process methods such as concurrent engineering. Further, case interviews reflect the situation in Denmark, related to the use of virtual building models, and investigates the collaboration between operators in the industry.

There are some clear challenges in making building intelligence modelling a time efficient and cost saving process, which the product of this report aims to solve through some very specific project management tools. They structure information and help to clarify product, organisation and process for individual construction projects.

Title
BIM and Collaboration in the AEC Industry

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Preface

The present report is a result of the research and work made in relation to my master thesis in Master of Science in Engineering in Management in the Building Industry. Work is completed from Marts to August 2011 at Aalborg University in Denmark.

The focus of this report is directed towards collaboration in the architect, engineering and construction industry, when building information modelling and virtual building models are used in design and construction.

All the persons which have been kind to devote time for the interviews in my research are presented without name.

Aalborg, August 2011

Mats Thomassen

Acronyms

AEC Industry - Architect, Engineering and Construction Industry
AEC/O - Architect, Engineering, Constructors and Owners
AECS - Architect, Engineering, Constructors and Suppliers
AIA - American Institute of Architects
API - Application Programming Interface
BIM - Building Information Modelling
CE - Concurrent Engineering
ICT - Information & Communication Technology
IFC - Industry Foundation Classes
ISO - International Organization for Standardization
ISO/PAS - Publicly Available Specification
LOD - Level of Detail
POP - Product, Organisation and Process
RFID - Radio-frequency Identification
SWOT - Strenghts, Weaknesses, Opportunities and Threats
VBM - Virtual Building Model

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1 - Opening

The opening consists of a brief explanation regarding the intentions of this report and a further description of the project approach. This is not directly part of the research, but supplementary knowledge to understand the structure of the thesis.

Introduction
A quick brief of the content and intentions of the thesis.

Readers Guide
Guidance in the structure and graphical presentation of the report.

Methods
Explains the methods used in the present report, and the approach of the project.

1.1 Introduction

Building Information Modelling (BIM) is proclaimed to become the future construction process of the Architect, Engineering & Construction (AEC) industry, involving all parts in new ways according to the project evolvement. (Eastman et. al., 2008) Project progression in BIM is made in Virtual Building Models (VBM), which is based on parametric modelling principles for exchanging information, in an iterative and cooperative process, including every stakeholder of a project.

Today a large representation of the AECs in the industry utilize BIM tools at some level, but unfortunately the digital devises are mainly used in independant design tasks and not for collaboration through the process of BIM. (Taylor et al., 2008; Kiviniemi et al., 2008) This means that the industry do not exploit the full potential VBMs have, and due to inadequate software ability the users of digital devices bear direct costs of almost 16$ billion annually. (Gallaher et al., 2004)

BIM is a collaborative undertaking which aims to achieve better design solutions, at lower budgets, in less time by using VBMs to communicate between design disciplines, owners, contractors, suppliers etc.. But despite the still increasing entity of digital devices and the current need for BIM, the ideology of BIM has for more than 20 years struggled to become the preferred process of the industry. (Eastman et al., 2008) So, the main goal of this project is to investigate how BIM intends to affect the AEC industry, and in what way the industry should adapt to benefit from the potentials of using VBMs.

BIM processes will include several stakeholders, to make it the collaborative time and money saving process it intends to be, there is a need to restructure the current process of the industry to support the use of VBMs. The product of this report supports the communication and collaboration which is in progress during design and construction projects. The result is a set of tools which contains several templates for structuring and leading a BIM process, also taking precautions for the use of VBMs and exchange of information between project stakeholders.

1.2 Readers' Guide

The present report is structured in 6 sections. Beside the current opening including the introduction, this readers guide and the selection of methods used in the project, the report includes 4 main sections and a final conclusion to the project.

The 4 main sections represent the separate phases of the project. It follows the approach on figure 1 which is introduced in the next chapter.

The 4 main sections are:

> The search which contains all introductory analysis for finding a potential for innovation.
> The selection phase where the strategy of the solution is discussed.
> The implementation which contains a prototype as a solution.
> The capturing which is an evaluation of the prototype.

Introductory there is a dictionary that defines the acronyms which is used in the report. At the final pages a list of referencing literature is structured by scientific papers and web-pages.

Each section starts with a short introduction including a quick brief of the content.

At the header, the current section is presented at the left and the chapter at the right.

1.3 Methods

The methods used to structure this project are based on scientifically acknowledged theories to define the approach. Successful innovation management concerns building and improving effective routines. This depends on the understanding of the situation and searching for potential problems regarding the existing system. (Tidd & Bessant, 2008)

The approach of the present project will follow Tidd and Bessants simple model for the innovation process. (figure 1) It is chosen for its ability to organise and structure the overall process of innovation related to product, process, position or paradigm. This is an approach used for systematic innovation within many industries, supported by four main steps to improve products or systems. The four steps will be representative to the approach of this project, also structuring the layout of the report.

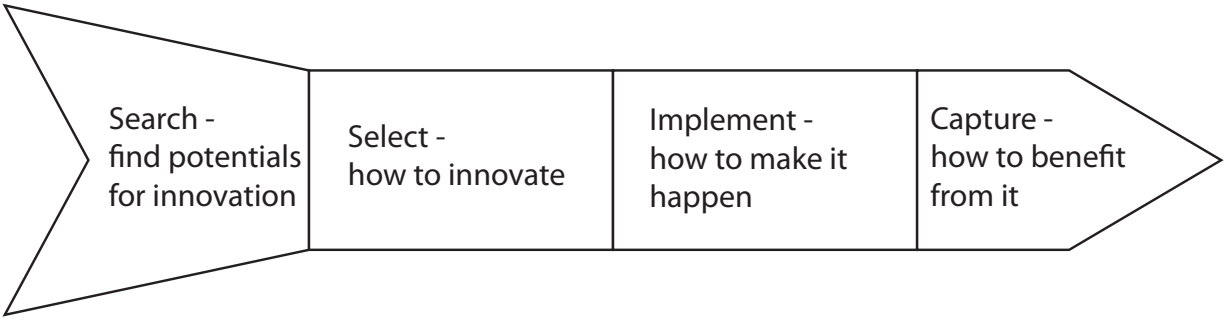


Figure 1 - Simplified model of the innovation process (Tidd & Bessant, 2008): *The model is a strategic mind-set to find potential opportunities for innovation and further considerations on how to improve, implement and capture the idea. As a model it aims to secure innovation to be systematically considered before executed, and in this way increase the chances of landing a product valuable to implement.*

While the innovation process model defines the overall approach, the methodology of *contextual design* (Beyer & Holtzblatt, 1998) is used to structure the working process. The contextual design methodology is chosen for its usability to support the development of customer-centred systems and its focus on how to fit the product to the user/customer. Theories from contextual design are strategically used by their ability to support the phases of search, select, implement and capture during the project progression.

Further the contextual design methodology is presented, and following is a description of how methods are used within each of the phases search, select, implement and capture.

1.3.1 Contextual Design

Basically, contextual design is a design approach to define software and hardware systems, moreover many of the aspects can be adapted in the search for valid data and development of usable systems within other industries as well. Contextual design operates in seven main steps for design development of a system. Listed in order, they are: *contextual inquiry, work modelling and*

consolidation used in the phase of search; *innovation from data and system design* which supports the phase of selection; *prototyping* used in the phase of implementation to define a potential solution; and *implementation* which supports the phase of capturing where the product is evaluated.

The basic of the contextual design approach is to involve the user in the product development by the use of contextual inquiry. This is an interviewing method used to analyse the relevant users. To better understand customers and their actual operations, the interviewer observes the procedures of the industry and asks into the daily routines. Information captured in the contextual inquiry should be graphically illustrated as work models as a representation of the work sessions.

Data from interviews and work models will be assembled in consolidated models too see the bigger picture of a marked. The design should be tailored to individuals but also be usable by the whole population. Data from the consolidated models is then used to capture the essence of the problem. The result is ideas on how the work flow should be. In general, work models are maps on the workflow.

Next step in the contextual design approach is to design a system based on the idea generation; a system to solve the conducted issues from earlier work sessions. Consolidated models can be used to restructure the organisation or processes, and define a vision on the optimal work flow. These models can be work models as described above, or storyboards which indicate how the intended changes will affect the daily work flow. This is a type of brainstorming, generating ideas on how to solve the situation based data from the earlier analyses.

The system should be tested by the use of prototyping, a wide definition that can be all from paper based prototypes to real time systems. Usually the feedback on prototypes is used to improve the system design in an iterative process. It is important to compare these prototypes to the earlier clarified work models to coherently evaluate the product. Final step is the term of implementation; a plan on how to get the system up and running correctly.

1.3.2 Search – Find Potentials for Innovation

The phase of search is based on the *Grounded Theory*, introduced by Glaser and Strauss (1967) with their book *The Discovery of Grounded Theory*. The theory was constructed as a means of collecting data, which have been systematically obtained through ‘social’ research. All data is a fundamental property of the grounded theory. Thus, not only interviews or observations are data, but anything which helps the researcher to define a concept for the emerging theory. (C. Goulding, 2002) This validates analysis based on individual experiences and theoretical knowledge related to the topics. Combined they are used to capture the essence of the current aspects related to BIM, VBMs and collaboration in the AEC industry of today.

In the search for potential fields to innovate, the BIM Handbook (Eastman et al., 2008) is an essential guide to understand the praxis of BIM usage. Supplementary literature will be used to study the latest trends within usage of Information & Communication Technology (ICT) in the AEC industry, and verify potentials and issues related to the use of BIM. Supplements will include internet research, scientific articles from organisations like CIFE (Center for Integrated Facility Engineering) and AIA (American Institute for Architects); the magazine of *Automation in Construction*, the international online journal *ITcon* papers; and other published books and papers about related topics.

The contextual inquiry (chapter 1.3.1) takes part in the social research by interviewing people within the AEC industry. The interviews are semi-structured with the goal of getting a constructive conversation about the use of BIM in the AEC industry of Denmark. In relations to these interviews, work models are be made to locate the potential issues related to the use of BIM processes.

1.3.3 Select – How to Innovate

SWOT-analyses are used to evaluate the current situation of BIM based processes based on strengths, weaknesses, options and threats. SWOT is a heuristic list more than an actual method, and has been selected for its clarity and widespread acceptance in practice. (Soerensen, 2009) The SWOT-analyses consolidates the information captured in the section of search.

SWOT evaluates organisations by looking at internal and external factors affecting the business. Strengths and weaknesses evaluates the internal aspects of the organisation, while opportunities and threats are factors that potentially can affect the organisation's current situation. Opportunities and threats are in many cases seen as external factors, but in terms of Roger Formisano (2003) and his book *Managers Guide to Strategy*, it is legal to explore for internal activities as well. In term of Formisano (2003) the SWOT-analysis should bring out between 5 and 10 sayings in each category.

To fine-tune the strategic development, a SWOT-strategy map is used to explore various combinations of the strengths, weaknesses, opportunities and threats. It ends up with four different strategies: strengths combined with opportunities (SO strategy); strengths with threats (ST strategy); weaknesses with opportunities (WO strategy); and weaknesses with threats (WT strategy). These strategies define a potential solution to the problem. (Formisano, 2003)

SO strategy – use our strengths to take advantage of an opportunity
ST strategy – use our strengths to minimise threat
WO strategies – oppose weakness through an opportunity
WT strategies – evaluate weakness in light of realistic threats

How to innovate and systemise the design is defined by a strategy on how the AEC industry should adapt to the process of BIM in the future. This is expressed in storyboards, to describe a visionary scenario of an optimal design process; a methodology expressed in the theories of contextual design. (Beyer & Holtzblatt, 1998) Storyboards are chosen by their ability to create visuals for use in the design optimisation, visuals which is representative to the imaginary thinking of design solutions.

1.3.4 Implement – How to Make it Happen

A prototype specification is defined from the solidified strategies in the selection phase; design requirements to be used in the development of a prototype. (Beyer & Holtzblatt, 1998) The prototype is paper based sketches, illustrating a solution to the specifications that are listed. Business Process Modelling Notation (BPMN) is used to express the respective processes and specifications of flow in the prototypes when required. BPMN is a notification system used to capture an ordered sequence of business activities and supporting information. (White, 2006)

1.3.5 Capture – How to Benefit from It

To get a qualified opinion on the prototype's usability, the evaluation is based on an interview with a BIM coordinator from the AEC industry. The interview is chosen to be semi-structured, this to maintain a constructive dialog and to get a further understanding of the current situation. An evaluation by an independent person, with experience from BIM in the AEC industry, is considered a valued method to criticize the project solution. The interview is central to the evaluation of the product and essential to this project's final stage of updating the prototype.

2 - Search

The section of search is representative to the introductory research made in this project. With the section of search, the main objective is to investigate on today's situation within the AEC industry. Analysis are performed to understand the current aspects of BIM as a process, and to unveil potential problems when BIM is used in the industry today.

Building Information Modelling
A general investigation of BIM as a process, and the intentions this process has in becoming the preferred design and construction approach within the AEC industry.

Delivery Processes Agreements
To specify what type of agreement that suit the BIM process best, analyses of today's most preferred design and construction agreements are presented.

BIM Standards
This is a general research on the standards C102 by Bips and E202 by AIA and how they refer to the use of BIM and VBMs.

Concurrent Engineering
An analysis of the well-known design process concurrent engineering, which objective is to obtain optimal collaboration within the design and production theme. The purpose of the research is to inspire the structuring of collaborative design process within BIM.

Case Studies
A set of interviews analyse how BIM is used in real life projects of today. The interviews bring up issues related to the current use of BIM in Denmark.

2.1 Building Information Modelling

BIM is regarded one of the most promising developments inside the AEC industries (Eastman et al., 2008). BIM is found relevant to investigate in order to locate potentials and issues related to the new design and construction approach. This chapter presents the intentions of BIM as a process and how it is expected that BIM affects the AEC industry of the future.

2.1.1 What is BIM?

BIM is not a thing or a type of software but a process to generate and manage building data. The VBM is the product of these operations. Not only do VBMs represent the geometry of the building, it also contains data supportive for construction, fabrication, and procurement activities needed to realize the building. (Eastman et al., 2008)

Inter-disciplinary collaborations within the AEC industry have revolved around the exchange of 2D-drawings and documents for a long time. Even though several design disciplines use 3D-models for visualisation and design development, collaborations between practices have remained 2D based. (Singh et al. 2011) BIM implicates change, encouraging the exchange of 3D-models between different design disciplines.

A VBM becomes a digital representation of the physical and functional characteristics of a building's facility. The VBMs are generated in three dimensions and utilize parametric intelligence to adjust their positions or proportions; a 3D-model also contains attributes, supportive for data integration and design analysis. (Eastman et al., 2008) BIM has the ability to include the 4th and the 5th dimension of building modelling to the process; incorporating construction scheduling (4D), and component pricing and budgeting reports (5D).

The objective of BIM is to collaborate by the use of VBMs, a technology which is essential to the design and construction industry of today. Figure 2 on next page presents the vision of BIM processes. BIM is based on the relation between the interchange of specific models from architects, engineers, contractors and suppliers (AECS). The models can be worked on separately and be combined in a consolidated model. An interoperable model collection procures for information to be accessible and retractable continuously, this means that quick simulations are always possible. It is permanent access to updated drawings and efficient cost estimations can be made from the information in the 3D-building-geometry.

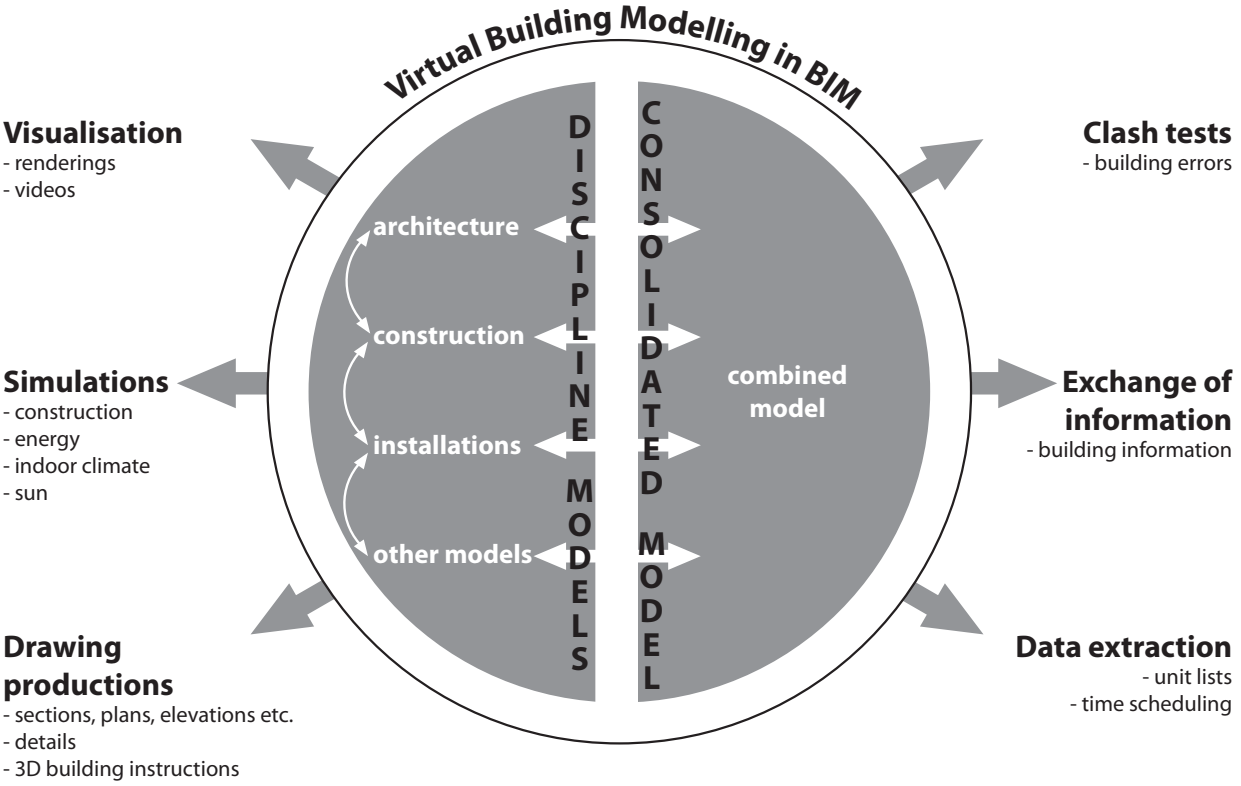


Figure 2 - Integrated BIM model (BIPS, 2008): The *model is representative to the vision of BIM processes. BIM is based on relation between the interchange of discipline models from architects, engineers, contractors and suppliers in a design and construction process.*

BIM aims for the Level of Detail (LOD) to rise iteratively. More informative models are created for utilization in structural detail and energy-use analysis, cost estimation, fabrication and construction management. Built-in intelligence provides for 2D-drawings, documentation and other building information to be automatically extracted from the VBM. The proclaimed quality of BIM is the process' ability to convert and/or hand-over building information without data loss, ensuring that the information stays intact. (figure 3)

Eastman et al. (2008) explains the profit owners will have from choosing BIM in figure 3. The losses of data from traditional paper based processes are significant. BIM processes work against this by storing all information digitally so it is easy readable to every person involved. While a traditional process fails in recapturing all information after each process during a design process, BIM ensures for the information to stay intact.

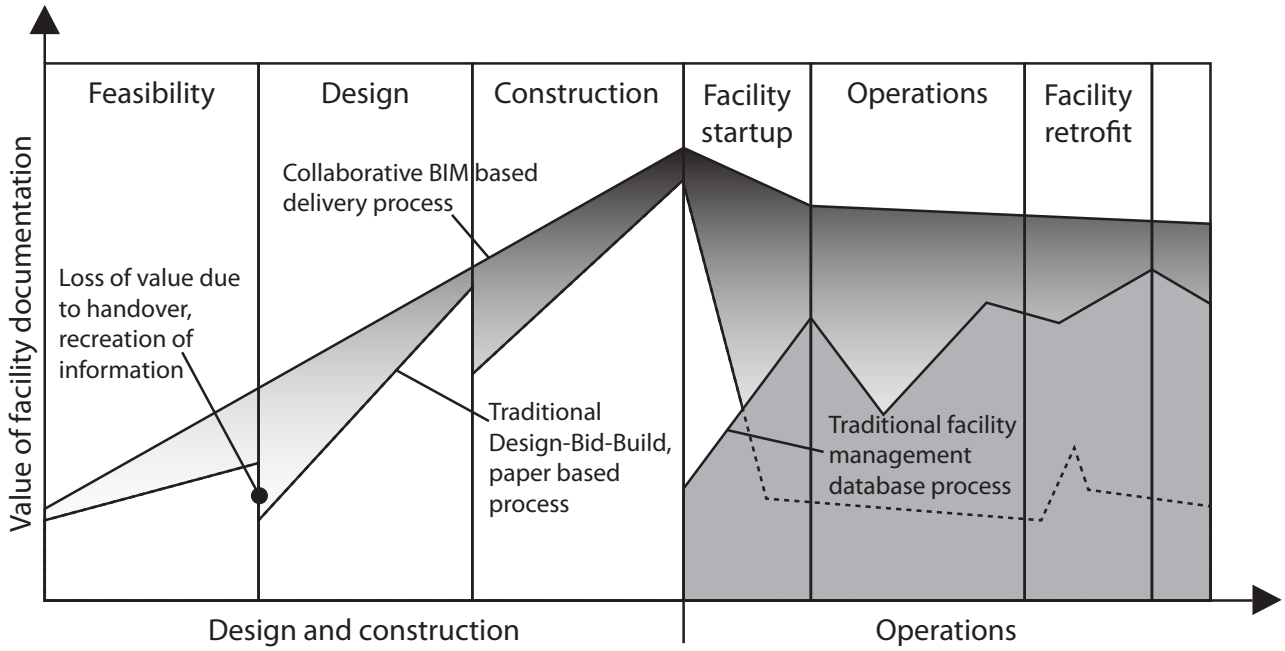


Figure 3 - Data integrity (Eastman et al., 2008): *Graphic presentation of the data losses during the lifetime of a building. Compared is the traditional paper-based process vs. a collaborative BIM based delivery process.*

Building design is a broad and collaborative undertaking, involving a wide range of issues that require technical detailing and focused expertise. The integrated model (figure 2) is a collection of information including all types of activities performed by architects, engineers, contractor etc. in each of the surrounding co-processes. Information exchange is co-ordinated via the VBMs, where every profession has the ability to involve in the design by their continuous analysis from adaptive geometries and information.

BIM intends to foster optimal collaborations between project stakeholders through the life cycle of a facility; to insert, extract, update or modify information. Using BIM, AECS seems to have the potential of coming closer in being an accurate and multi-disciplinary collaboration. BIM can therefore be seen as a new and modern development process for integration and utilisation of today's software options. BIM's goal is to become a more time efficient and cost effective production process.

2.1.2 BIM as Project Development Process

BIM control the process of how to use VBMs for design, construction, and maintenance of facilities. When the flawless exchange of building information between 3, 4 & 5D tools becomes intact, new project development processes will probably take place in the AEC industry to maximize value engineering.

Figure 4 shows the increase of cost when design changes are made along with the time of the construction design, where the ability to impact cost and functional capabilities decreases by time. Traditionally the design process peaks while the construction documentation is made; a critical point where changes cannot be made without negatively affecting the costs of the project. The preferred design process peaks at the schematic design and design development; a curve which

BIM supports by its possibilities of creating precise models at earlier stages in the design process. (Eastman et al., 2008)

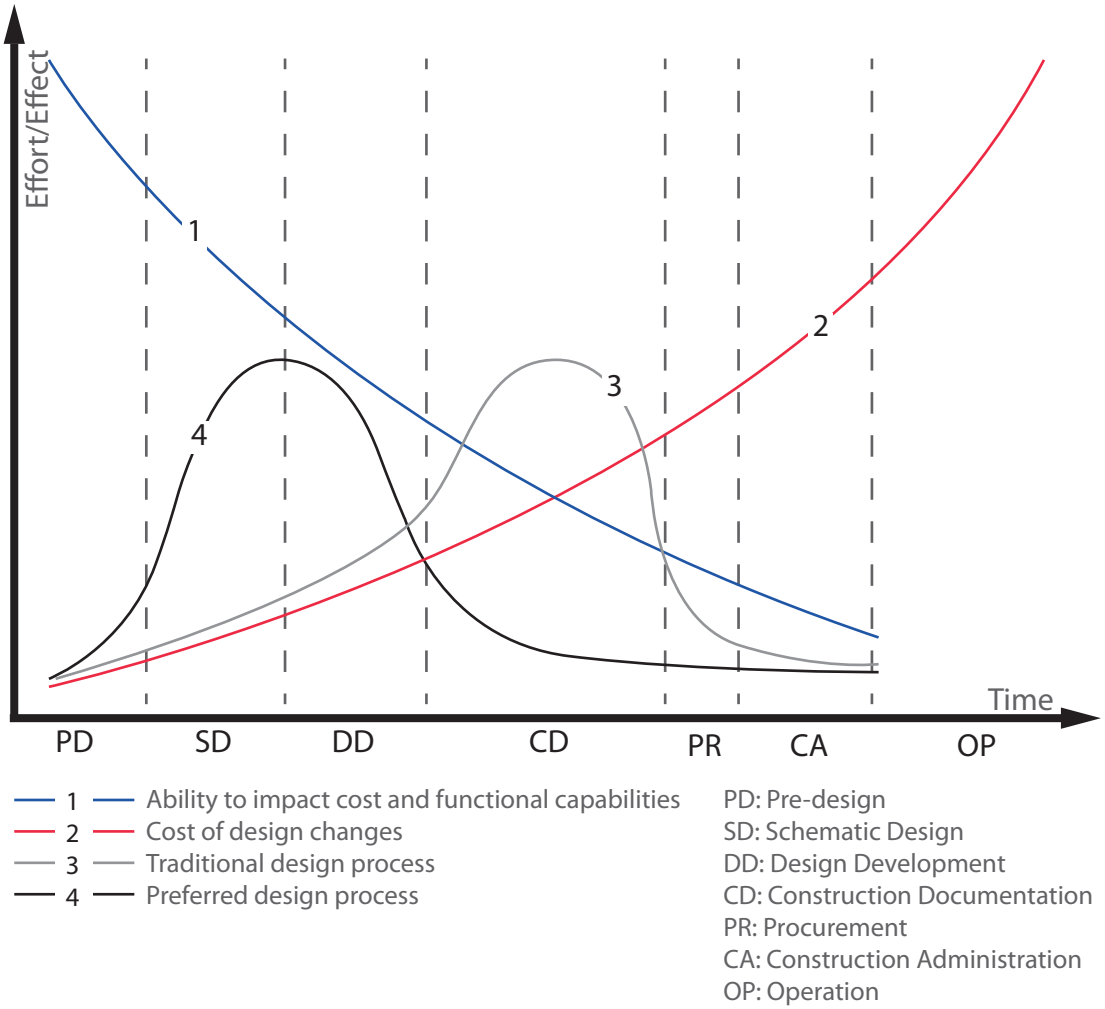


Figure 4 - Added value, cost of changes and current compensation distribution for design services (CURT, 2007): *The model describes how the preferred design process should evolve compared to the traditional design process. In the early phases abilities are bigger to impact on cost and functionality where the cost of change is lower.*

To forecast critical aspects usually discovered at later stages of construction, the informative level in the VBMs must increase at earlier stages. This means that BIM demands a bigger effort during the design development, where VBMs ability to automate detailing decreases the time required to produce construction drawings. In terms of figure 4, BIM do not necessarily minimize the work load but forces a lot of decisions to be made in the early design phases where the risk of change is lower.

This indicates the need for specified expertise to be included in the project at earlier stages. A process similar to line 4 (figure 4) means that bigger loads of work has to be made during the schematic design and design development. Detailing which usually is performed in the construction design phase now has to be executed earlier. Meaning that architects and engineers either are forced to pull of bigger loads and have a broader expertise, or contractors and suppliers needs to take part in the design at earlier stages.

A mini guide in BIM implementation indicates that up to 70% of the design decisions must be made at an earlier stage than by traditional construction processes. (Levring, 2010) As the graph on figure 5 indicates, the amount of work during the schematic design will be up to 60 % higher than traditional progressions, where the remuneration is only about 15% of the total amount to the project.

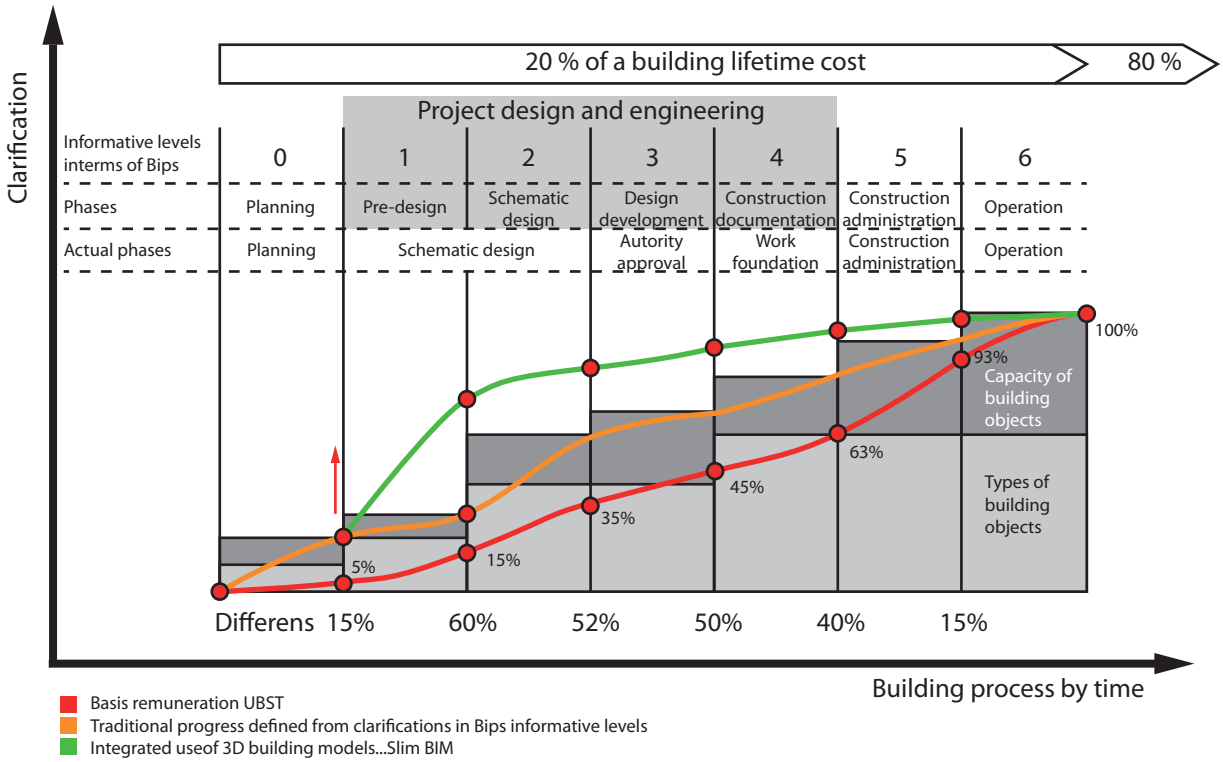


Figure 5 - Simple picture of how clarifications in digital projects are significantly different from the traditional building processes. (Levring, 2010): *A lot of time is offered in phase #1 where the basis remuneration is only between 5-15% of the total project fees. This accounts for approximately 75% of design decisions to be made in phase #1&2 before the authority approval.*

If BIM is similar with increased detailing of projects and bigger amounts of work in the earliest design phases, the remuneration has to be changed due to the development of the project. In such cases, the progression is probably better suited with some specific type of delivery processes. Obviously traditional contracts have trouble in supporting the design process of 3D-building models, and in some way this graph indicates BIM's dependency to other delivery process agreements.

Levring (2010) states the importance for models to have the right informative level. Every participant of the project is then able to utilise the model-work made by other stakeholders. Therefore, it is very important that the model is sectioned in the right way, and that the design team understands each other's needs of information. So, agreements to the process of model development have a very significant value to the coordination of digitally design projects. It is a need to restructure the traditional design process for it to suit the use of VBMs. (Levring, 2010)

The purpose of BIM as a co-operative business solution is to involve all parts at earlier stages of design. Thus, it is important that the design team clarifies each of the colleagues task at the factual level of design. It must be obvious when, how and with what software the contractor plans his constructions, the engineer does his calculations, or the architect develops the design.

2.1.3 Level of Detail

(Based on the documents AIA E202 (AIA, 2008) & BIPS CAD 102 (Bips, 2008))

To control the process of BIM, Level of Detail (LOD) is introduced. This is a categorisation of the digital information available and a representation of the information clarification level in the design development of a construction project. LOD does not describe actual work tasks or how they are carried out, but is an overall description to specify agreements between different parts in a construction process.

The informative levels are presented differently by the Danish standards and the American standards. AIA (American Institute of Architects) describes the LOD to be in five stages (LOD100-LOD500), and the Danish *CAD-manual* from 2008 by Bips describes the information levels in 7 stages (0-6). While the American is purely focuses on the geometry of the building, the Danish standard also include specifications on complementing services. Model development do not necessarily has anything to do with services and should be counted as separate entities. The system introduced by AIA is therefore preferred.

The scale of LOD rises from a low detailed level to a high detailed level. Usually, several VBMs are represented in a design and construction process and the LOD is representative to single entities within the VBM or a smaller sections of the model. LOD is suited to the parametric abilities which BIM related software has to offer and supports the progress of the programmatic task.

LOD100-500

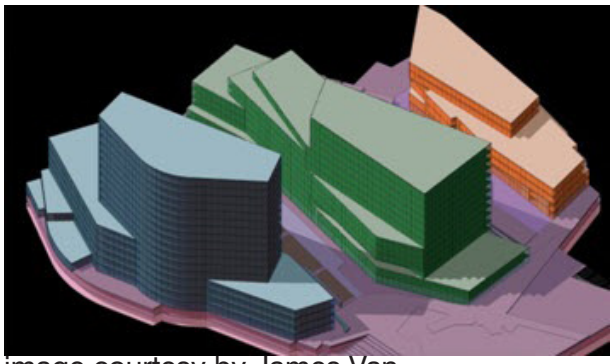


image courtesy by James Van

LOD100 is equivalent to the conceptual design phase, involving whole building types of analysis in overall design purposes. It is based on building volumes and orientations. At this stage the preliminary goal is to define the overall form-expression and functionality of the design; making sure that the design holds the spatial requirements and that light and shadows are harmonic.

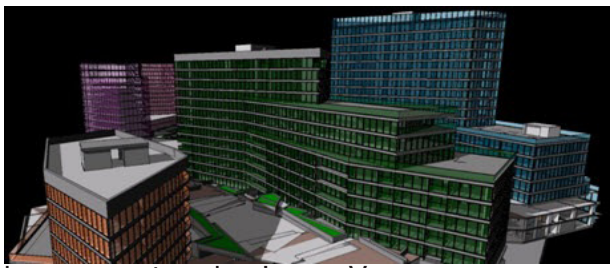


image courtesy by James Van

LOD200 is more related to the schematic design of the building. The model now contains geometry and functionality of building objects, including spaces, base, walls, decks and roof. Objects do not need to involve design specific data, but relates to more object based design purposes including modular systems, approximate quantities, size, shape, location and orientation. LOD200 also include early analysis of selected systems and design performance in terms of sustainability, technical systems, structure, cost indications etc..

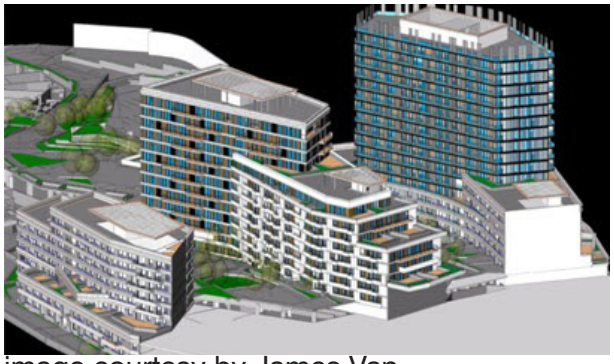
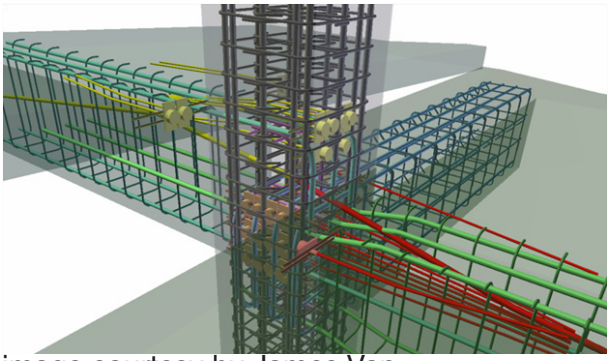


image courtesy by James Van

LOD300 is a precise description of the geometry where model elements become suitable to generate traditional construction documents and shop drawings. It includes confirmed 3D object geometries, precise definitions of wall thicknesses with engineered dimensions, time-scaled ordered appearances of detailed assemblies, precise quantities of materials and related aspects.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LOD400 is the industrial level of building construction, shop- and fabrication drawings for purchase, manufacturing, installation etc. This includes details of assembly, purchase prices, precise simulations based on the specific manufacturer and their detailed system components. Often this stage will be conducted by manufacturers and contractors with specific knowledge within the fields.

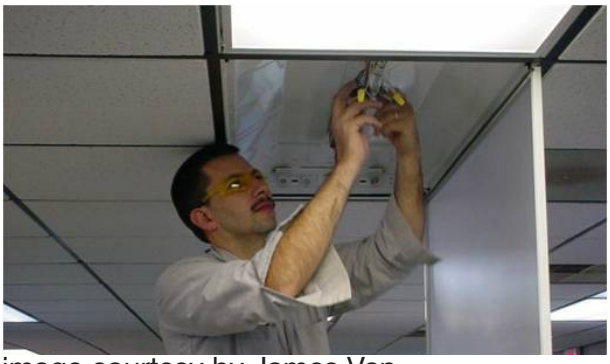


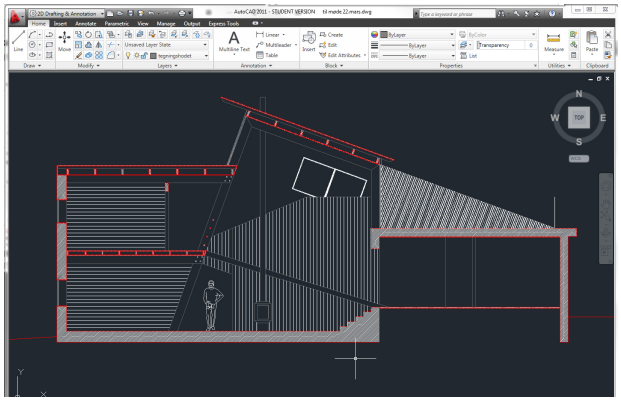
image courtesy by James Van

LOD500 is the final possible level of detail representing the as-built project; it could also be defined as information to be used in the management of the facility.

2.1.4 Software Solutions

As previously described a BIM process is a consolidation of many models from several design and construction specific professions. BIM is not one process solved by one software, but several processes relating to several software solutions, each with individual abilities to perform specific work related tasks. All software will take part in the information sharing at a BIM based design process and therefore becomes a collection of VBMs representing the LOD during the design and construction process.

Listed are the capabilities of well-known software modelling tools in the building industry of today.



2D/3D visualisation and conceptual modelling software as AutoCad, 3dMax, Rhinoceros and FormZ are used basically as a substitute to traditional drawing and modelling. 3D-modelling is used in preliminary design phases and to produce visual images and video presentations. 2D-modelling generates blueprints and other types of construction drawings to be used in construction and production.

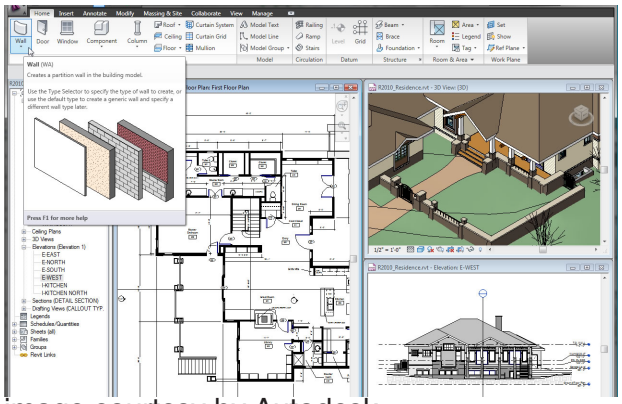


image courtesy by Autodesk

3D parametric architectural modelling is performed by software like Autodesk Revit, ArchiCAD, Bentley Architecture, and is structured and designed to support BIM. Models are created from parametric information, generating 3D-objects from 2D-drawing principles. As a supplement to the geometry, the software also supports information to be assigned to design objects. Parametric qualities enables furnished with pre-designed building units in the 3D-model.

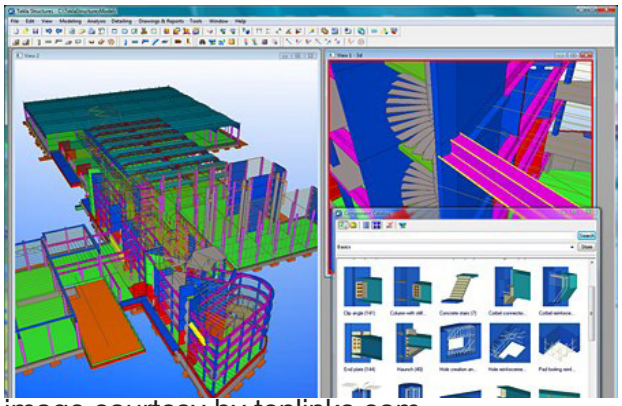


image courtesy by tenlinks.com

3D parametric structural modelling and analysis are performed within construction engineering software like Tekla Structures and Robot Structures. These tools operate within the field of information modelling with additions of structural capabilities. The software manages to model precise structures, including details as bolts and welds, usable in stress analysis. Drawings from these tools are directly used for construction and production purposes.

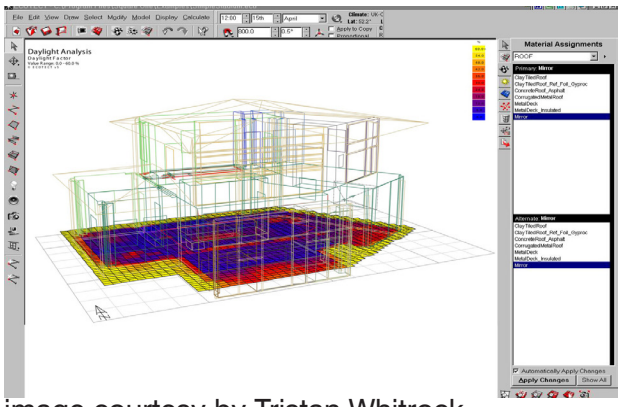


image courtesy by Tristan Whitrock

3D sustainability analysis is supported by software like Ecotect and EcoDesigner. These tools have the ability to estimate energy usage and carbon footprint, thermal performance, daylight, and solar radiation among more. Analysis can be performed in iterative processes of remodelling and material experimentation.

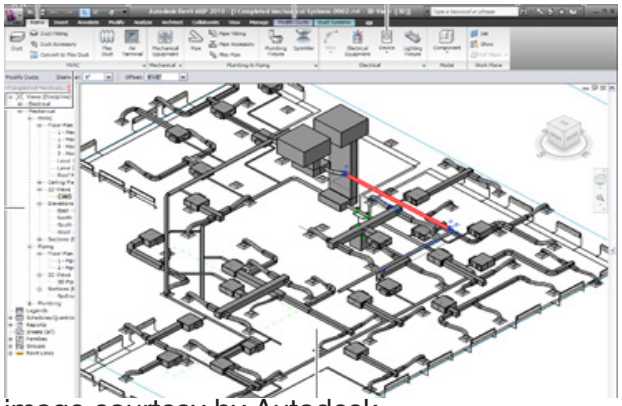


image courtesy by Autodesk

3D MEP is used to design mechanical, electrical, and plumbing in projects. This is performed in software like Revit MEP and MagiCAD, specially designed for the structural purpose of these components.

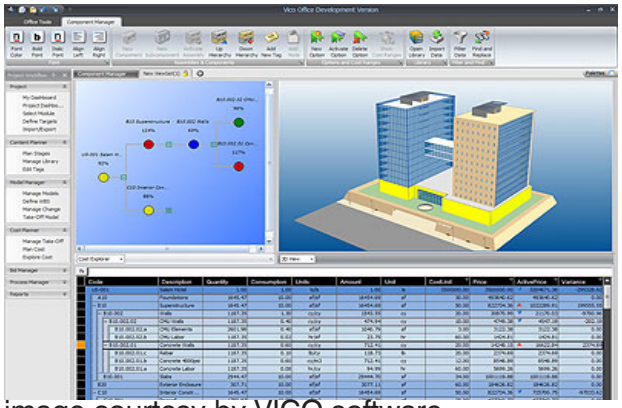


image courtesy by VICO software

4D/5D management and cost estimating systems like Navisworks and VICO software have the ability to use information from the VBMs to schedule and estimate costs of the project.

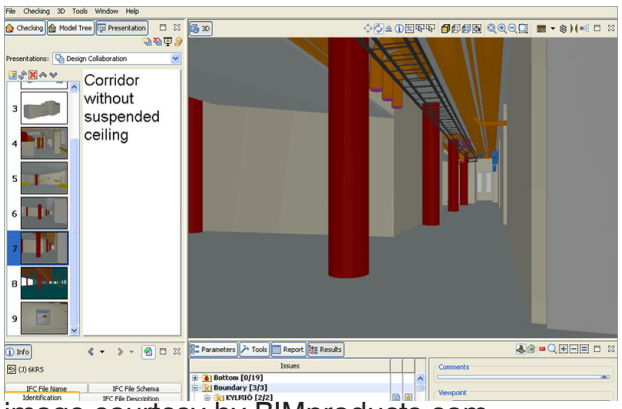


image courtesy by BIMproducts.com

3D clash detection and model reviews of the building construction are carried out in tools like Solibri (also operable in tools like Navisworks and VICO Office). A clash test tool, detects potential complications in construction, searching for overlaps, clashes, connections etc. to redesign before construction. The software is also used as a dynamic model viewer to be used in presentations and for design purposes.

2.1.5 BIM of Today

Despite the still increasing entry of digital devices in the AEC business, BIM has for more than 20 years struggled to establish as the preferred process of the industry. Not a clear answer is posted on this, but new design technologies are normally challenged by senior design team leader's willingness to adopt to new practices. Old expertise therefore coalesces with the new capabilities of BIM through a natural evolution. (Eastman et al., 2008)

According to recent surveys by McGraw-Hill, BIM is broadly adapted across the building industry in the USA. Over 50% of AEC and owners (AEC/O) in 2008 utilized BIM tools at moderate levels or

higher. The surveys also emphasise that the industry rapidly will increase their use of BIM in the future. Architects were at this point of time the heaviest users of BIM, while contractors were the lightest users of BIM related tools. (Taylor et al., 2008)

A report from Erabuild (2008) partly confirms the results, by their survey of the Nordic construction business. About 50% of architects and 40% of engineers in Denmark were in 2006 using BIM in some parts of their projects. But according to the proportions of usage of CAD and BIM for architects and engineers in Sweden, below 20% of the work is actually used in object based databases with access for several participants. This indicates that BIM operable tools mainly are used in independent design tasks and not for the process of BIM. (Kiviniemi et al., 2008)

A workshop related to the use of BIM and Radio-Frequency Identification (RFID) at Ramboll in 2011, highlighted that the VBM-work made by architects and engineers not necessarily was used by contractors and suppliers in later phases. The process often got staggered between the professions, which mean that all the extra effort made to create detailed 3D-models was none usable to the rest of the process. Caused by the fact of inconsistent use of BIM, VBMs were mostly acclaimed to be used in production of 2D-drawings and for traditional handover between stakeholders.(Appendix A)

So, even if a great amount of stakeholders within the AEC industry practises with BIM does not mean that they fulfil the requirements of a fully integrated BIM model. Over the past two decades, a great amount of computerised tools for design and analysis have been developed. Some of the computer programs have established itself as the preferred selection to construction engineering, while others are tailored to the need of architects and contractors. Operations are solved by separate tools, specific to the relevant task; if possible, every task should take advantage of the information in other VBMs.

The interoperability between software will influence on BIM to be the natural choice in construction building processes. If information is in-exchangeable between the tools of the AEC industry, BIM wont have any chance of becoming the integrated design process it aims for. Each of the software utilities then stands back as independent complex design tools, only usable for traditional project handovers.

2.1.6 Interoperability

The U.S. National Institute of Standards and Technology found that users bear direct costs of almost $16 billion annually from time wasted due to inadequate AEC software ability; a fact instantly confirming the lack of interoperability between software programs of today. (Gallaher et al., 2004)

Companies like Autodesk, Graphisoft and Bentley Systems have each developed AEC operable software packages within separate file-formats, challenging the interoperability between the profession's preferred tools. Unfortunately, none of today's software solutions are able to perform all BIM related tasks, and when the preferred tools within the industry are developed by diverse companies, interoperable challenges becomes a barrier for BIM to expand as a operational process between AECS.

IFC (Industry Foundation Classes) is a large set of data representations of building information for exchange between AEC software applications. It is developed by the buildingSMARTalliance (founded 1995) which through NBIMS (U.S National Building Information Standard) and the IFC file format works toward interoperability and open standards to the built environment. (buildingsmart, 2011)

In April 2008, IFC became registered by ISO (International Organization for Standardization) as ISO/PAS (Publicly Available Specification) 16739; an intermediate specification, published prior to the development of a full International Standard. (iso, 2011) It forces bigger software companies like Autodesk to become IFC-certified and is a big step towards IFC to become the preferred exchangeable file-format of the future.

Interoperability issues are present between software applications, where over 60% of the AEC industry list software incompatibility as the primary factor impacting team members 'ability' to share information electronically. (Pniewski, 2011) According to Bentley Systems Incorporated (2008) import and export of IFC files cannot be made without any loss of data or functionality. According to Pniewski (2011) interoperability issues is most certainly caused by lack of attention to the way IFC files are created for export. Complications are present in the resolving of geometry-related interoperability issues, but fully assembled interdisciplinary IFC models is found compliant, still requiring very careful monitoring and adjustments on case-by-case basis.

In July 2008, not long after IFC became ISO/PAS certified, Bentley Institutes and Autodesk agreed on exchanging software libraries, to improve the ability to read and write the companies' respective DWG and DGN formats in mixed environments. The companies aimed to improve AEC workflows by enabling broader reuse of information generated during the design, construction, and operation of buildings and infrastructure. This enhances the ability for project-teams to choose among multiple software sources to be used in their BIM services. (bentley, 2008)

Bentley and Autodesk's position in the AEC industry market makes their co-operation a clear threat against IFC to become the preferred file-format of the industry. Autodesk and Bentley are working on improving the API (Application Programming Interface) between their software solutions, which will ensure better information flow between programs. Today, Tekla Structures and Vico Office also have API solutions which support Autodesk Revit by exporting compatible Revit models for direct usage. (vicosoftware, 2008; tekla, 2011)

Time will tell if the IFC-format will survive, or the direct proprietary API-based integration between software solutions will be the future in interoperability between software. Either way, the most important fact is the software developer's willingness to make interoperability succeed. This states that the companies believe in the process of BIM to be the precursor of the future, and it kind of solidifies the necessity of adapting to the use of interoperable software solutions.

2.1.7 Future of BIM

Research indicates that BIM related modelling tools are widely used within the architectural and engineering industry, but do not exploit the full potential of the processes abilities. Interoperability between software applications is an important parameter to this, but a second factor is the resistance by earlier generation's ability to adapt to the process. As the bigger software operators now aim to increase the interoperability between software tools, BIM will become a process to count on in the nearest future.

Parametric modelling is a huge part of the BIM process. A wall is therefore no longer just a wall; it is a wall related to a line, so when the line changes the wall also do so. The fact that a VBM is a set of objects, all related to each other, means that when changing one object, all objects in any relation to this objects automatically change. This is of course a very effective way of updating models and drawings, but it also demands that the relations are correct; the modelling suddenly becomes a programmatic task which has to be carefully considered before execution.

Known from the computer industry, there is big amounts of work behind a simple application, but a fully working application can also save a lot of time and work later on. Therefore, the VBM should gradually evolve to create a base for later efficiency. The software performs most of the underlying programming, so the evolution of the design in BIM will be controlled from rules set by the software.

Suppliers to the building industry have started to offer detailed 3D objects as a service, in an attempt to prepare their business for the next generation of BIM. This means that architects are able to create buildings based on elements picked out of a construction library. Future modelling could therefore go towards being object based – grabbing elements from a database and assigning them in the digital model.

Software like Autodesk Revit is performing by the same rules as described in chapter 2.1.3. The evolution starts with the conceptual design of geometries, through functionality, constructional detailing and finally fabrication drawings. Tools to perform analysis within energy efficiency, construction, acoustics etc. are able to support the decision-making of the design and are continuously representative in the model development.

All of the software is dependent on specific types of information from the VBM to perform their tasks. Critical changes in constructions could affect the total design, and it is important to keep the LOD relevant to the stage of the project to avoid that unnecessary work is made. The design progression should evolve strategically, so BIM can become the time- and money-saving process it aims to be.

Software services related to the BIM process are the AEC industry's personal toolbox. In the same way as a carpenter knows when to use which tool for efficiency and accuracy, the architects, engineers and contractors must do the same when designing. It is therefore not necessarily a need for a constant co-operation between the three trade groups, but a more structured use of each professions quality to gain the project. To control the operative process, this structure needs to be supported by the project's agreements.

2.2 Delivery Process Agreements

Since the development of the design in BIM are significantly different from more traditional design processes, a need for tailored solutions are present. Therefore, it is found necessary to take a look at today's design and delivery processes in order to decide which suits the process of BIM.

2.2.1 Traditional vs. Collaborative Processes

BIM is only a process and needs to be supported by agreements on project responsibility between project stakeholders. Several project-delivery-agreements exist for different purposes in the AEC industry of today. Traditional delivery-processes as Design-Bid-Build (DBB) and Design-Build (DB) are currently the most practiced in the industry. (Eastman et al., 2008) Further, there are newer approaches like Partnering, Public Private Partnership (PPP) and Integrated Product Delivery (IPD) which focuses on value for money in an integrated co-operative process.

Generally, where DBB (DB partly) is related to the more traditional construction flow where AEC hand their work over in phases, the collaborative processes aim to have a constant flow of iterations between all/some of the participants. (figure 6) These approaches are significantly different and needs to be planned in different ways. While the linear flow is clearly defined, the collaborative flow has no pre-defined structure and will be harder to predict.

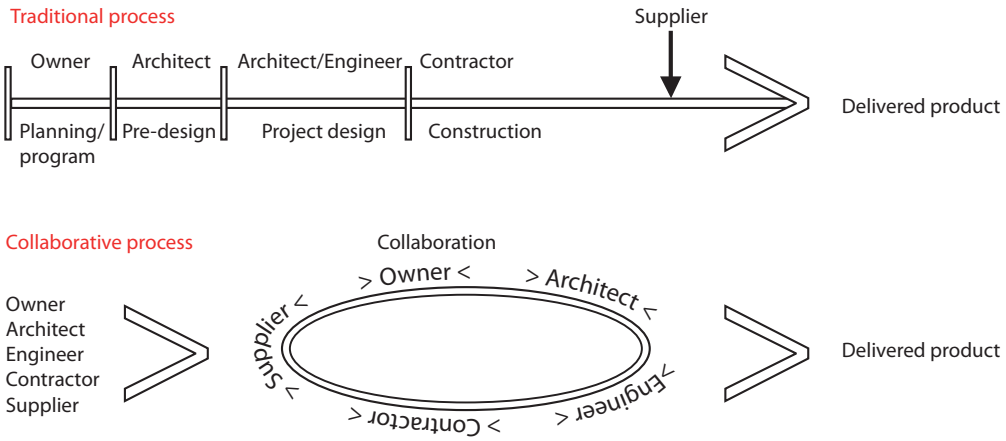


Figure 6 - Traditional vs. collaborative process (Dansk Byggeri, 2005): *Instead of the traditional workflow where the project is developed in sections, the partnering aim for all of the participants (owner, architect, engineer, contractor and supplier) to become a collaborative unit, where the projects develop in an integrated process until the product is delivered. (Dansk Byggeri, 2005)*

2.2.2 Design-Bid-Build

The owner contracts with separate entities for each of the design and construction disciplines in a DBB project approach. (figure 7) The main sequential phases are the design, the bidding and the construction, as the name describes. The full-service consultant is in collaboration with the owner, where architects and engineers are hired to develop the design and complete drawings and

specifications for the contractors to bid on.

The project can be offered to one general contractor or multiple sub-contractors that bids on sub-components of the work. The project usually involves several suppliers, to solve separate parts of the construction. This is usually rewarded to the lowest bid by the best qualified contractor. (ebst_1, 2011)

In cases where the offers are too high, the architect may revise their design or reduce features or elements of the project to bring the costs down. The owner also has the possibility to elect the most qualified bidder to join the architectural team to assist with cost reduction, a process often referred to as *value engineering*. (Eastman etal., 2008)

The general contractor usually limits his role to manage the construction process. Architects/ engineers are the owner's agent to review the progress of work; changing orders, or documentation, to solve issues within the construction process. Failures within the design team have no effect on the contractor's financial risk, but can result in delays of the project when redesign is needed. (ebst_1, 2011)

To the owner, the clear benefit of the DBB approach is the design team's impartiality, where they look out for the owner's interests in the project. All contractors place bids based on the same set of drawings, ensuring fairness to potential bidders, and the owner are free to select the most beneficial offer to the project. (ebst_1, 2011)

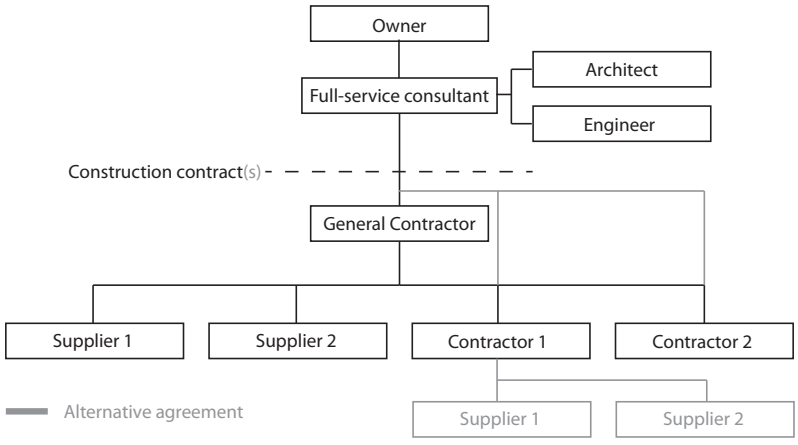


Figure 7 - Design-Bid-Build organisation: *Architects and engineers is the owner's full service consultant, providing the complete design of the project. A general contractor or several sub-contractors are signed to construct from drawings provided by the full-service consultant.*

2.2.3 Design-Build

Opposite from a DBB approach a DB approach only contracts with one single entity - the DB-contractor. (figure 8) The building construction is based on a set of preliminary descriptions to indicate the owner's requirements. This consists of written specifications only, or may be supplied with more detailed drawing-specifications. The system is used to minimize the risk of the owner/ investor and to reduce the schedule of delivery by overlapping parts of the design and construction phases.

The responsibility of the project is usually in the hands of the contractor, who includes a team of architects and engineers to manage the design. Being the risk takers of the project's success, the contractor will possibly control the detail of the design. DB-contractors are responsible for delivering the right product at the right time, regardless of the nature of fault.

The owner resigns from any direct design involvement going into a DB-contract, leaving the detailing of the project in the hands of the DB-contractor. The contractor is free to interpret within the specifications of the design requirements. While a DBB process claim for designers to keep the design dissociated from the contractors interest, the DB does not. Therefore, a DB process will be poorly suited for projects that require a complex and elaborative design for aesthetical and technical purposes.

Using the DB approach, the owner is fully aware of the total cost of the project and leaves the risk of the project completion in the hands of the contractor. The owners risk lies in the delivered product, where the contractor focuses on cost-benefit – still meeting the requirements of the contractual agreement.

(Danskbyggeri, 2011)

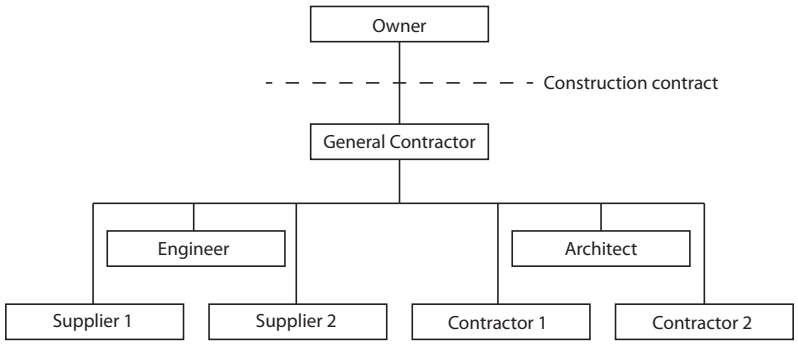


Figure 8 - Design-Build organisation: *Architects and engineers are engaged to design a project by the general contractor. The owner only contracts with the general contractor, who controls the complete process of the project and involves suppliers and sub-contractors if necessary.*

2.2.4 Partnering

The objective of partnering is to be a long-term collaborative effort between a group of companies, aiming to benefit clients and companies alike. Today, this is mostly a single-project strategy based on the idea of dialogue, trust and openness, seeking for closer relationships between parts in a project. Partnering involve all parts regarding design and construction early in the project, integrating the knowledge of different professions. (Gottlieb, 2010)

Partnering is based on the partners' common goals in the project where process and product are solved in the most economic and time efficient way. The project's success parameters are formulated by common activities and economic interests within the owner and AEC group. The partnering method design and construct the project in a collaborative process as defined on figure 9. This means that contractors influence the design with their experience and specific construction knowledge at much earlier stages. (ebst_1, 2011)

The process aims to give the owner a process with potential of saving time in both design and construction, resulting in better quality at more reasonable prices. Every part of the team has an interest in the shared profit from the project, and the process reduces many of the disagreements which usually influence design and construction projects. The project is dependent on fair regulations of the initiatory agreements and the partner's willingness to co-operate. (ebst_1, 2011)

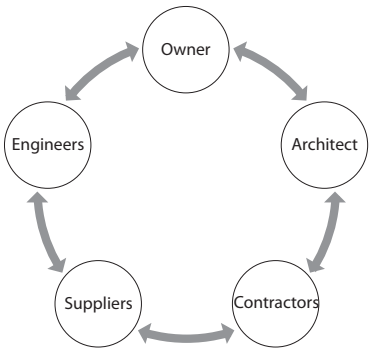


Figure 9 - Partnering - collaborative organisation: *Owner, engineers, architects, suppliers and contractors all co-operate. They have an equal responsibility for success in the project, where the contractual agreement is based on common goals and shared profit from project savings.*

2.2.5 Public Private Partnership

Public Private Partnership (PPP) is an agreement between the public and the private sector, where the financial share from the private partner is substantial to the project. (ebst_2, 2011) The contract is a long term rental agreement, where the private sector takes care of finances, design, construction, operation and maintenance for a typical period of 20-30 years; a typical organisation is illustrated in figure 10. PPP could be used for a public building like a school, sports arena, etc. or a public service like the subway (pwc, 2011).

With the objective to increase project quality compared to traditional construction agreements, it is a shared risk in the project like in partnering (chapter 2.2.4). The facility is owned by the investor, which means that the private sector is responsible to the construction and maintenance of the building. Investor, operator and general contractor have a long distance perspective in mind when designing and constructing the building; cost effective solutions can in this matter be essential to the total profit of the project. (Grimsey & Lewis, 2004)

The public sector has full awareness of their expenses in a long period of time when choosing PPP, also secured a fully functional complex for all of those years to come. The financial risk of the project is mainly in the hands of the investor, operator and general contractor.

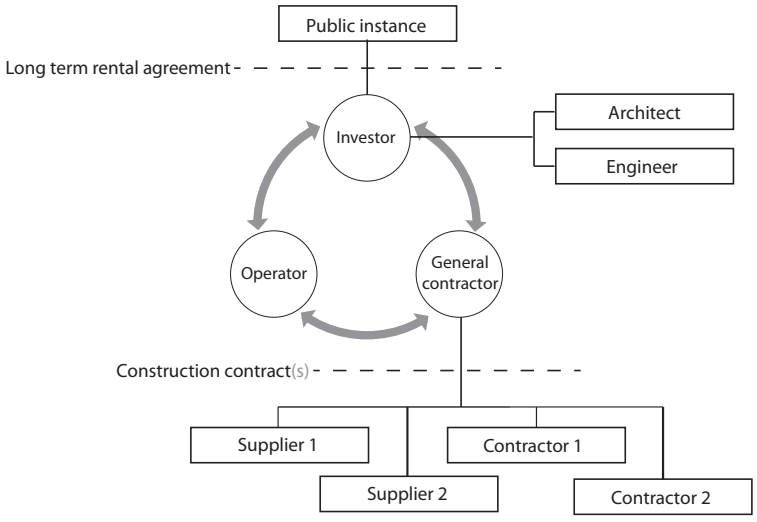


Figure 10 - Public Private Partnering organisation: *Public instance sign a long term rental agreement with an investor, who in collaboration with an operator and a general contractor are responsible for the result and quality of the product.*

2.2.6 Integrated Project Delivery

Integrated Project Delivery (IPD) is a project delivery approach that harvest on the full potentials of the complete design team; a collaborative model sharing the risk of the project between owner, consultants and contractors. IPD integrates people and system, business structures and practises into a process that collaboratively exert the talents and insights of all participants. (figure 11) The objective is to optimize project results, and increase value to the owner, by reducing waste and maximize the efficiency through all phases of design, fabrication and construction.

In IPD, collaboration between the owner, the prime designers and the prime contractors commence at early design stages, continuing their collaboration until project handover. IPD teams can include bigger selections of members, applying the principles into a variety of contractual arrangements suited to the individual project. Key participants should be involved from the earliest practical moment, dependent on the presumed need of knowledge and expertise.

Trust is a essential factor since IPD involves many participants in a collaborative undertaking. Obtaining an optimal collaborative process, includes the need for a transparent process, open information sharing, shared risk and reward, value-based decision making, and utilization of full technological capabilities and support. Each member's success will rely on the team, which like the approach of partnering is tied up on the success of the project.

IPD increases the effort from designers and contractors during early design phases, aiming to reduce documentation time and improve cost control and budget management. Early estimates on the project are used to optimise design in benefit of project quality and financial performance. Challenges in leading the process and have full benefit from all of the participants is present and the stakeholders must rely on everyone to perform as a team. Generally, IPD is very similar to the partnering process, but in IPD all of the partners commit to a defined system; a system which could be BIM or similar.

(AIA, 2007)

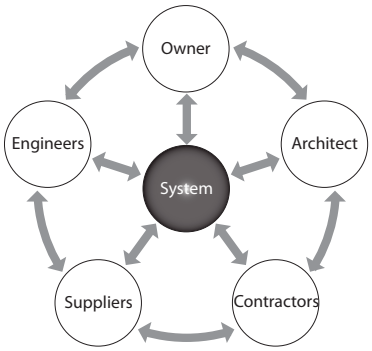


Figure 11 - Integrated Project Delivery - organised around a system: *Owner, engineers, architects, suppliers and contractors all co-operate. They have an equal responsibility for the success of the project, where the contractual agreement is based on common goals and shared profit from project savings.*

2.2.7 Approach for BIM?

Beyond the described processes there are several other ways to assemble a design and construction team. To fully benefit from the use of VBMs, it is important that the approach of the project suits the system of BIM. BIM is a process aiming to involve stakeholders in a systemised information flow for optimal collaboration, having many of the same intentions as IPD.

Even if IPD seems to be the natural choice between the delivery processes, one cannot expect this to be an overall process to all BIM usage. All other processes are set to be co-operative in one way or another as well, involving AEC/O at different stages and for specific purposes. BIM is useful on many levels and the combination of contractual agreements depends on the owner's intentions with the building. Generally, it is possible to involve BIM as a process within all of the described delivery agreements.

Either way, BIM is designed to be active from the beginning of the project, through the construction and during the operation of the product. So, BIM must be seen as an integrated delivery of a VBM and needs to consider the system and structure like IPD does.

BIM defines collaborative use of VBMs, so linear approaches as well as iterative are usable. Knowing that a lot of work is put into the early construction of VBMs, where the effort made not always is useful in later phases of design and construction (chapter 2.1.2), a need to strictly define how to evolve on the project is present. Using structured agreements for when to involve parts and for what purpose, will gain the evolvement of the project.

To define each participant's involvement is a difficult task to perform preliminary to a project. The purpose of using VBMs is to keep the informative level intact from one phase of the project to the next. The transferability depends on the interoperability between the stakeholders completed work models and the model to be made next.

One business cannot be expected to put extra effort into their work in order to please another business if no incentives are present. Therefore, to secure that VBMs are usable to all participants of the project, BIM is probably better suited with the use of collaborative agreements between stakeholders.

2.3 BIM Standards

To support the agreements between stakeholders of a project, certain standards are developed to support BIM as a process. Both in Denmark and the United States of America (also present for other nations) documents are worked out by official building organisations on how to practice a BIM process most coherently. It is found relevant to evaluate the Cad-manual C102 from Bips and the Building Information Modelling Protocol Exhibit E202 from AIA, for their ability to structure a BIM based project and to further inspire how to overcome the challenges which AEC projects encompass.

2.3.1 C102

In Denmark the *CAD-manual C102* from 2008 by Bips (acronyms which translated to English means: construction, information technology, productivity and collaboration) lists a set of guiding frames to BIM projects. The *C102-manual* describes the intended use of VBM in a BIM related production; specifically it describes the model structure and how to model productively between project stakeholders.

The *C102-manual* suggests that the project is developed in subject specific models each controlled by the executer, and that they are consolidated through a shared model. This structure is recommended to the respective trade group's use of individual work tools. Discipline work-models for internal use are needed and also discipline models for exchange with the other professions (figure 12)

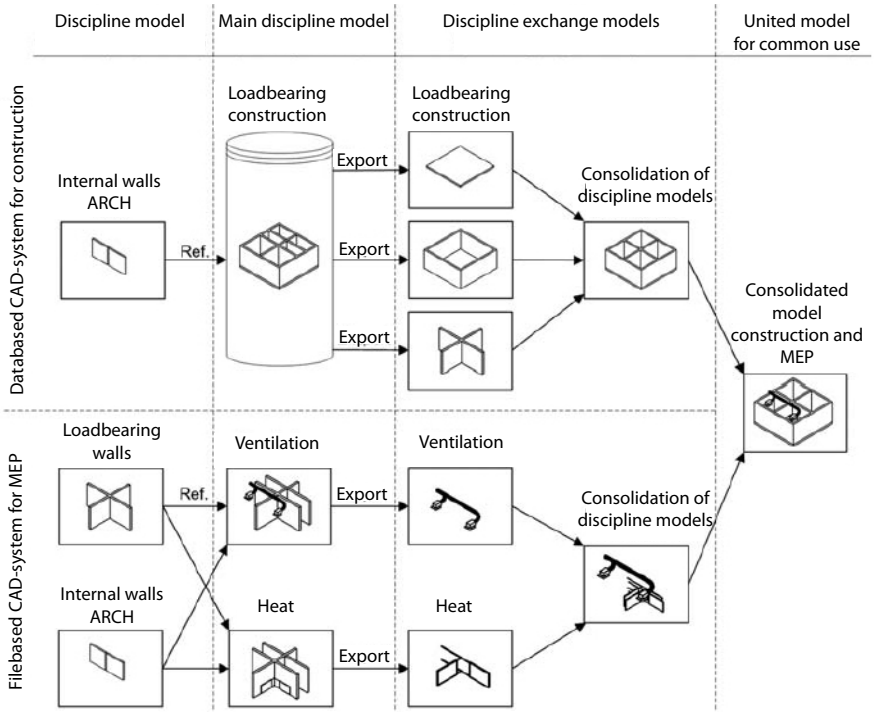


Figure 12 - Interdisciplinary use of VBMs (Bips, 2008): *The figure illustrates how C102 intends that we structure the VBMs in interdisciplinary collaborations.*

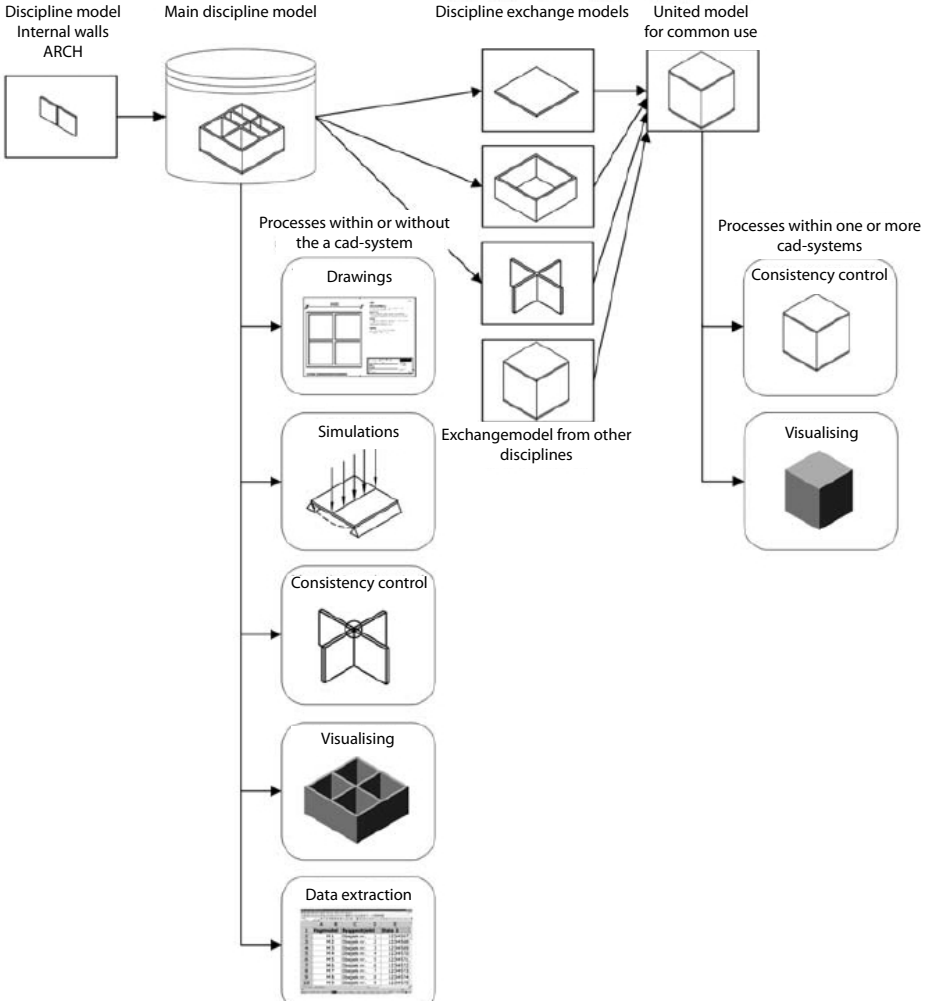


Figure 13 - Principle use of VBMs (Bips, 2008): *The figure illustrates how C102 intends the structure of VBMs to be using discipline models, exchange models and consolidated models for different purposes.*

In figure 14, *C102* suggest that subject specific models will be used in drawing production, simulations, consistency control, visualisations, and other specific services. From the basic model, several models can be extracted for specific purpose, e.g. shell construction, internal walls or other categories. Work can be made within these separately, and then later consolidated through a main model including every design discipline in a consistency control and review of construction.

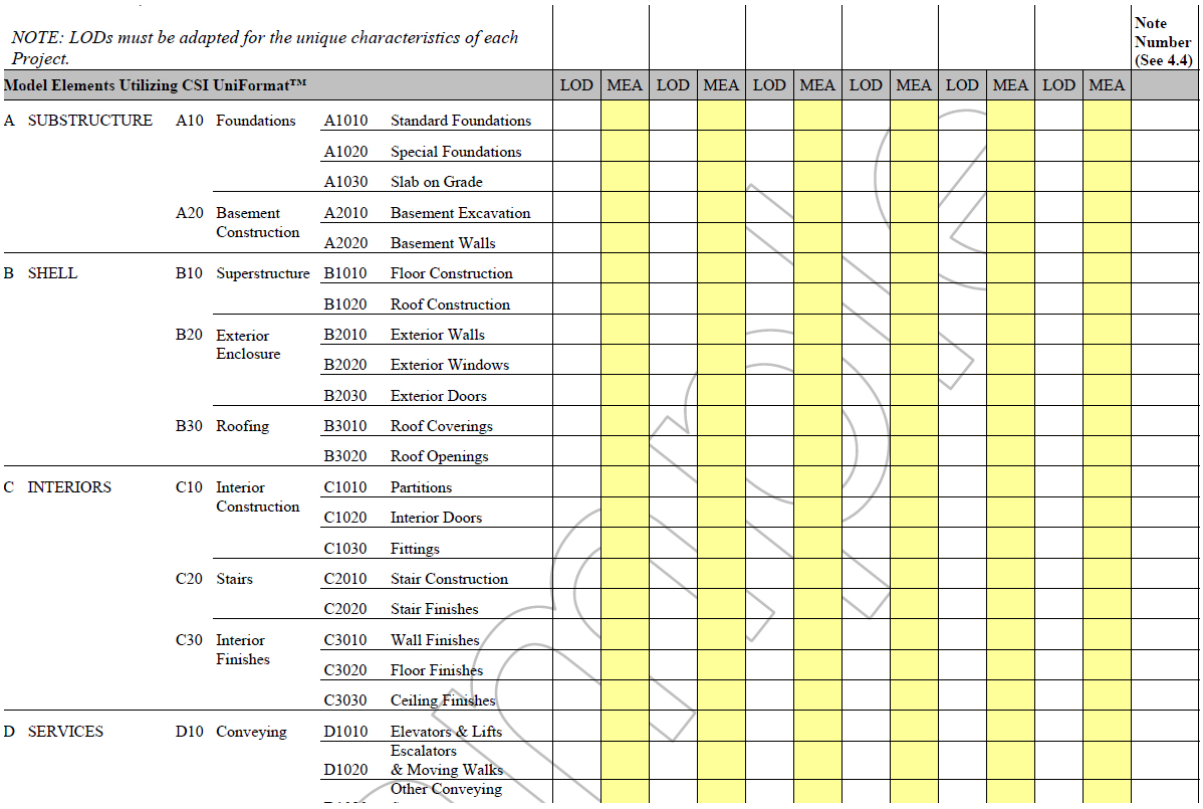
Building attributes should be attached through layers, either as a separate database or directly in the building model. There are pros and cons for both solutions, very dependent on the organisations and the cad-specific opportunities. The system aims for the model to be manoeuvrable, still securing the information to be attached within the geometry.

C102 lists a lot of design requirements and guidelines to follow, but no real agreements on how to develop the model. A supplement is a set of Bips paradigms, that structures ICT-specific agreements on how to communicate, structure processes, exchange file-formats, where to position the model, etc.. The paradigms are used as agreements and refers to the use of *C102*, this do describe how to structure a set-up and make the system work when using VBMs, but it do not define an agreement on how the design process should progress.

Construction and design processes are very individual and the manual is therefore important to the communicative understanding of how BIM processes are intended to evolve. The structure of planning BIM processes can be developed from the intents in this manual, but the manual is to diffuse for design and construction entities to purely rely their agreements on.

2.3.2 E202

Construction design tasks are very individual and what AIA have done in their *Building Information Modelling Protocol Exhibit – E202* is to create a manual to be used as an agreement between individuals, including a *Model Element Table* (figure 14) to define the development of the model to the responsible parts. This is a supplementary template to the standard agreements relevant in BIM and IPD based processes.



NOTE: LODs must be adapted for the unique characteristics of each Project.

Model Elements Utilizing CSI UniFormat™					LOD	MEA	LOD	MEA	LOD	MEA	LOD	MEA	LOD	MEA	LOD	MEA	Note Number (See 4.4)
A SUBSTRUCTURE	A10	Foundations	A1010	Standard Foundations													
			A1020	Special Foundations													
			A1030	Slab on Grade													
	A20	Basement Construction	A2010	Basement Excavation													
			A2020	Basement Walls													
B SHELL	B10	Superstructure	B1010	Floor Construction													
			B1020	Roof Construction													
	B20	Exterior Enclosure	B2010	Exterior Walls													
			B2020	Exterior Windows													
			B2030	Exterior Doors													
	B30	Roofing	B3010	Roof Coverings													
			B3020	Roof Openings													
C INTERIORS	C10	Interior Construction	C1010	Partitions													
			C1020	Interior Doors													
			C1030	Fittings													
	C20	Stairs	C2010	Stair Construction													
			C2020	Stair Finishes													
	C30	Interior Finishes	C3010	Wall Finishes													
			C3020	Floor Finishes													
			C3030	Ceiling Finishes													
D SERVICES	D10	Conveying	D1010	Elevators & Lifts													
			D1020	Escalators & Moving Walks													
				Other Conveying													

Figure 14 - Model element table (AIA, 2008): *Section of a model progression specification table. The table divides the potential subject specific VBMs into systemised groups where each model have a LOD and MEA (model element author) defined to each phase of the project.*

The exhibit establishes the protocols expected levels of development, and authorised uses of VBMs on the current project. When used correctly, the document assigns specific responsibility to the development of each subject specific model and the defined LOD at each project phase. *E202's model element table* is required in listings of the LOD and responsible person (MEA) in each of the model specific design tasks.

E202 very well define the model characteristics through their model content requirements at each LOD, and further the models ability to perform analysis, cost estimation, scheduling and other

authorised tasks at this stage. Combined with the model element table presented, the exhibit covers many aspects in leading design evolvement within VBMs.

2.3.3 Use of Standards

Comparing *E202* and *C102* to the IPD (chapter 2.2.6), they support the functionality of the central system. Instead of relating to the general project approach of pre-design, schematic design, design development, constructional design, etc. they both relate to the development of the model by informative levels. There is a clear mismatch between the processes from using BIM and the traditional constructional processes of the AEC industry. While the traditional phases of a project purely rely on the linear approach, BIM focuses on collaboration and iterative design development. This means that model specific tasks in BIM do not need to be made parallel to one another and the LOD only raises when information is needed.

From both *C102* and *E202*, the model development is described as a collaborative process including several stakeholders of the project. Even if they describe the functionality of the system, it does not relate to the communication between the project stakeholders. The division of tasks are clear but no considerations are made on relations between tasks. Indications for what purpose the models are created or how to design information to gain the process is not presented in any template.

2.4 Concurrent Engineering

While the building industry has struggled to stay productive and increase their profit of construction, the non-farm industries have increased their efficiency and profit over the last couple of decades. (Teicholz, 2004) BIM wants to alter this tendency by using VBMs in a parallel co-operation between AECs. This ideology is similar to the management system of Concurrent Engineering (CE) which therefore seems relevant to be inspired from.

CE is a relatively new design management system approaching to optimize engineering design cycles. CE aims to produce higher quality, well-designed products at lower prices and in lesser time. Awareness is directed toward the design process in CE; theoretically it takes distance from the linear design process and aims for the preceding design activities to occur at the same time - as a parallel design process. (Jo, Parsaei & Sullivan 1993)

The purpose of CE is to modify the sequential waterfall model in figure 15 into an iterative and integrated design model like figure 16. Using tight integration of applications and parallel engineering it is possible to achieve concurrency and close-up evolution in the production and manufacturing processes. (Ma et. al. 2008) CE aim to utilize the best equipment and techniques available at the right time. (Aswald, 1996) This involves bigger parts of the design team, allowing errors and redesigns to be discovered at earlier stages where cost of changes still are relatively low.

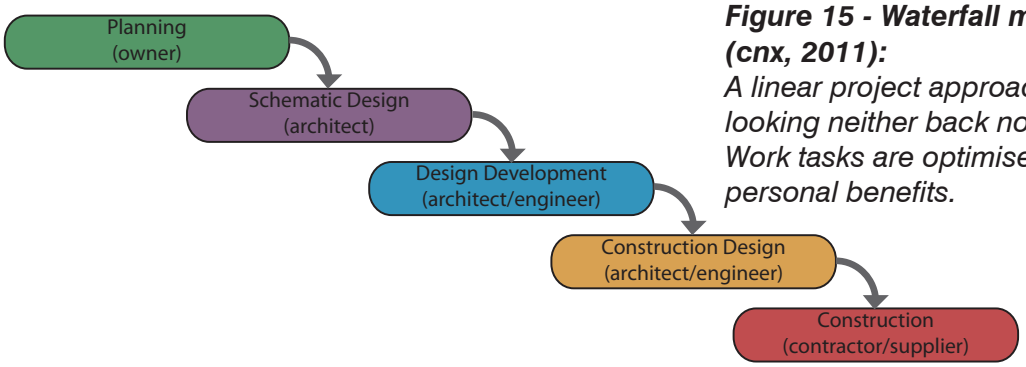


Figure 15 - Waterfall model (cnx, 2011): *A linear project approach looking neither back nor forward. Work tasks are optimised for personal benefits.*

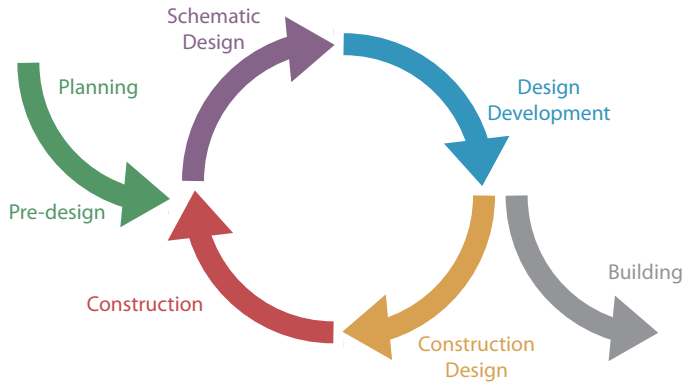


Figure 16- Iterative process (cnx, 2011): *A cyclic progression of the building construction, where all aspects of the design are integrated in an iterative process. Involves owners, architect, engineers, contractors and suppliers in the design evolution.*

While the waterfall method works in a completely linear fashion, looking neither back nor forward from the present step to fix problems from. Iterative processes are more cyclic, where the individual engineer is given much more to say in the overall design process. In those cases where things fail in a waterfall model, the design usually becomes heavily altered, or in worst case scrapped; flaws which are avoided by the use of iterative design processes.

CE has the same intentions as the collaborative processes within the AEC industry. CE supports the iterative thinking by the definition of activity relations. This to control the engineering processes related to the industrial design and production.

2.4.1 Activity Relations

Making concurrent engineering work properly, activity based relationships need to be clarified. The intention is to map the process in order to evaluate how the activities affect each other. If two activities can be effectively overlapped depends on the relationship between the two activities. Four types of relationships are described to be possible between activities: dependent activities, semi-independent activities, independent activities, and interdependent activities. (figure 17)

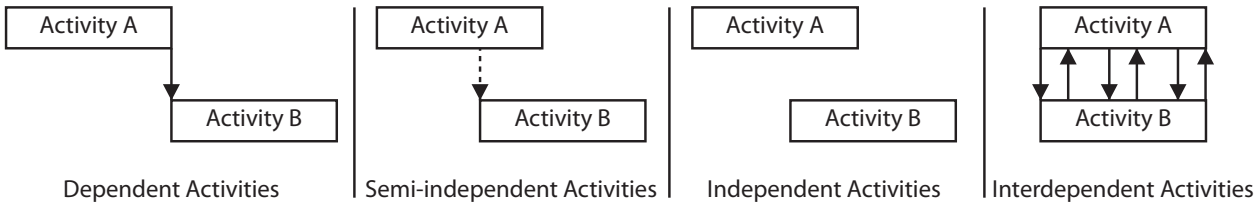


Figure 17- Activity relations (Bogus et. al., 2005): *Figure describes the relations between different kind of activities, it is used to map which activities to be made at what time.*

For dependent activities, the second activity will require completion of the first activity to start; semi-independent activities only require partial information from the first one to be processed. Independent activities require no information from other activities to begin, while interdependent activities requires a two-way information exchange between the two activities before either of them can be completed.

Only independent activities can be overlapped without any risk of delay or rework based on the other activities. In dependant activities, the downstream activity relies on information from the upstream activity and it is risky to perform parallel to one another. In semi-independent activities, the downstream activity has to begin before all information is transferred from the upstream one. In these cases increased communication and exchange of preliminary information becomes very important.

(Bogus et. al., 2005)

2.4.2 Concurrent Engineering in the AEC Industry

CE was designed to reduce product development time and has through the last couple of decades received much attention within the manufacturing industry, but has with lesser extent been practised

within the AEC industries. (Bogus et. al., 2005) Contractual agreements as DBB delivery processes are based on the waterfall model, supporting individualism by not bestowing any risk from one level to the next. The responsibility of success is left at each step and within the hands of the executer.

Several researchers have addressed CE in the AEC industry, based on the many similarities between product development in manufacturing and the design construction process in the AEC industry. DB delivery processes are partly based on the CE where general contractors use a team of architects, engineers and suppliers to perform under their leadership. IPD gets closer, partly based on the same type of values as CE. Both are collaborative construction processes where each individual engineer and contractor is highly integrated in the design development.

As the integrated BIM model shows (figure 2), BIM is based on information from several engineering professions. To maximize the investment in a BIM based workflow, it is necessary to apply a bit of planning to the initial process; defining a strategy to answer: what processes are needed to employ; which people and team members is key to these processes; and what technologies or applications are needed to support people and processes. (Krygiel, Read & Vandezande, 2010) To obtain full potential from BIM, one have to rely on the leadership of such a process, being fully aware of when to utilize the right tools and perform the right activities.

Practice of leadership in BIM processes has potential to benefit from implementation of CE management. Inspiration from the way CE plan activities by relations, can be used to make the iterative collaborative process become a highly effective and cost saving design approach.

2.5 Case Interviews

BIM is a relatively new type of project process for constructions in Denmark. A new project at the harbour in Aarhus has decided to take in use BIM. It is a rather large project with an estimated price of about 2bn DKK and it will take almost a decade to complete. There is hired a client advisor to the project, being the owner's supportive act in the project.

The full-service consultants at the project were chosen from an introductory design competition, where three design teams were selected to do a project negotiation. The client advisor structured a nearby cross examination of the design teams, where they had to certify their project constructions, design and economic evaluation. The winner was selected from the finalists' ability to keep their design within budget and solve the risks related to complex constructions or similar.

Interviews have been made, with one representative from the owner and one from the advisor group, to get closer to understand BIM usage in a real time processes and their intentions of using BIM in this project. Described in this chapter, is the most important facts from the two interviews (their intentions, collaboration and strategic evolvement).The presentation is based on the answers given, with following comments from the interviewer (author).

Interviews can be read in Appendix B and C.

2.5.1 Interview with Owner

The interviewed person is part of the owner's board of secretary and is the voice of the future users of this facility. The person entered the project after the full-service consultants where selected and is responsible for the 3D-model supported by the client advisor.

(Interview was made in Danish as presented in appendix B)

Answers & Author's Comments

O: *The board of secretary had expectations for the VBM to be used active in their decision-making, but the operability of the Revit model is not as user-friendly as expected. Even the architects who do representations in the model have difficulties with navigation caused by what seems to be massive loads of information.*

Author comment: As the group use Autodesk Revit for all design purposes, means that the model becomes massive. Looking at the software opportunities described in earlier sections, software like Solibri, Navisworks or VICO Office will probably be more appropriate to these services. Otherwise, it indicates that a lot of unnecessary detailing are included in the model which have no direct effect on the owner's use of the model.

—

O: *It is heavily debated if the full-service consultant delivers a VBM in accordance to the contractual agreements. But it seems that the VBM effectively extract 3D-images and 2D-drawings for visual presentations. These presentations are used to make decisions within the board of secretary.*

Author comment: Even if the project is carried out in a VBM, most of the material seems to be made on traditional manners. This indicates that the VBM is not designed for dynamic navigation, but for drawing production. The positive effect is for 3D-images and 2D-drawings to be effectively produced when needed.

—

O: *Tools which are used by architects, engineers and landscape architects do not operate well together which is emphasised when VBMs are used in presentations. The professions are forced to take software in use which they are not used to. Some work will be produced twice; both in their preferred tool and later in a BIM related software.*

Author comment: This solidifies BIM's position in the market, where the interoperability between design disciplines is lacking. Also cultural aspects within the AEC industry, seems to obstruct the flow of the BIM process as they do not adapt to new and BIM supportive design tools.

—

O: *At this stage, where the design development is completed, only major decisions about construction, energy related aspects, indoor climate, solar radiation etc. are made. Every aspect related to internal walls, inventory and surfaces are not decided at this moment. Often the architect brings us more information than needed for us to make decisions. It is no general indications on when project specific decisions should be made.*

Author comment: Most of the major decisions about construction and building geometries are made in early stages, while more detailed aspects about the sectioning is postponed. To architects who usually incorporate all aspects of a building when designing, this can become a difficult barrier to handle. Their natural way of thinking a design must change in terms of the owner's willingness to progress on the project. An overview on project evolvement could probably benefit the understanding of the project progression.

—

O: *There are different perspectives on the use of visual presentations in the project. Architects are very much focused on representing the architectural vision, while the group of owners sometimes have another objective with the use of information. If I knew that the discussions about visual presentations would have caused so much effort, these aspects would have been cleared out earlier in the project. The contract between the full-service consultant and the owners do not seem to fit the ambitions of the project.*

Author comment: A cultural barrier is affecting the amount of work devoted to the project at each presentation. While architects wants to offer a lot of time on creating esthetical perfect drawings, the owner group usually have lower expectations to the presented material. This can cause a lot of extra work which in general could have been avoided by stricter agreements and common understandings of the personal needs.

—

O: *3D-models have a great effect to the understanding of the building's geometry and spatiality, where 'normal' people like me can have a hard time converting plans and sections into 3D-visuals.*

Author comment: The VBM has potential to explain the spatiality and geometry in ways that are easily understandable to everyone; this probably avoid lots of misunderstandings.

—

O: *We work on an interactive presentation of the building on-line, so citizens can enter the building virtually. These models will be based on validated phases of the project, so when the project becomes more detailed the on-line presentation will be as well. The goal is for citizens to come with their personal comments on the project design, for use in the design development.*

Author comment: The ambitions for interactive use of the VBM, demands very clear guidelines on the VBM's LOD and considerations on how citizens will respond to the model. If citizens expect a realistic view of this new building, but only have access to low levelled detailed illustrations the effect can turn negative. In these cases, it should be considered how to achieve the most optimal presentation.

—

O: *The owner group have intentions of using the VBM in their operation of the building, always having access to detailed building information. It should be possible to extract information on flooring and window areas, and technical information about certain installations for use in service operations.*

Author comment: For later operational usage it is obvious that the VBM needs detailing that supports the facility management. It is kind of worrying that the VBM is not operable in the early design phases - will it then be operable to the owner. It demands a strategy for the informative level of the VBM when it is handed over at the project's completion.

—

General
It became obvious in the interview, that the VBM was hard to operate and not user friendly. This delimitates the potential use of the model in the project decision making. There were disagreements between stakeholders on material handover, and drawings and illustrations did not match the owner's requirements. Usually, the project handover was more detailed than necessary. The complications of the workflow is illustrated in the work model (figure 18).

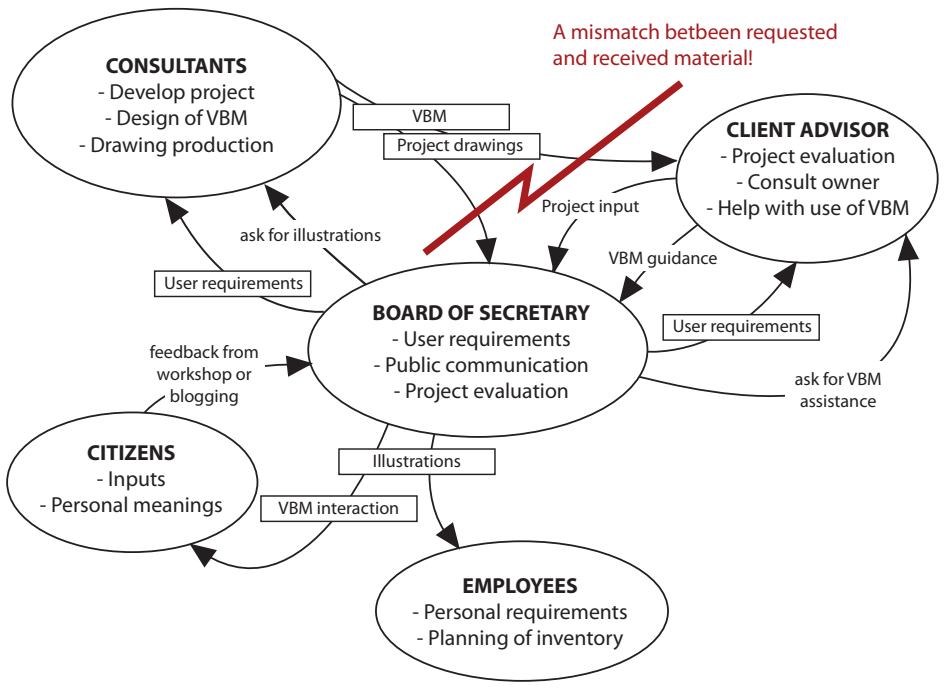


Figure 18 - Work model for information flow around the board of secretary:
The board of secretary collects requirements and feed-back from citizens and employees. The feedback is based on usage of illustrations and the VBM to obtain project understanding; this information is requested from the consultants. VBMs and drawings are handed over by the consultants, both to the client advisor and to the board of secretary.

2.5.2 Interview with Client Advisor

The project leader of the client advisor is interviewed. The person's task is to make sure that the project stays within the economic frames and scheduled time and take care of the owner's interests. Therefore the client advisor is in close relation with the full-service consultants.

(Interview was made in Danish as represented in appendix C)

Answers & Author's Comments

CA: *There were no restrictions on the use of BIM in the design competition, and the design propositions were made in 2D/3D-software. It would not be reasonable that the design teams should work out projects in BIM, because the architects continuously change their design concepts.*

Author comment: Even if the project later is executed in BIM, there is no need for architects to use these principles in their preliminary design development. It is important that tools with the highest efficiency will be used - there is no guarantee that the project will win. Otherwise, a preliminary design made in BIM supportive tools are directly usable in the next step of the process, but if the process becomes too time consuming when sketching, there is no gain to the overall process.

—

CA: *It is made clear in the design competition program that the project has to be made in VBMs, so the information can be used continuously in an integrated design process between architects and engineers. There is no specific contract related to the use of VBMs, but certain notes describe the owner's intentions by the use of VBMs.*

Author comment: It seems like the agreements between owner and the full-service consultant are a little diffuse on how to the design in VBMs, probably this cause confusions on which services to deliver through the project.

—

CA: *The intentions of using BIM in this project were the desire to keep the project within budget, and to arrange early procurements on specific construction services. We also wanted the project to be editable where the parametric abilities in the VBM could reflect the consequence of these changes both economic and construction wise.*

Author comment: To include contractors in early procurements and keep a constant eye on the strict budget is something that affects the progression of the project. The LOD has to be precisely described to the different phases of the project. The model must be well structured to retract units and have a complete overview of the consequences of design change.

—

CA: *All the project designs are made in Autodesk Revit, software not supportive to all design professions; as client advisor we personally use Tekla Structures. The landscape architects refuse to use 3D-software in their design planning. This only reflects the landscape architects lack of technological knowledge within the field; several other projects are carried out with high precision in digital 3D-software. I guess that the design models are consolidated at least once a week for clash tests and information exchange.*

Author comment: Designing in Revit is not the most effective way for all trade groups involved. A lot of the designs are carried out in none interoperable software and later redone in Revit. This do

not relate to the basic intentions of BIM processes.

—

CA: *The structure of the project design development is controlled by us, where we operate by something referred to as last-minute calls. This is a deadline on when certain parts of the project must be fixed - the point of no return. These decisions are graded by their risk of affecting the final building design. Caused by the specific restrictions of the technology the fully automated parking arrangement is one of the first aspects to fix. This also counts for the shell construction which involves a contractor.*

Author comment: This is a specific strategy for decision-making based on the risk of affecting the final result of the project. Therefore, the LOD needs to rise differently through the whole project, some parts will be detailing while others still are in a schematic phase. This thinking harmonises with the iterative process of CE, where decisions are made when needed to maintain optimal progression.

—

CA: *The full-service consultants do not always agree on project-evolution; they have clear intentions on the project to be* ***more*** *detailed than we want it to be. At certain stages the LOD is not defined initially, but is demanded from us when project decisions are needed.*

Author comment: Even if the client advisor has a strategy on decision-making, it does not seem to be communicated clearly to the counsellors of the project. Different approaches to the project evolution results in unnecessary work to be made. An agreement on the strategy will be helpful to optimise the design progression.

—

CA: *Architect designs by their most effective strategies, mainly relate to more traditional design routines. When consultants' assign to the design progression which we find best suited for BIM, it seems like they become challenged. Even if the architect wants to, it is no need to fix decisions on internal walls when they are not to be constructed in years to come.*

Author comment: It is a cultural barrier between traditional design processes and the design development of this project. For BIM to have a positive effect on the total work flow, new design progression agreements must be developed to these projects. AECs and owners must agree on how to carry out the design in the most cost effective and time saving way.

—

CA: *Between us (owner/advisor group) and the full-service consultants, there are constant disagreements on which decisions to make. We are very clear on the fact that decisions related to surfaces, glass, roofing etc. will not be made until later on in the project. Postponing decisions means that certain precautions have to be made, for instance all columns are made with space for installations, and the roof is constructed to carry sedum if wanted.*

Author comment: Preparing constructions for every kind of need will increase the project's costs. Therefore, it is important that the owners do not postpone every decision. If too many costly precautions are made, they might end up with no savings and none of the solutions.

—

CA: *When changes are made in design or construction, it is incredibly effective to recalculate the project based on the VBM. This is really helpful in keeping the project within budget.*

Author comment: VBM and BIM is obviously an effective design method to extract information. Precise cost calculations will affect the decision making based on exact information, minimising the risk for unexpected expenses. The VBM also helps the contractors to calculate their offers based on the very same information. Contractors do not need to make the same precautions since the list of units is precise and cannot be misunderstood.

—

CA: *The shell contractor of this project is responsible for the construction-work to run properly. The contractor is connected through a partnering inspired agreement, aiming to optimize the building construction in collaboration with the architects. Their offer is based on a mass unit calculation from the VBM which makes it is easier to sign incentive deals. I believe that incentive agreements have gained the quality and economy of the project significantly.*

Author comment: The precise information a VBM contains seem beneficial to partnering agreements. Precise masses and units are precise and expose the contractors calculated profit. Thus, it is easy to retract or add elements based on these calculations. So, if design changes affect the construction, the new remuneration will be recalculated from the contractor's earlier offer. A pre-agreement on the cost of the construction and incentives offered on design optimisation is probably a preferred way to include contractors or suppliers in earlier design phases.

—

CA: *Only constructions which effect the design of the building is offered in a collaborative agreement. Other services like construction work etc. are offered at lowest price, where the contractor themselves are responsible for the design of the project.*

Author comment: It optimises the project quality to let contractors' specific knowledge be part of the project design. Owner must make clear that this is the intentions of the project, to avoiding that the full-service consultants carries out detailed work for no reason.

General
It is obvious that the client advisor has an approach on the development of the project. The company uses last-minute calls to systemise the need for building information and to deal with case specific agreements with contractors. To some contractors the LOD needs to be higher than for others. But the consultants do not necessarily follow the same idea on model development (figure 19) hereby avoiding an incongruence between the requested VBMs and created VBMs. Owner/ advisor and consultant do not share the same expectations to the project, and do not have common understanding on the project development. This might be caused by poor agreements or general lack of communication between the project stakeholders.

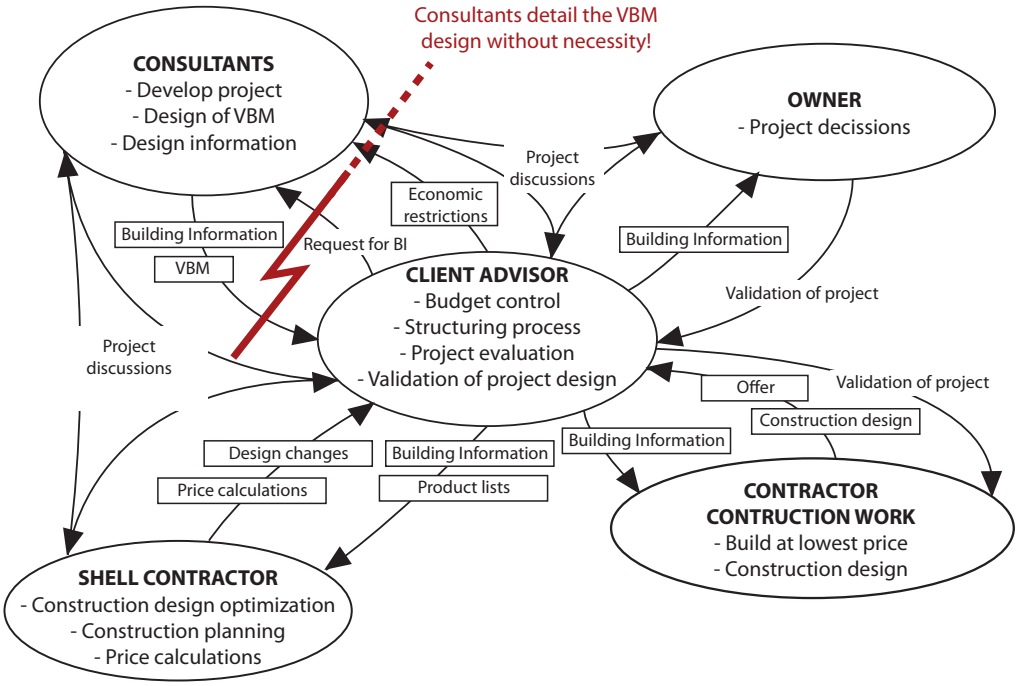


Figure 19 - Work model for information flow around client advisor: *Client advisor is the central communicator of building information to contractors and owners, validating the project before handover. Referring to the client advisor, the requested models are more detailed than necessary, and the information currently irrelevant.*

2.5.3 Consolidation of Interviews

One aspect repeats itself from both interviews – the disagreement about the VBM services. It is obvious that the intentions of the owner/advisor are not the same as the intentions of the full-service consultant. Aspects from visuals and drawings, onto the detailing of the VBM are under constant discussion between the owner and consultants. This results in incongruence between requested and received information from VBMs.

None of the BIM standards mentioned in chapter 2.3 were used in this project, and the process seems to suffer from the lack of a process-structure. Agreements between owner/advisor and consultants are weak, and results in discussions on project progression. Chapter 2.1.2 underlines the importance of a structured and clear project approach, to avoid large amounts of unnecessary work to be made early in the design phases.

A cultural barrier is present, besides the communicative challenges on model development in the project, it is somewhat confusing to change from the usual way of working in the AEC industry, onto the process of BIM. Project progression is controlled by the client advisor and their understanding of optimal BIM processes, a progress which consultants are not informed about. Intentions on the BIM process are different between stakeholders of this project and confuses the structure of development.

2.6 Consolidation of Search

BIM is a collaborative design process based on an interoperable model collection where geometry and information is grounded in 3D-constructions and 2D-drawings stored in VBMs. Several types of software perform design-specific-tasks through the life cycle of a facility, and the VBMs are consolidated in a collective model (figure 3). The VBM is used proactive in interactive design communications between the stakeholders.

The BIM process aims for more efficient design development and generation of production drawings. Though, not making it an efficient and cost effective solution, and the process needs to be structured correctly. Overdeveloped models cause operability issues and include unnecessary work hours, while underdeveloped models results in lack of information. The project shall not be designed in phases of pre-design, schematic design, design development etc., but focus on the development of the VBMs LOD needed to proceed in the project.

Currently, there are interoperability issues between software when the IFC file-format, or direct proprietary API-based integration, is used to exchange information. As software operability is an external factor which will continue to develop and improve, these problems must be accepted. Therefore, an interesting aspect is the cultural and human relations to progress on construction in BIM development processes.

BIM is a collaborative undertaking and, like IPD, it forces partners to structure their processes in this system. The process must consider design development in terms of the functional aspects of VBM usage, and include the right profession at the right time in the project. Referring to the interviews, different types of construction agreements can be used in BIM projects; relations between tasks and how they influence on the design defines in these cases the agreements needed. Concurrent engineering uses relations between activities to control and map the structure, an inspiration on how the construction industry can arrange collaborative processes.

Further, it was obvious that no general design development process were agreed on between the stakeholders of the project referred to in the interview. This seemed to disturb the overall process, where the model was not detailed for the right purpose. The result was incongruence between the **requested VBMs** and the **created VBMs**.

Overall, BIM seems to endure from being a new and very different design approach. Owners, architects, engineers, contractors and suppliers must break with their cultural behaviour when performing a construction task when using BIM. However, the process of BIM is designed for collaborative project development, where AEC's can benefit from each other's effort. Therefore, BIM's success depends on the ability to structure the project flow, using the right type of expertise and software to evolve the LOD of the project strategically.

3 - Select

The section of select identifies the potentials and problems in BIM usage. Information captured in the section of search is structured and the essence of how to make BIM a successfull collaborative process is reflected. A strategy for improvement is defined from the results of the analysis in the section of select, and a problem specification of how to support the strategy is presented as well.

Strategy
Information from the search is used to define strengths, weaknesses, opportunities and threats to the BIM process. They are combined in a strategy-map to identify potential improvements to the process. A discussion defines a potential strategy based on the SWOT-analyses, and the strategy is described and further illustrated by a storyboard.

Problem
The problem is defined from the strategy and presents the challenges remaining for the strategy to be supported.

3.1 Strategy

From the section of search it is obvious that BIM as a collaborative process has trouble in becoming the preferred design approach in the AEC industry. BIM dependens on each stakeholders ability to utilise each others effort to make the process as time efficient and cost saving as possible. BIM will remain a collaborative undertaking between several design and construction disciplines, and effort must be made to collaborate most efficiently during the use of VBMs in the construction process.

3.1.1 SWOT - Analysis

To locate issues which obstructs the collaboration between project stakeholders when using VMBs, a SWOT-analysis (figure 20) is used to list strengths, weaknesses, opportunities and threats to the system. The SWOT-analysis focuses on the aspects related to BIM and collaboration, based on the information in the section of search. Aspects are defined by an overall theme and clarified through a brief explanation.

Strenghts

VBM – the VBM secure for information to be intact and up to date when project developes, and has several oportunities for supporting analysis regarding the building construction.

3D overview – the possibility of using the VBM for orientation and visual understanding (chapter 2.5.1)

Consolidation of data – 'real time' testing of the constructions through VBM and clash tests catches flaws between project stakeholders

Precise information - about masses and units (chapter 2.5.2)

Quantity retrieval - possible to pull out excact quantity of construction masses and units (chapter 2.5.2/2.1.4)

Efficient drawing production - construction drawings and snapshots of building composition are efficiently produced from VBM (chapter 2.5)

Weaknesses

Poor interoperability – complications with software interoperability (chapter 2.1.6)

Consistency – VBM do not support the project progression (chapter 2.5.2)

Complex organisation – process becomes complex when involving several stakeholders in a collaborative BIM process

Communication – work is often produced wrong or unnecessarily caused by lack of communication between stakeholders about personal needs (chapter 2.1.5/2.5)

Opportunities

Workflow – ability to create a better workflow between project stakeholders, better information and reuse of work models

Libraries – VBM design based on pre-designed construction units

Simulations – analysis within construction, energy, indoor climate, solar radiation etc. based on the VBM

Automation – (semi)automatic production and construction based on VBM

Parametric usability - use parametric qualities to do design work

Work illustrations - new types of illustrations

Threats

Cultural difference – tools and processes are different from older traditional design and construction approaches

Project agreements – successful collaborations need precise agreements

Legal framework – legal restrictions demands for well documented processes, which BIM do not handle

Diversity – the building industry consists of many small professions which must be comfortable with BIM

Economy – economic conflicts between stakeholders can affect the collaborative process

Figure 20 - SWOT-analysis regarding BIM and Collaboration: Strengths, weaknesses, opportunities and threats to BIM and collaboration in the AEC industry.

3.1.2 SWOT - Strategy Map

The SWOT-strategy-map supports the development of a strategy, based on the aspects listed in the SWOT-analysis. Strengths and weaknesses are combined with opportunities and threats to locate how the different aspects can affect each other. Strengths are combined with opportunities to trace how the strengths are able to pursue the opportunities, while strengths combined with threats identifies how to reduce the vulnerability to external threats. Weaknesses are combined with opportunities to list potential solutions and utilise opportunities to overcome weaknesses. Finally weaknesses combined with threats will reflect on how vulnerable the situation is, being able to establish a defensive plan to prevent weaknesses from becoming highly susceptible to threats.

	Strenghts	Weaknesses
Opportunities	Utilise VBM between professions to do designs, analysis and simulations Let the VBM use supplier's unit libraries and other pre-designed entities Use the 3D overview to produce logic manuals and illustrations for presentation and construction Use the design precision for automatic production and construction	Control model development from the workflow of the project Let the parametric usability do the main workloads Suit the organisation to gain the efficiency and quality of the project development Develop the VBM for its purpose, also having in mind automatic production as an example Develop the VBM to suit software simulations and collaboration between design disciplines Optimise workflow and LOD to suit the current software operability
Threats	Let precise information about units and quantities be fundamental for project agreements Do agreements based on model development instead of design and production phases Suit VBM development for each of the project stakeholders Use the quantity retrieval to control the economy of the project Use 3D overview, and efficient production of drawings and illustrations to support communication and collaboration	Non supportive agreements on VBM development; will cause conflicts Complex organisations will include many diverse cultures Poor interoperability makes it harder for everyone to be comfortable with the BIM process Poor communication will trigger the cultural difference and make stakeholders do things their own way

Figure 21 - SWOT strategy map: *Combination of strengths, weaknesses, opportuinities and threats, from the SWOT-analysis, for use in the development of a strategy .*

3.1.3 Strategy Discussion

From the SWOT-matrixes (analysis and strategy map) the strategy needs to include some general aspects on utilisation of VBMs in a BIM based project development. The VBMs are mentioned both in strengths and weaknesses, while included in second position under opportunities; this indicates the importance of the VBMs in BIM processes. A VBM secures that information is always up to date and accessible to all stakeholders of the project. The effect from this is partly reduced if the model is non-supportive with the progression of the project. The VBM is mentioned secondary as an essential factor for the opportunities to become relevant suggestions.

The SWOT-strategy map indicates that the VBMs are essential when combining strengths with opportunities and threats, and also weaknesses with opportunities. The success circulates around the VBMs ability to support the construction process, letting the model be optimised for its current mission. The combination of weaknesses and threats is more focused on the organisation of project stakeholders, making the communication succeed and the project agreements suit the process of BIM. Therefore, the aspects in the SWOT-matrixes do not relate to one current field, but is affected by uncertainty about product, organisation and process (POP).

BIM is dependent on POP to become one interconnected entity to succeed. BIM is fundamentally a communication working method and generally the project process. (Senescu et. al., 2011) While the VBM itself is more or less the product which virtually represents the final construction the organisation is the link between the product and process – who is involved and for what purpose?

Project Complexity and Communicative Challenges

Considering POP is not necessarily the right strategic solution for BIM projects in general. Though, one paper (*Relations between project complexity and communication* (Senescu et. al., 2011)) also indicates that the same type of issues is present. The paper emphasises that: even if the project team was collocated it did not mean they were connected, still struggling with their design effective collaboration.

In terms of the paper, there is relevance between POP complexity and communicative challenges within a design and construction group. The paper aims to motivate for the development of more efficient and effective communication tools for usage in the AEC industry – compensating the increasing complexity of projects developed to meet the financial, social, and environmental targets of stakeholders.

Even with the increased availability and pervasiveness of ICT, project teams still struggle to communicate properly. (Senescu et. al., 2011) Product communication between companies have improved when information exchange is increased within the system of BIM, but still there is difficulties in using BIM for anything else than coordination of geometry. (Taylor & Bernstein, 2009)

The report (Senescu et. al., 2011) describes the importance of distinguishing between three modes of information exchange to avoid cost-benefit mismatches in communication. The three categories of communication are: 1. People exchange information within project teams in order to COLLABORATE; 2. People exchange information between projects teams with the intention to SHARE; and 3. People gather information from projects across the companies or industries to aggregate and visualise with the strategy of UNDERSTANDING.

For informative communication to be efficient, one must consider what the information shall be used for; collaboration, sharing or understanding. To solve communicative challenges related to the use of VBMs, project participants must use this information in the collaborative design development. This means that the VBMs should be tailored to the purpose of supporting the project development.

3.1.4 Strategy

To obtain BIM processes which are able to utilise the potentials of VBMs, it is important to consider the projects in relation to POP. Principles from IPD and CE support this process and secure better collaboration between project participants. Each project should be considered individually on behalf of product, organisation and process; aiming for optimal project collaboration between stakeholders in the development of individual strategies for progression. As mentioned previously, BIM based processes are different approaches than traditional ones and there is individual needs to abstract from the design and construction phases, and focus on the model development by LOD. When collaborating, each stakeholder should request the information needed, this to reduce useless information to be produced in the design and development process.

Product

The final building is the main goal of a construction process, and even before starting a project it is important to establish a set of requirements and pre-designs to launch the project. In a BIM design approach the extent of this pre-design should carefully be considered to support the following process.

BIM defines an efficient and money saving process by the use of VBMs in design and construction planning. Therefore, the focus is on the product of the process - the VBMs! The main model is the product of a range of minor models produced during design and construction development. Relations between these models need to be considered from their interoperability and parametric qualities. An organised model-structure should be representative in the sectioning of the models, ensuring that the models are operable and exchangeable for the right purposes.

Organisation

The organisation should be considered from the design development, where participants are involved from the earliest practical moment they are needed. Therefore, considerations on who to involve and for what purpose is relevant to the project's quality and efficiency. Participants' involvement should defined by the need of information to the project, and agreements should be tailored to the system of LOD.

A design process does not need to be linear, and the participants should be included to support the iterative development of the project. Building elements which affects the rest of the building design have a need to be clarified early. Therefore, the design executer must be implemented to do so. As the project evolves, a constant evaluation of the qualities in the design group is necessary. The organisation must be structured with the purpose of raising the LOD strategically.

Process

The process is the main stake of BIM as a methodology, and therefore an essential part to control. Going from a linear design process into an iterative process, new design flows will appear in the development of the project. Design is no longer made in phases, but from the need of information. Considerations on how the process should be structured are defined from relations between activities, responsibilities among stakeholders, and LOD in term of project progression.

It cannot be expected that each participant suits their product to the design team. It is a significant need to define the progression at all times, which requires an overall leader of the design development (BIM coordinator). Working with different design disciplines and several software solutions, it is important to agree on exactly what model and information that is needed for the process to continue effortless.

Consolidation of POP

The strategy is related to a set of objectives on the workflow between project stakeholders, considered from the results in the sections of search and select. The story underneath presents the vision on how to structure design processes within BIM in the future. The story is expressed by an imaginary story, followed by a storyboard to illustrate the intended flow of the process.

Imaginary Story About John the Project Leader

John is a prominent project leader who recently was signed as a client advisor on a new library in Odense, Denmark. Reports had proclaimed that BIM was a design effective and cost saving solution in construction projects. Therefore, John convinced the investors to adapt to BIM and require that involved parts do the same. A consultant was chosen to do the design. The consultant was sceptical to BIM as a design progression; in earlier projects they had bad experiences.

John took the consequence and hired a BIM consultant to brief the owner, advisor and consultant in how to use BIM efficiently. Most of the trouble related to the previous projects, was caused by poor interoperability and slow performance on models. The BIM consultant sub-divided the model into smaller entities to increase the model-performance. A model structure was created also including smaller design disciplines.

The project kicked off with great enthusiasm, and slowly the design evolved in Revit. From his experience within the industry, John knew that consultants' designs often were redesigned by contractors before construction. He decided to integrate other professions in the design of the building, but he did not want interference for the whole design process. Therefore, he asked the consultants to continue the work, but no further than the LOD200.

John listed the activities that affected each other; from this an overview on the design task's order of execution was created. The project was under big pressure, and John wanted the substructure to be completed as quickly as possible. Great experience was made on leaving the substructure design in the hands of the contractors, signing them on a fixed price on design and construction.

To do so, the LOD of the substructure needed to be at 200, and the shell construction at LOD 300. John did not want to risk for the consultants design to be redesigned when left at the shell contractor. Therefore, it was necessary to sign a shell contractor in an early collaboration to consult the shell

construction design.

John presented a list of information requirements needed to sign contractors and consultants in order to proceed to extend the organisation. Aware of his needs, John made sure that the consultants raised the project to the intended level, and then implemented the best qualified knowledge to solve each LOD.

Every new stakeholder of the project now contributed to the planning of the design progression. The total amount of tasks and information escalated quickly and it became diffuse how the model information was intended to benefit the progress.

As a solution, John started to list the tasks in a table; purely relying on each of the components expected LOD at a given time. Further, he listed how every activity affected each other, and made clear for whom to collaborate and communicate, and for what purpose the information was needed. Everyone in the design collaboration could see the benefit of collectively creating and reusing each other's information in the design. So, willingly they repeated the process to consider how other disciplines could design to benefit their needs, letting each profession perform their expertise.

John acclaims that the project became a virtual construction process, where the team placed one brick at the time in their models. The efficiency of letting every stakeholder contribute with their expertise at the right moment of time was stunning, and the results were remarkable on costs and quality of the project.

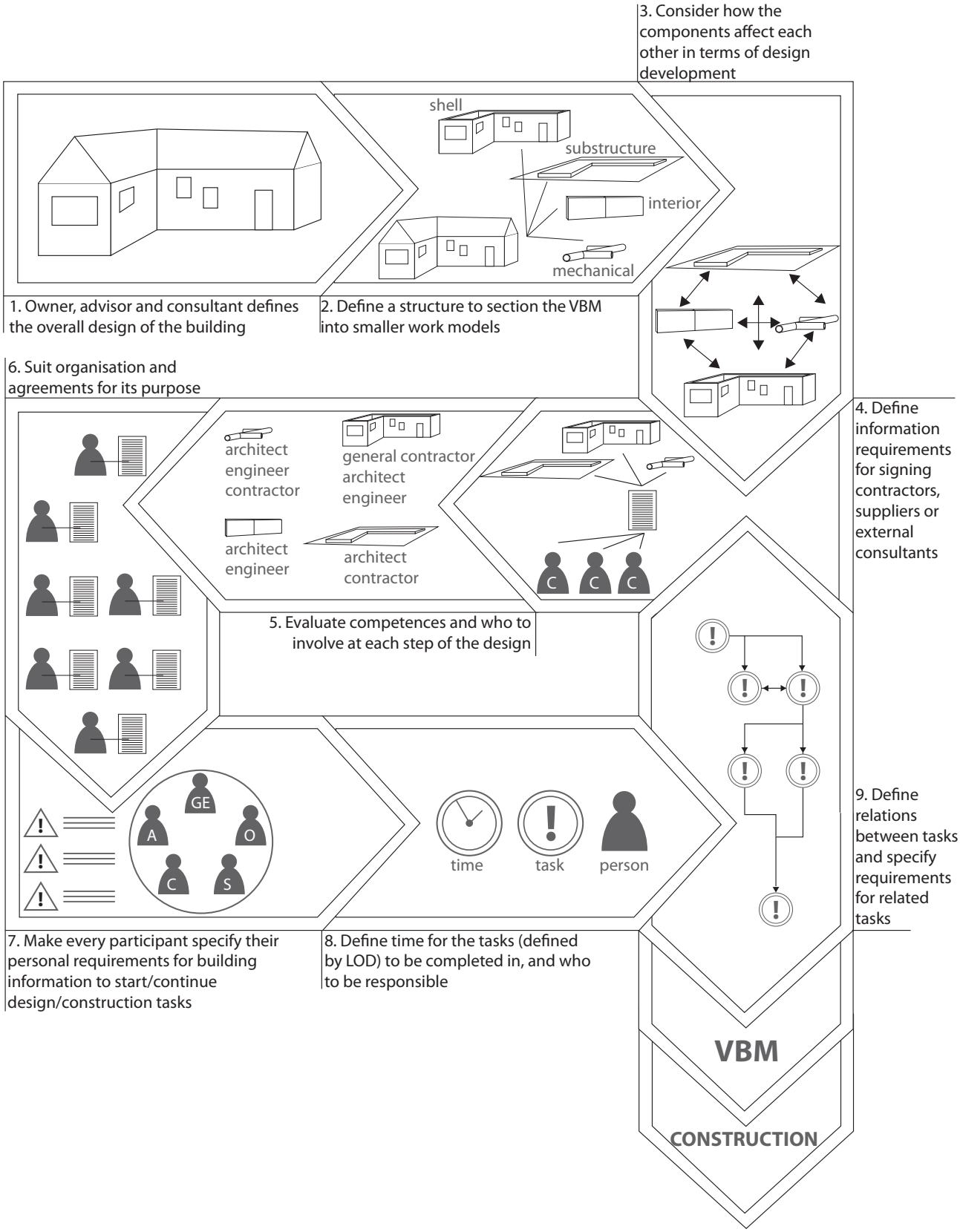


Figure 22 - Strategy for a successful VBM development processes: *Defines the intentions of how BIM based process should structure to obtain optimal development of the VBM.*

3.2 Problem

For BIM to be a collaborative successful design approach, the system must evolve with the abilities of the technology. The theoretic thinking will always be in front of the technological development. Instead of adapting to the theory, one needs to consider the project teams ability based on the current situation of the AEC industry. BIM is a complex collaborative process, where each contribution supports the whole team practice and not only each of the project stakeholders.

It cannot be expected that each of the project participants perform in the benefit of everyone. Each profession use customized software tools to perform the work, and architects, engineers, contractors and suppliers cannot expect each other to understand the individual needs for building information along the project design development. Agreements on how VBMs should be constructed will potentially gain the collaborative process of BIM.

Constructing a project, precautions must be taken for the POP to strategically be part of the project design development; obtaining efficient and time saving design solutions. When a POP strategy is developed, considerations must be made in relation to the three categories of informative communication. Information is exchanged in order to collaborate and share, where information is captured for the intentions of understanding. Considering why information is used and for what purposes, the stakeholders will presumably suit their VBMs better for interdisciplinary purpose.

Optimal collaboration within BIM project teams relies on each parts willingness to operate on behalf of each other. Creating a common understanding to the VBMs development is the goal. From this contractual agreements that support the project's POP can be made. This could be obtained by following the project development strategy on how to communicate for better collaboration. (chapter 3.1) Once understanding how POP is established, the planning of an optimal design progression for the project is possible.

The challenge is to define our product properly and to define the organisation after our informative needs. Thus, the planning of the development process can be executed by information on the current support. To structure the design and construction for optimal collaboration within BIM and between stakeholders, a tool is needed. A tool which considers the themes of VBMs and the progression of the models as presented in the storyboard (figure 22).

Defined problem

A system which considers POP for individual projects is needed. Further it should support the VBMs structure to achieve optimal collaboration between project participants when using the principles of BIM.

4 - Implement

This section proposes a prototype to a system which considers POP in individual projects and supports the VBM structure when using BIM. Different templates is presented and explained by illustrations and descriptions, with the goal of designing a system which is useable in the leadership of a process based on development in VBMs.

Prototype specifications
Explain the specifications to the system: a manual for designing the tools required in a systemised leadership in BIM.

Product
Describes the situation related to the product of the building and the VBM, and precautions to be made in relation to this. A definition of the product secures for the model structure to be right and defines a common understanding that gains the later design development in the project.

Organisation
Defines a spectre of tools to support the making of a solid organisation, and design specific agreements to suit the project for the right purpose

Process
Present tools to supports the agreements on design development through the use of LOD. Activity relations and delivery requirements needed to structure the process in relation to time and informative needs.

4.1 Prototype Specification

Digital tools and methods require planning, preparation and structure of knowledge. It is essential that the group of leaders understand these challenges in order to create specific goals and to structure the planning of the process. BIM can be defined as the method which ensures a structured and methodical access to information at the right time and in the right place. Further, the information must be accessible, which requires a strict structure to define the informative development through VBMs. (detdigitalebyggeri, 2011)

To achieve this the structuring of the project should relate to the current situation, and POP must be considered. From the earlier deliberations in this report, the essence of considering certain aspects is related to a construction process. Mainly, the project and the BIM process is combined through organisation, model structure, activity relations, model development and project responsibility to support the information exchange needed in collaboration, sharing and understanding.

From the section of select, the conclusion is that planning should relate to three main project specific themes - product, organisation and process. The prototype specification (figure 23) defines tools and their requirements needed to support a POP based leadership-process. There is a total of 7 sequences found relevant to control the process, all related to the POP as followed: Project: Project Proposal and Model Structure; Organisation: Model Impact, Critical Assessment and Organisation Involvement; Process: Model Element Table and Activity Relations.

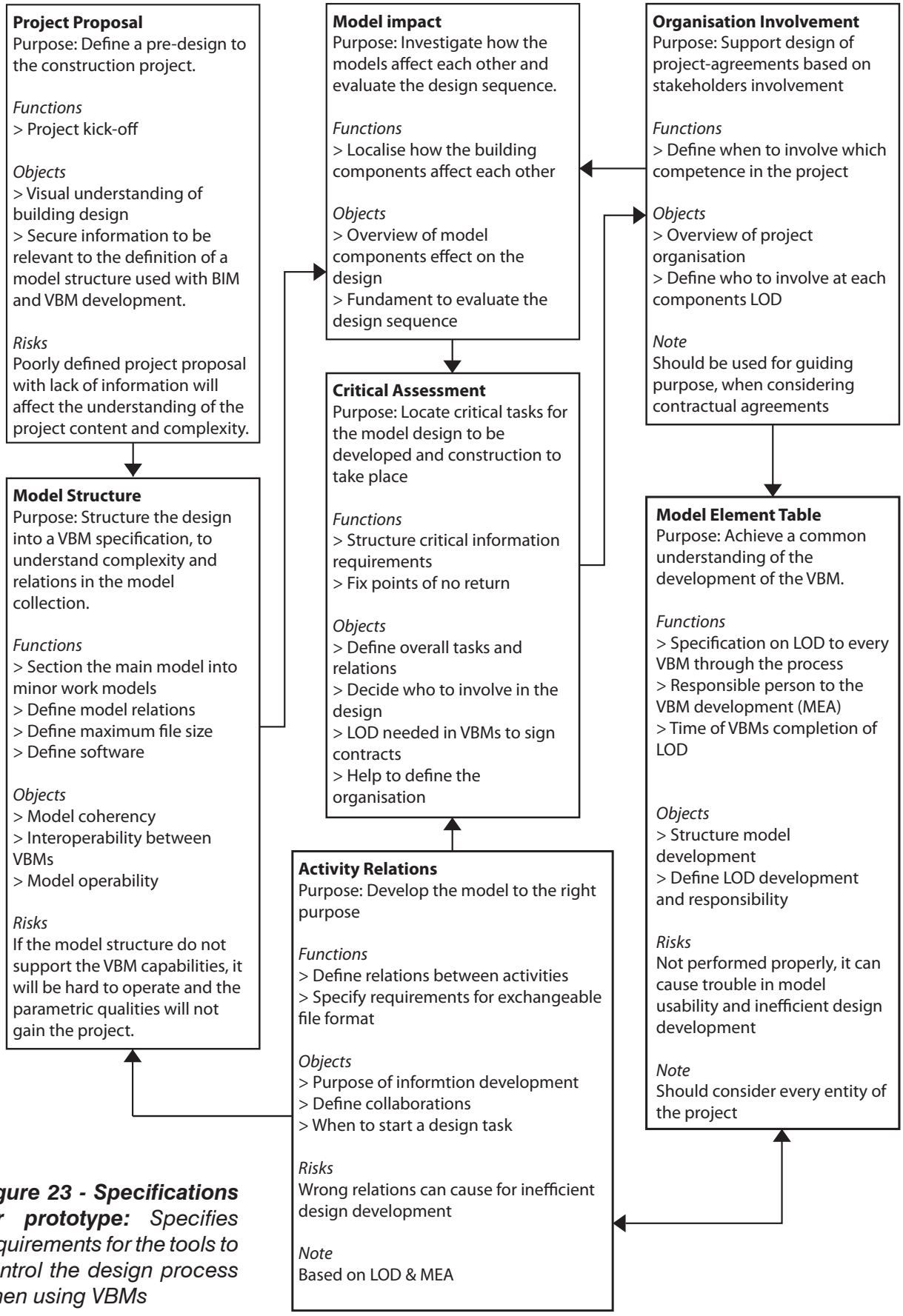


Figure 23 - Specifications for prototype: *Specifies requirements for the tools to control the design process when using VBMs*

4.2 Product

In relation to the product, two sequential tasks are listed to be performed and secure a fundamental start in BIM and to support the definition of the product. The final product in BIM is the VBM used throughout the design and construction process. Information is essential to further considerate the organisation and process of the project.

4.2.1 Project Proposal

No tool is developed to define the structure of a project proposal; a very specific task which do not directly relate to the system of BIM. At this stage of the process it is important to have a base for project kick-off. A clear idea is needed on the project design and economy, which requires specific information to evaluate the product. This is similar with today's practice of pre-designs or design competitions. The most important design parameters are listed below.

Design specific concept - to have a clear understanding of the project's idea and values

Drawings - sections, plans, elevations and illustrations for visual understanding

Areas - specification of areas for every room, and overall

Volume - room heights are important in price estimations

Construction principles - how the load carrying structure will be constructed

Facade areas - define areas of windows, and areas of standard facades

Technical solutions - is there automatic ventilation, complicated electrics or plumbing etc.

All information from the project proposal is used to decide whether or not the project should carry on. It is important to calculate the most risky parameters of the building and estimate the overall cost of the project and an evaluation on the project's ability to complete within the defined budget must be made. Further, a well-defined project proposal makes it easier to define the VBMs structure.

4.2.2 Model Structure

The model structure in a 3D-based model and a 2D-CAD-model is different, so the layering structure used for CAD-drawings are no longer applicable. The design should be considered from a holistic point of view and therefore avoid isolation of individual components.

VBM should no longer be divided into walls, doors, ceiling etc. as this cause in cohesive modelling solutions. Without the ability to affect the wall, when modelling a door, or moving a wall without the related door disharmonises and do not utilise the parametric. Walls, doors, fixtures etc. must be regarded as related units which are dependant of each other.

The challenge is to ensure that models are operable, regarding size and parametric qualities. Considerations on how to connect models and how design teams should operate must be made. All VBMs from the construction and design teams are consolidated in one main model. When breaking up the project proposal into a logical partition of VBMs, it is wise to include a BIM expert (internal or external) to secure proper sectioning.

Model Structure Scheme

Figure 24 exemplifies a possible solution to the structuring of a model, placing the VMBs in separate themes. Columns are defined as consolidated models, building units, discipline models, worksets and components to visualise how the models' interfere. Software and maximum file-size are defined to take precautions on slow performance and poor interoperability.

The structure is not permanent, but it should only be changed under supervision of a BIM coordinator. Main intention of the *model structure scheme* (figure 24) is to become aware of the model unification, and visually relate to the model structure.

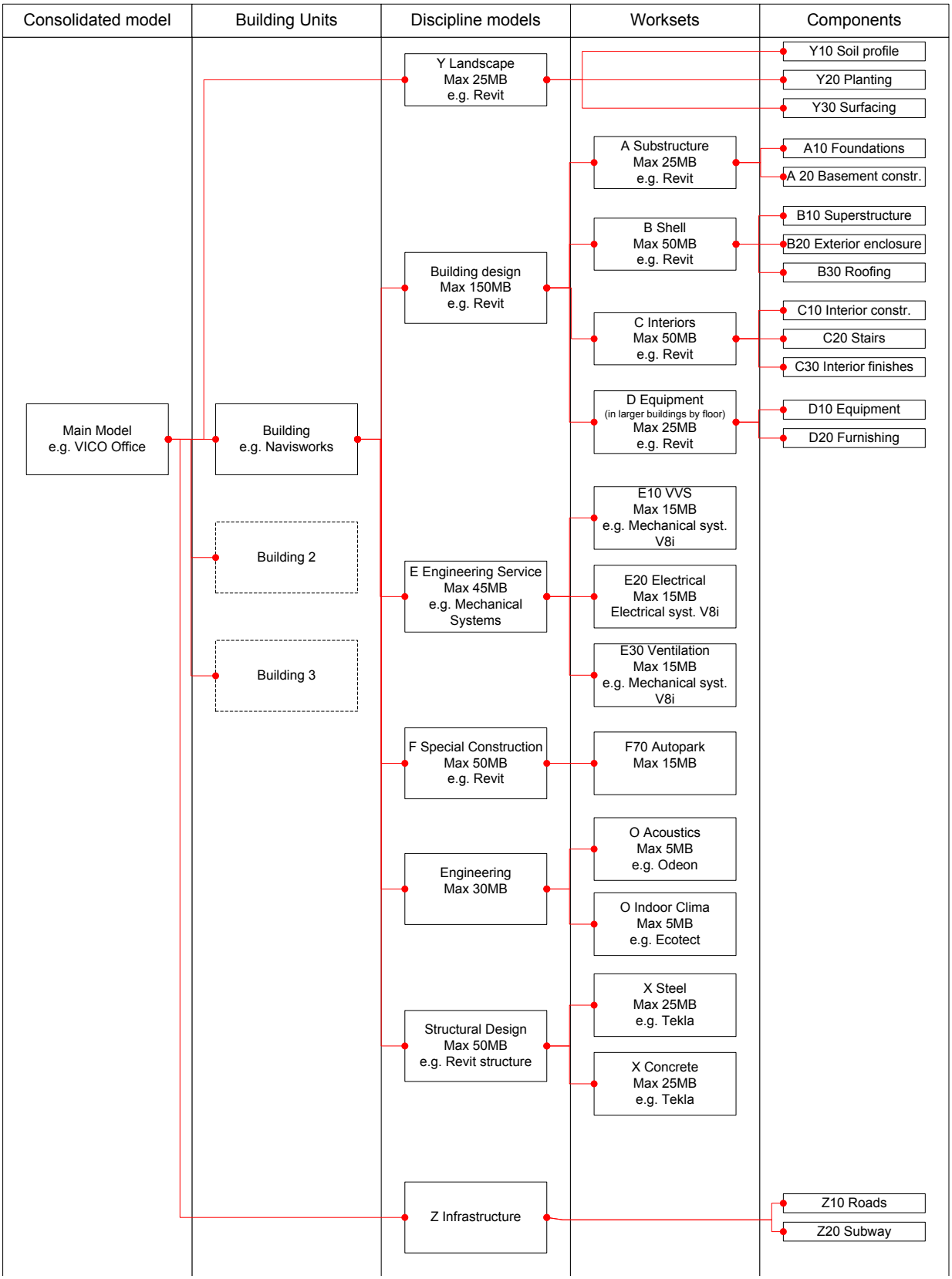


Figure 24 - Model structure scheme template: *The scheme structures the VBMs to achieve better performance and more solid interoperability. It specifies the components and their relation to the rest of the models. The structure should be representative to the sectioning of the VBMs.*

Definitions

Starting with the **consolidated models** in lane 1 - one model represents information from all design disciplines; a final design representation of the unified project complex. A lot of smaller models are represented in this consolidation. The main model defines primary coordinates for the following units to operate by, and maintaining all other models in a structured position.

Building Units are models which basically are independent of each other and are operable on their own. The models' each represent a single unit's composition. If the project consists of more than one building unit, separating these into single model units are recommended. (Krygiel, Read, Vandezande, 2010)

Discipline Models are defined for collaboration to take place among different design disciplines. Each model is operated separately and links to the building unit models. (Krygiel, Read, Vandezande, 2010) Linking models ensures that each design unit can manage the design in their preferred software, to obtain more efficient design approaches.

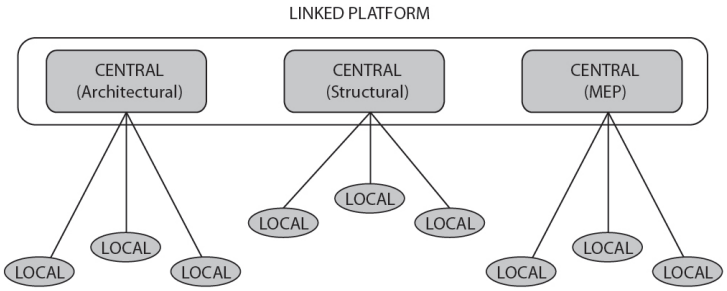


Figure 25 - Linked models (Krygiel, Read, Vandezande, 2010): *Linked models connects VBMs from different engineering professions into one main file on a common platform. Each linked VBM can consist of several local small VBMs compose a central model.*

A workset is a section within a VBM, making it possible for more persons to work on different tasks inside the same model. It is important to notice that the worksets do not affect each other parametrically, except from the shared grid and level system which is defined as a separate workset. The sectioning has to be considered on behalf of relations between building units. Working with worksets, each set is based on the same central model, but is developed locally by each participant. Each workset becomes available in read-only format preventing model complications along the way. (Krygiel, Read, Vandezande, 2010)

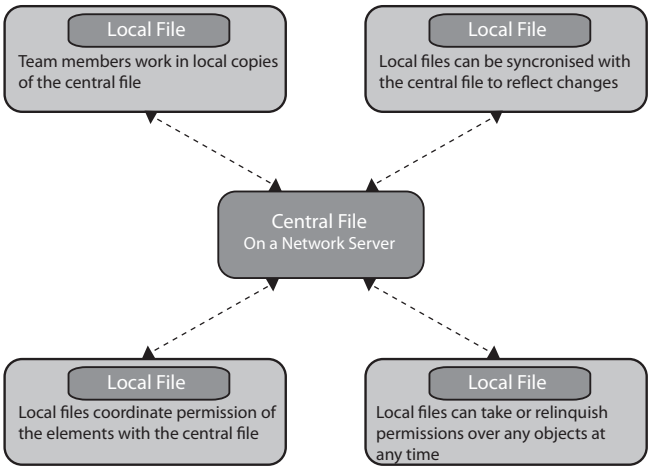


Figure 26 - Worksets (Krygiel, Read, Vandezande, 2010): *Worksets divide a central model into minor ones to separate work tasks in a building complex. Each central file can be divided into several local files, where each local file can be worked on separately. They are synchronised to reflect on changes. This is a collaborative design process within a limited group, and communication is made through the central file.*

A component is a supplementary description of a design definition taking part in a construction project. The intention is that the design participants are aware of what components the worksets represent, and thereby prevent some potential design conflicts.

4.3 Organisation

From the *model structure scheme* (figure 24) an overview of models needed to complete the project design and construction are given. Next an organisation can be defined with relation to the model development. The organisation supports the development of the project and is under constant re-evaluation along with the planning of the process. There is no need to implement the whole organisation simultaneously, so, the organisation can expand when needed.

Three proposals are presented to structure the organisation, specifying the different stakeholders intended role in the project.

4.3.1 Model Impact

The first step of this process is to evaluate how the building components affect each other, and hereby, defining in what order they need to be executed. Doing so, one can localise how one component has influence on another components design. The bigger influence, the earlier it should be involved. A design task which is restricted by a third part's rules or limitations is be a potential first task.

Affects and Affected by Table

The table defines how it is expected that the different designs of the project affects each other. This list can later be used to define the critical assessments in the project (the next tool presented). The table is structured with a simple cross checking, marking all the construction design tasks interfering with each other.

From the example, F70-Special construction-Autopark directly affects the substructure, core construction, facades, floor/roof, ventilation and electrical system. Contrary, nothing affects the parking arrangement that is technically restricted. Therefore, this is one of the first tasks to solve. Further, A-Substructure does not affect any other constructions, but itself is affected by the parking arrangement, core construction, facades, roof/floor and VVS. The substructure then needs information from all these tasks to be executed.

Analysing the main construction activities of the project, current overviews of the impacts between constructions are achieved and potential clashes are underlined.

AFFECTS	AFFECTED BY: A Substructure	B10 Shell- Superstructure	B20 Shell - Ext. Closure	B30 Shell - Roofing	C10 Interior - Construction	C20 Interior - Stairs	C30 Interior - Finishes	D Equipment	E10 Mechanical services - VVS	E20 Mechanical services- Electric	E30 Mechanical services- Vent.	F70 Spec. Construction - Autopark	O10 Acoustic regulations
A Substructure	■												
B10 Shell- Superstructure	▒	■	▒	▒		▒							
B20 Shell - Ext. Closure	▒	▒	■		▒								
B30 Shell - Roofing				■									
C10 Interior - Construction			▒		■	▒	▒	▒		▒	▒		▒
C20 Interior - Stairs						■			▒				▒
C30 Interior - Finishes							■			▒			
D Equipment								■	▒	▒			
E10 Mechanical services - VVS	▒				▒				■				
E20 Mechanical services- Electric										■			
E30 Mechanical services- Vent.					▒		▒			▒	■		
F70 Spec. Construction - Autopark	▒	▒	▒							▒	▒	■	
O10 Acoustic regulations					▒		▒						■

Figure 27 - 'Affects and affected by' table template: *By cross checking the construction activities, the table marks out which to affect each other. In the left side, every activity is listed to present what they affect, while the upper row is representing all the activities for how they are affected. The vertical mark-up defines which of the other construction activities that affects the vertical activity. List of components can be detailed after need.*

4.3.2 Critical Assessment

The purpose of the critical assessment is to define information requirements needed for the design development to proceed. Fundamental points of the project are fixed, avoiding that dependent designs' risk to be effected by changes in the fixed design. Information from the table on figure 27 is used to establish an overview on which tasks to consider.

The main objective is to define the overall tasks and relations, and to illustrate a logical progression to the process based on information required to assign new expertise's to the organisation.

Information Delivery Manual on Critical Information

An *Information Delivery Manual* (IDM) is applied to define the information and decisions needed to sign specific contracts in the project. Therefore, each design component is considered individually in separate structures.

Each of the components, which process' is relevant to capture requested information, is defined.

Figure 28 exemplifies the situation. To sign a contractor on A-Substructure, F70-AutoPark needs to be at LOD300 so the design of shell and structure can begin. B10-Superstructure then needs to reach LOD300, and further a definition on the sewage should be defined, before a contractor is signed.

B10-Superstructure should implement a contractor when reaching LOD200, meaning that the contractor is signed in an early collaboration. Every member of the design team should be aware of the information requirements that are needed to implement 'specialist' for further detailing of the design and construction.

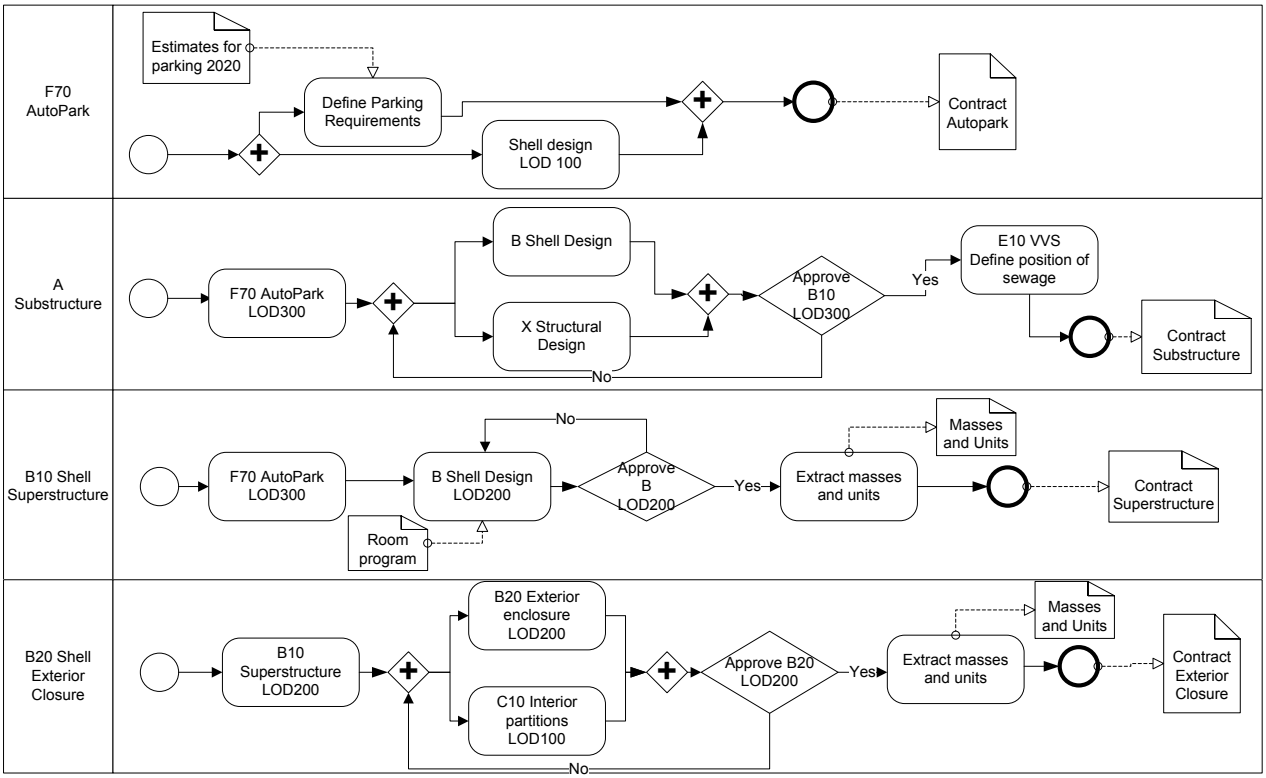


Figure 28 - Information Delivery Manual, template for critical assessment: *It is based on the BPMN methodology for relations between processes. (Karlshøj, 2011) Design components are listed (detailed after need) and to define the information needed and tasks to complete before contracting new actors to the design development.*

4.3.3 Organisation Involvement

It is found important to consider how the design and construction team is composed. Given that the design team defines the overall aesthetics of the project, it also is possible to include other professions in the design development. Critical tasks were defined in the IDM (figure 28), where the objective of this template is to create an overview, of the organisation and each part's involvement.

For the project to develop most efficiently, it is important that the owners, advisors, architects and engineers discuss their qualities and knowledge to define the involvement of others. The predefinition of stakeholders' involvement makes it possible to better structure the contractual agreements.

Organisation Involvement Table

The *organisation involvement table* (figure 29) lists all the participants' role in the design and construction of the components. A listing of construction activities and LOD to the project makes it possible to place the owners, advisors, architects, engineers, contractors, suppliers, consultants etc. in relation to the specific task.

The example on figure 29 shows that E70-Special Construction-AutoPark is a very design-specific task solved by the supplier of the product. From LOD200 the supplier completes design and construction, further they are also responsible to the maintenance. From this information, the parking arrangement could be considered signed at a fixed price on design and service.

A-Substructure is handed over to a sub-contractor from LOD300. The substructure does not effect the final design. So, the design can be made by the contractors themselves, using their expertise to design the cheapest qualified solution in a fixed price agreement.

At B10-Shell-Superstructure, the general contractor is intended to be included in an early collaboration with architects and engineers from LOD300. Since the design potentially will affect the buildings' aesthetics and opposite, an incentive deal is better suited.

The *organisation involvement table* forces considerations of the best suited stakeholder to solve the LOD requirements at each component. Type of contract can be considered from information captured in this table (figure 29) and in the critical decision making (figure 28).

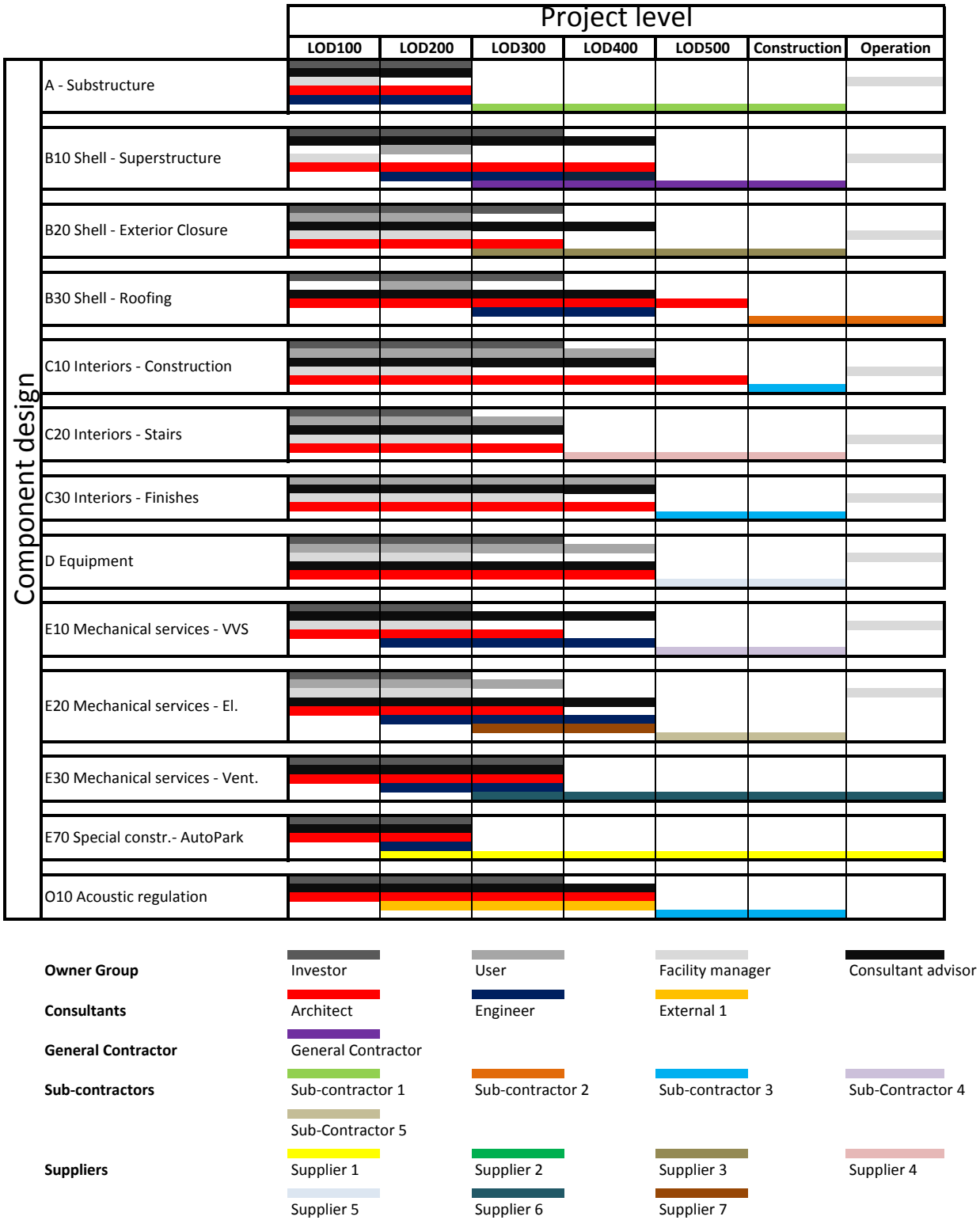


Figure 29 - Organisation involvement table template: *Construction activities are present in the left column and phases in the header. Colours illustrate participants' involvement at each of stages in the design and construction process.*

4.4 Process

Between stakeholders in the AEC industry there is important to create a well-defined workflow. The team must have a common understanding, for the process evolution to succeed. Use of digital software solutions need specific requirements to operate optimal and to be constructively used in the design process.

Two tools are created to structure the project-progression illustratively.

4.4.1 Model Element Table

The LOD and responsibility to each VBM is necessary to define. Information related to the previous product and organisation is used to fulfil this task in order to place the correct LOD and MEA (Model Element Author). It is essential to have clear restrictions on the workflow so the VBM is useful at any stage of the design. The table is used as a supplementary project agreement between stakeholders to obtain optimal collaboration in the project group.

Model Element Table E202 by AIA

AIA has introduced a well-defined table called *model element table* (chapter 2.3.2) that structures the LOD & MEA in a VBM design process. The table lists all design tasks related to the model structure (figure 24) and requests LOD & MEA at each stage of the project. The process is not definitely defined from the beginning, so the table shall be completed parallel to the project progression.

Every design task is presented with a letter and number in front, to maintain the right order; also when producing alphabetical lists. Meaning that A-Substructure is the workset of the subject-specific-model, and A10-Foundations is a component within this workset. A1010-Standard-Foundations, A1020-Special-Foundations and A1030-Slab-on-Grade are generally only preferences to specific design-tasks in the category of the component.

Date of Completion (DOC) is added to specify when each MEA must complete their task. This is necessary if two activities within the same period is dependant of one another. The table is an agreement between the current stakeholders of the project. Therefore, it should be defined in common. Specific requirements or supplementing information to the design task can be added in notes.

			W37_2011 - W48_2011			W49_2011 - W02_2012			W03_2012 - W___2012			
Model Elements			LOD	MEA	DOC	LOD	MEA	DOC	LOD	MEA	DOC	Notes
A SUBSTRUCTURE	A10 Foundations	A1010 Standard Foundations				100	E-GRI					
		A1020 Special Foundations				100	E-GRI					
		A1030 Slab on Grade										
	A20 Basement Construction	A2010 Basement Excavation				100	E-GRI					
		A2020 Basement Walls				100	E-GRI					
B SHELL	B10 Superstructure	B1010 Floor Construction	200	E-GRI	15-nov	300	GC-FKJ					B 10.1
		B1020 Roof Construction	200	E-GRI	15-nov	300	GC-FKJ					
	B20 Exterior Closure	B2010 Exterior Walls	100	A-LVF		200	A-LVF					
		B2020 Exterior Windows	100	A-LVF								
		B2030 Exterior Doors	100	A-LVF								
	B30 Roofing	B3010 Roof Coverings	100	A-LVF								B 30.1
		B3020 Roof Openings	100	A-LVF								
C INTERIORS	C10 Interior Construction	C1010 Partitions	100	A-LVF								
		C1020 Interior Doors	100	A-LVF								
		C1030 Fittings										
		C1040 Fixed Furnitures				100	A-LVF					
	C20 Stairs	C2010 Stairs	100	A-LVF								
		C2020 Stair Finishes										
	C30 Interior Finishes	C3010 Wall Finishes										
		C3020 Floor Finishes										
		C3030 Ceiling Finishes										
D EQUIPMENT	D10 Equipment	D1010 Commercial Equipment										
		D1020 Institutional Equipment										
		D1030 Other Equipment										
	D20 Furnishing	D2010 Movable Furnishing										
E SERVICES	E10 VVS - Plumbing	E1010 Plumbing Fixtures										
		E1020 Domestic Water Distribution	100	E-FRI		200	E-FRI					
		E1030 Sanitary Waste	100	E-FRI		200	E-FRI					
		E1040 Rain Water Drainage										
		E1050 Other Plumbing Systems										
	E20 Electrical	E2010 Electrical Service & Distribution										
		E2020 Lightning and Branch Wiring										
		E2030 Communication & Security										
		E2040 Electrical Heating										
		E2050 Other Electrical Systems										
	E30 Ventilation (HVAC)	E3010 Energy Supply				100	E-FRI					
		E3020 Heat Generating Systems				100	E-WLE					
		E3030 Cooling Generating Systems				100	E-WLE					
F SPECIAL CONSTRUCTION	F70 Autopark	F7010 Parking Structure	100	A-LVF	16-okt	300	P-CME					
		F7020 Construction				300	P-CME					
		F7030 Mechanics				300	P-CME					

MEA's	
Architects	
A-LVF	Architect - Lars Vind Frederiksen
Engineers	
E-GRI	Engineer - Gunnar Riis
E-FRI	Engineer - Frederik Ringdal
E-WLE	Engineer - William Leipheimer
General contractor	
GC-FKJ	General Contractor - Frank Kjeldsen
Suppliers	
P-CME	ParkAuto - Conrad Meissheimer

Notes:

B 10.1	Sign on General Contractor after LOD 200 is completed
B 30.1	Waits for owners decission for roof windows

Figure 30 - Model Element Table template (AIA, 2008): *Each design task is followed by the requested Level of Detail (LOD) and Model Element Author (MEA) in every period of the project. The finish date is in the Date of Completion (DOC) if it differ from the period's. A task marked with yellow means it is started, green means completed, while a red task is put on hold. Supplementary information is marked with notes at the right*

4.4.2 Activity Relations

The *activity relations scheme* (figure 31) supplements the *model element table* (figure 30) and is operated parallel to it. No general indications on relations between tasks are presented in the *model element table*. The contractor relies on work made by the architect or engineer, and vice versa. The *activity relations scheme* structures collaborations between participants and the purpose of the design developments. Misunderstandings are avoided and unnecessary work prevented.

Task relations is categorised in 4 different ways; there are dependent, semi-independent, independent and interdependent activities (chapter 2.4). This highlights the activities relations, and structures the order of the tasks execution. This assessment ensures that even complex iterative processes are structured to obtain optimal collaboration.

Activity Relations Scheme

To control the design evolution, activity relations must be structured for shorter periods of time and in relation to the *model element table* (figure 30). Activities and relations are presented within the planned period and expand along with the process. The complexity raises when the project becomes more detailed and when the organisation expands.

Processes are defined with a specification-number and supplementary information of LOD & MEA. Related tasks should be performed first if possible, to maintain a constant workflow. If a design task is interdependent (i.e. C1010/1020 and E1020/1030) a collaboration is present; in this case between A-LVF and E-FRI. Semi-independent activities can be started and performed with minor involvement from other ones, while activities which do not effect other activities only needs to be solved within the given period.

There is one ‘swim-lane’ to each participant of the project (in this example 5) so the tasks can be placed at the right executer. The scheme should be designed by inputs from every participant’s request on essential information. Processes are marked with green when completed and yellow when started. If any specific file format is required, this is illustrated in the link between two design tasks.

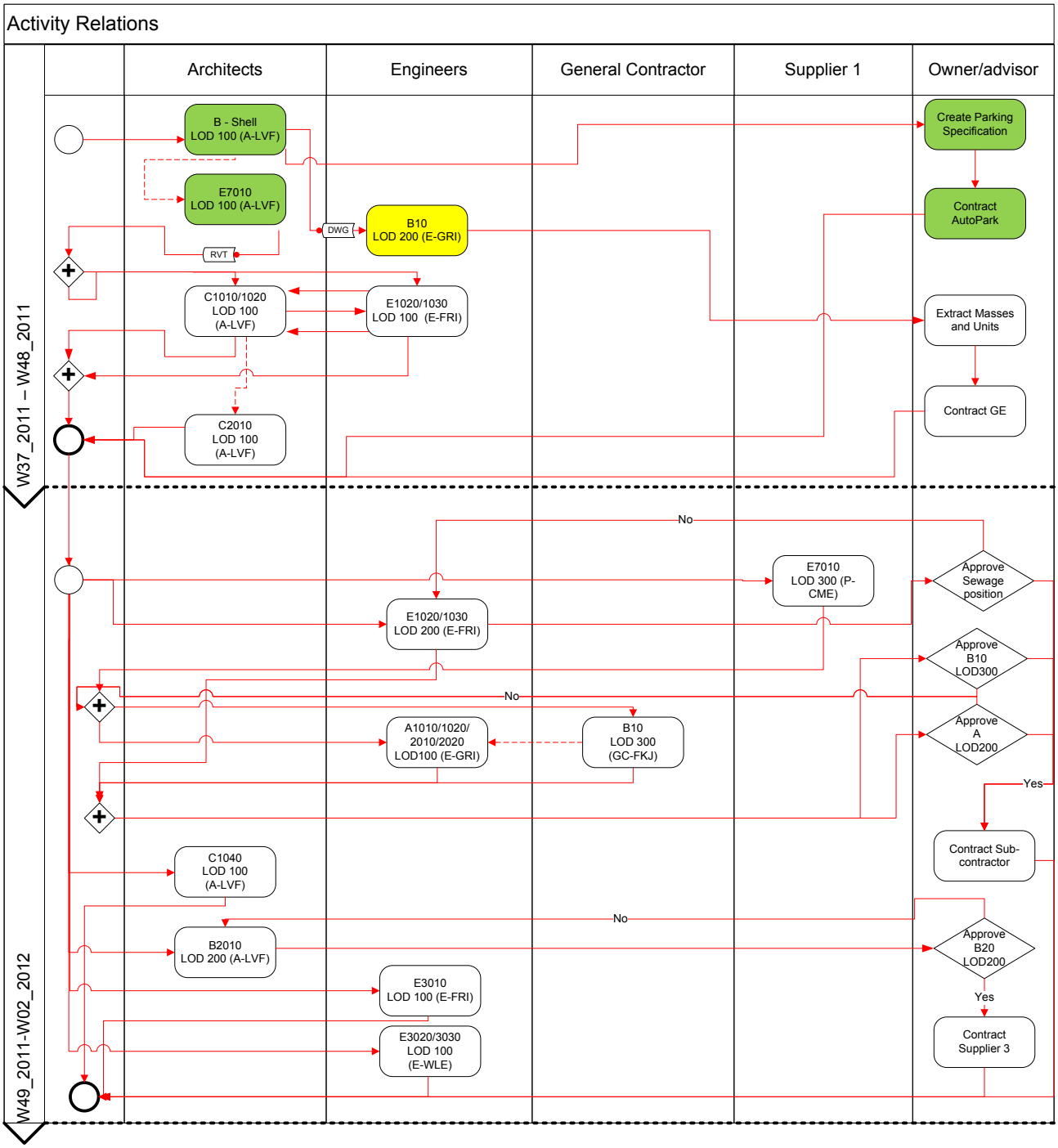


Figure 31 - Activity relations scheme template: *Tasks defined in the model element table (figure 30) are listed in this template to identify the workflow; BPMN is used to visualise the process. Each vertical 'swim-lane' represents the participants of the project, while the horizontal sectioning defines the project-periods. Green, yellow and red defines if a task is completed, started or on hold. Every task is defined by its component number from the model element table. A specification on preferred exchange format is illustrated on the relation between two activities.*

4.5 Implementation Suggestions

The prototype's different tools have variable influence on the project and do not have the same informative effect. It is recommended that the tools are handled by one of the main stakeholders of the BIM project. The tools have different opportunities to illustrate project delivery agreements among stakeholders.

The *model structure template* (figure 24) is essential to everyone, but should be controlled by the leader of the current project. This does not need to be the client advisor, but could as well be the general contractor of a DB approach, or the architect. The model structure functions as a project management tool and as a supplement to traditional agreement.

Tables and schemes related to the organisation are designed to be used in the owner's project leader group. It is a systematic approach to secure the right agreements to be made in the benefit of the project development. Therefore, it is recommended to use the organisation tools as a project management accessory, and for this purpose only.

The two process specific tools are both related to the workflow of the project. They can be seen as a to-do-list and should be implemented in the entire project group. One person should structure the requirements and informative needs in the *model element table* (figure 30) and *activity relations scheme* (figure 31). It can be used as a project management tool by the leader, or be present as a supplementary agreement to the contracts. Potentially they can be revised at the project meetings and be added to the report as a binding agreement.

Though the examples in this report is designed for use within the owner's group, they can as well be utilised by sub-contractors, suppliers etc. to define their own product delivery, organisation or process. The tools can be used by any responsible entity of a design/project task and are adjustable for use at bigger or smaller scales.

5 - Capture

The prototype presented in section 4 is evaluated in this section. With support from external opinions, considerations on how the prototype support the AEC industry are made. Further, it is evaluated how to benefit from them in BIM processes, and potential changes to the product before implementation is discussed.

Interview
It lists the most important sayings from the interview made with a BIM coordinator. The coordinator comment on: the BIM process in the earlier defined project in Aarhus and the usefulness of the tools presented in section 4.

Evaluation
Evaluates the product and suggest for potential changes and strategies to implement the product in the AEC industry.

5.1 Interview with BIM Coordinator

The interview with a BIM coordinator intends to evaluate the prototype presented in the section of implement. The person is, one out of four coordinators at an architecture office, and BIM manager on the actual project in Aarhus. The coordinator's main role at the office is to evaluate the workflow, and to support his colleagues when technical assistance in VBM usage is needed. The expertise is relevant and the person's qualified opinions are essential to the evaluation of the project.

(The interview was made in Danish and is presented in appendix D)

A Reproduction of the Comments from the BIM Coordinator in the Interview

Underneath are all the most important sayings from the BIM coordinator the interview. Each paragraph represents one theme within the BIM coordinator's comments.

General Comments from BIM Coordinator on BIM Use

Agreements in BIM are hard to control, which also can be read in the report from the project. Because this is our profession, we have better knowledge on what BIM processes include. The owners have another vision on this which affects the agreements. There are some missing links, especially related to the services and use of ICT.

—

Even if there are problems in achieving a common understanding of BIM, we make the process between us work. In many ways, the project is a unique case involving both public and private funding, and at the top of the hierarchy is the city councillor. Many stakeholders and, different opinions and knowledge of BIM, makes the process hard, but no problems stays unsolved.

—

On-going meetings clarify everyone's expectations; sometimes we disagree. As BIM is a new type of process, this can cause for extra difficulties. It is all the services we commit to deliver, these definitions have been to diffuse in order to support the rest of the agreements. Basically, this should not be any more difficult than within the traditional processes.

—

When I speak to the BIM coordinator in the engineering group, there is no trouble in communicating and defining processes. The problem appears when we communicate with the rest of the organisation - yet, they do not know the process well enough, and our intern agreements are not well defined. Therefore, a need to speak about the processes on different levels appears, making the intentions of the progress obvious.

Comments from BIM Coordinator on the Model Structure Template (figure 24)

The model structure is defined from the beginning, partly in the same way as this model structure template (figure 24). By practical or unpractical reasons, the model is mostly sectioned during the processes. The building is evaluated initially, to determine if the model should be divided by floors or

by components. Floors will be sectioned as quickly as possible, but first after the critical points are defined. I will not define how engineers should place their mechanical elements, but it is discussed in the beginning, and we seem to agree on this topic.

—

Everyone knows the size-limitation to each model, and when the models become too heavy to use they are divided and linked. Changes are communicated to the rest of the stakeholders. At the office the detailing of the model structure continues. Because an overall idea is needed, I attempt to define this structure initially from project to project.

—

The office is in a partnering agreement with the main contractor. They supervise the counsellors during the design and project engineering. While the counsellors do all the designs, the contractor makes sure that our designs are usable in construction. The evaluations are grounded in better constructability, economical parameters or resources useful to the project. The contractor is consulted about these things, and I assume that the engineers do the same.

Comments from BIM Coordinator on the Organisation Templates (figures 27, 28, 29)

The definition of the external entities of the project is attempted to be registered in some LOD based schemes, but it got staggered during the process. Primary the intention was to control the process between counsellors and entrepreneurs on what to deliver. You are absolutely right; there is a need to define the organisation like the organisation involvement table (figure 29). Expectations between all parts of the project should be defined. When everyone are more experienced with the process of BIM, we can define this in detail at the beginning of the project.

—

The model development is based on the 3D-handbook. It defines the LOD for model development and this is what supports the evolvement of the VBMs. But references on pre-design, schematic design, construction design and as-built is needed, fortunately LOD is comparable to this.

—

There is no need to develop every design parallel to each other, but articulations of these options are lacking. It is not defined why we should detail on one component in one period, and another in the next. It is difficult to make everyone understand the intentions of the process, since every profession has their own way of doing things. Divisions of tasks should be made initially to every project. Illustrative schemes like the organisation involvement table (figure 29) can potentially benefit this.

—

It cannot be expected that each project leader understands the full process of BIM, support is needed. What is missing in the office's personal process is something illustrative to support the project leader/director when signing agreements with entrepreneurs, counsellors and owner, making sure that everyone understands it equally.

—

Speaking of LOD, the office is aware on what each level defines and what expectations there are to the levels. Based on my investigations, I am able to lead my colleagues in what to do and when. This process needs to be held tight and big challenges are present when adapting to new principles with BIM.

Comments from BIM Coordinator on the Process Templates (figures 30, 31)

Our pure intention is to define the process initially. The model element table (figure 30) you show me is exactly what I started to use, but did not continue with. This scheme is a necessity, not said that we cannot succeed without, but it is helpful to have something emphasised. This information is usually present as text in a piece of paper or an e-mail. This is a very nice tool, usable to structure processes. Between counsellors and entrepreneurs it is an essential tool - the process cannot be controlled without. The model element table makes it much easier to understand the progress. The reason why we stopped using the scheme was because the time was lacking - there is always something more important or more interesting to do.

—

Regarding our services, some things were not cleared with the owner initially. This was especially the agreements on the requirements on the as-built material. Usually, this is at a lower level than the tender documents and, needs and classification should have been clarified with the facility-management. The struggle should be made initially to decide what the facility is better served with.

—

The hard thing about BIM is: not only should you know what to do yourself, but also what others can, should and will do. Often the material from our partners is not received on time; typically a result from us did not deliver what they needed. Using the relations scheme (figure 31) will benefit the structure, but these relations are hard to define initially. The other models you showed me (figure 24, 27, 28, 29, 30) can be made early in the process, but I do not think that the industry is ready for such a detailed level as presented in the activity relations scheme. In general, I will say: I believe in your basic ideas as the right way to do things.

—

Initially in a project, critical decisions should at least be discovered. Some critical points will always be present along with the project, and an advantage can be found in defining those and relate them to each other. The activity relations (figure 31) can be used supplementary to the meeting reports, but I find them difficult to structure during a meeting. Either way, we will always be forced to solve problems as the project progress.

5.2 Evaluation

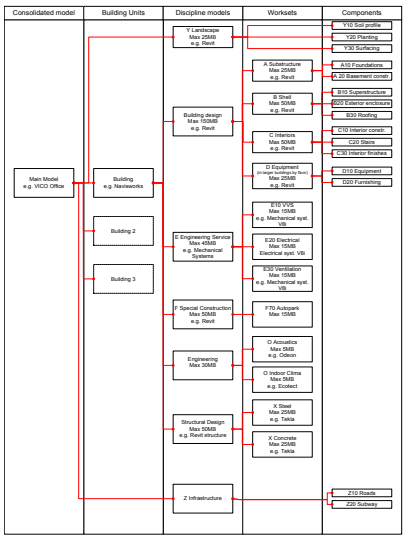
Based on the inputs from the interview in chapter 5.1, a personal evaluation is made to consider potential changes to the product. The requirements listed in the prototype specification and the comments from the interview are used to evaluate the prototype. Each of the 7 proposals will be evaluated separately.

5.2.1 Project Proposal

The project proposal did not include any specific tool, but listed some specification needed to successfully start a BIM process. From the interview it seemed obvious that the project proposal was not important in itself, in order to achieve a successful process. Rather, there was a need for common BIM understanding and a more defined specification of the final product of VBMs. Especially the facility-management was mentioned as an important factor to the agreement.

Still there is need for a well-defined design, because all the information is fundamental to the understanding of the project. At least as important it is to make agreements on phases and final deliveries according to the standards of BIM. This affects the model development and is therefore essential parameters to consider initially.

The biggest threat against the success of this, is the owner's and stakeholder's current lack of BIM knowledge.



5.2.2 Model Structure

Referring to the interview, structuring the model is a highly complex and important factor in BIM operations. The structure is considered from task to task, and can be structured by components, floor, or both, all dependant on the project.

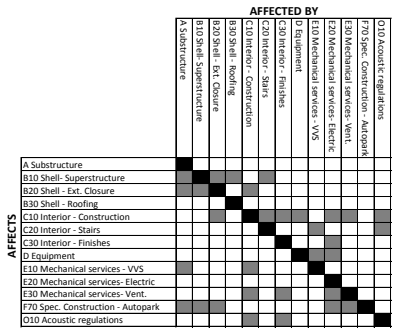
The BIM coordinator did structure the model in similar ways as the *model structure scheme*. This does mean that it is usable. In accordance to the coordinator, the structure was considered initially, but most of the sectioning was made when the need became present.

One can believe in the model to structure itself along the way and obtain model coherency inside each profession. But if models are used for more than information-exchange only, the model structure spots potential interoperability and coherency issues between

software solutions.

Even if one profession has structured their model-development, a discussion in plenum gains the overall process. An overview of the expected model-structure should be created to everyone as a team. Not everyone relate to BIM in the same way, and a definition of the model structure helps as a visual to the general understanding of BIM as a complex.

Even, if the whole structure is decided to be defined from the beginning, or not, the scheme can be used to highlight the participant's information-structure. Overall it gains the complete understanding of the project complexity. Issues will come along the way, and when new sectioning appears they can be added.

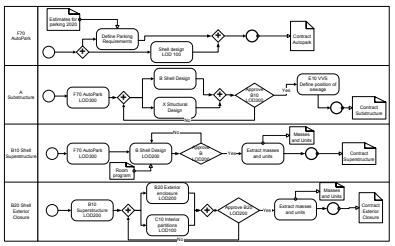


5.2.3 Model Impact

No specific comments were made on the *affect and affected by table* (figure 27) in the interview. The table is mostly a guide to structure the next two schemes in the organisation process, and will possibly be skipped by most project leaders, as they do not find it directly usable.

Either way, the importance of enlightening the critical decisions, and define the relations between tasks was commented in the interview. The table forces the user to reflect on each combination and relation in the project, and the model is therefore relevant. Possibly, it should be limited to the main components and only list the most critical parts of the project.

Whether or not the table gives a clear overview of the model components' effect on the design can be discussed. The table is possibly better used by one person and not as a common definition to the project. It could be a nice exercise to a rookie and his reflections on project relations.



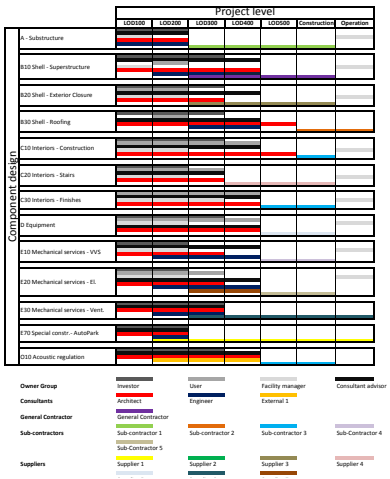
5.2.4 Critical Assessment

In the interview, the critical path was stated as important to locate. Therefore, the intentions of the *IDM scheme* are relevant. It enlightens the critical aspects in BIM processes, and is also usable in more traditional processes.

The structure clarifies the critical path to each of the components so contracts can be signed from the right set of information. A critical path cannot be defined without connecting relations across the components. Time is not a part of the scheme, a factor stated as

essential in the interview.
When drawing a critical path between all the different components and tasks, it ends up in a complex scheme. A suggestion to improve the scheme is to insert a horizontal timeline, and then structure the tasks in relation to this; the timetable will then define the path.

The components should be sectioned as suggested in the scheme, but supported by the timeline to achieve a better overview. Generally, it will help to define critical points and have a base for agreements to be defined in the project leader group. The scheme can be used in the project organisation in common, or internal in the counsellor group.

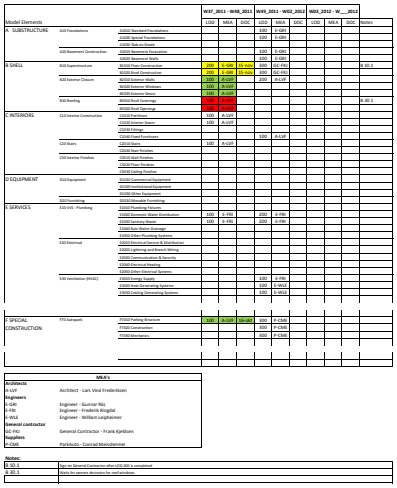


5.2.5 Organisation Involvement

In the interview with the BIM coordinator, it was said that every profession has their own interpretation on how BIM works. So it is needed to agree on when to involve the partners in the process in the beginning of a project. The *organisation involvement table* (figure 29) illustrates the implementation of each part along the project, and was considered to have potential benefits.

Something illustrative to support the project leaders in their making of agreements with entrepreneurs, counsellors and owner was missing in the project presented in the evaluating interview. Potentially, this table could support the stakeholders who are involved. The table is simple and illustrative, and easy to understand for every part.

The table expresses the organisation to each of the main components of the project. This is important since the components design can evolve separately. Components involving the facility-management are marked as well and help to define the final need of as-built material requested at project handover.



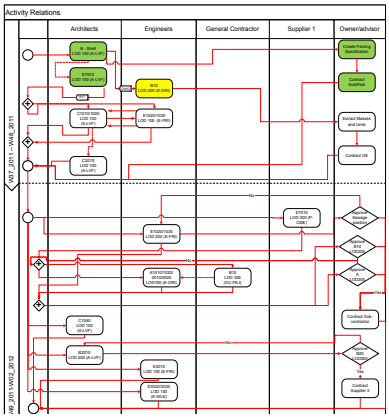
5.2.6 Model Element Table

The BIM coordinator intended to use the *model element table* to control project workflow in the design development. Further, AIA have published this as a tool to support process and agreements in BIM, which confirms the usefulness of the tool. Krygiel, Read and Vandezande (2010) also mention this as a way to structure VBM processes in their mastering Autodesk guide.

Stated in the interview was that the table is essential to structure work and agreements between architects, engineers and entrepreneurs when developing projects, and to define agreements made at meetings or along the way. The table is found better than some text in a report or an e-mail.

The table can be used to define how the project is intended to evolve. Essential information from meetings becomes easier to access in a table like the *model element table*; making it a visual method to lead projects from.

Further, usage as a combined timetable and supplement to the project agreements is possible, but it all depends on the willingness to use the table. Time is required to create and update the table along the way. The *model element table* is usable on many levels, but probably most relevant between model developers.



5.2.7 Activity Relations

Referring to the interview with the BIM coordinator, sometimes the office did not receive the material they needed from their collaborative partners. Often, this was a result of the architects not delivering what the collaborative parts required in the first place. It became a vicious circle.

The *activity relations scheme* helps to define the purpose of the design, as one task is related to the next one. It defines collaboration between disciplines and when to start and finish tasks for the next designer to be implemented. The BIM coordinator saw benefits in making relations like this, but also questioned if the AEC industry were ready to implement it.

The scheme is functional to its purpose, but relations must be linked over smaller periods of time. If not, it will probably be confusing and indefinable, especially to others than the creator. Also, the scheme should not contain all tasks and relations, but mainly the critical ones. Otherwise it becomes a time consuming tool, and it will not be used.

5.3 Implementation of Prototype

All prototype templates are generated by the use of Microsoft Excel and Visio, and only as separate entities. Realistically, it is necessary for these templates/tools to be combined in a more efficient user interface. Project leaders will otherwise omit to use the tools, as they become a time consuming duty. To successfully implement the prototype on the market, a more interactive user interface must be created between the tools. A software system should be developed to manage all of them within the same user interface, so they efficiently can be used to the purpose of project leadership. (figure 32)

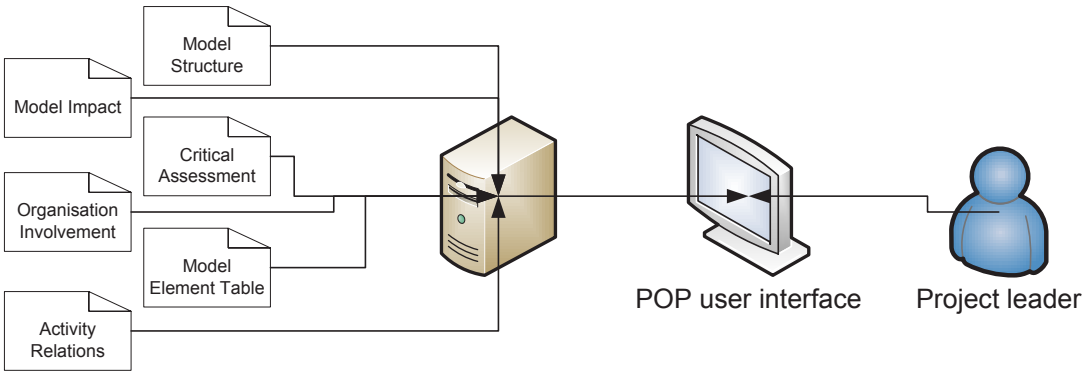


Figure 32 - Database to compile tools: *Every table and scheme should be related to a digital server, consolidated in a united POP user interface for the project leader to work in.*

5.3.1 User Interface

The user interface will be the main controller of the tools, where all of the tools are accessible in the same window. For overview, it is still relevant to keep POP separated in product, organisation and process. The screen could potentially look like figure 33. At the header there is a menu including product, organisation and process. Selecting one of them releases a sub-menu which includes all of the tools related to the specific subject (in this example, every tool related to ‘organisation’). When selecting a tool, it emerges on the screen. Actions made in the window are stored in an external database.

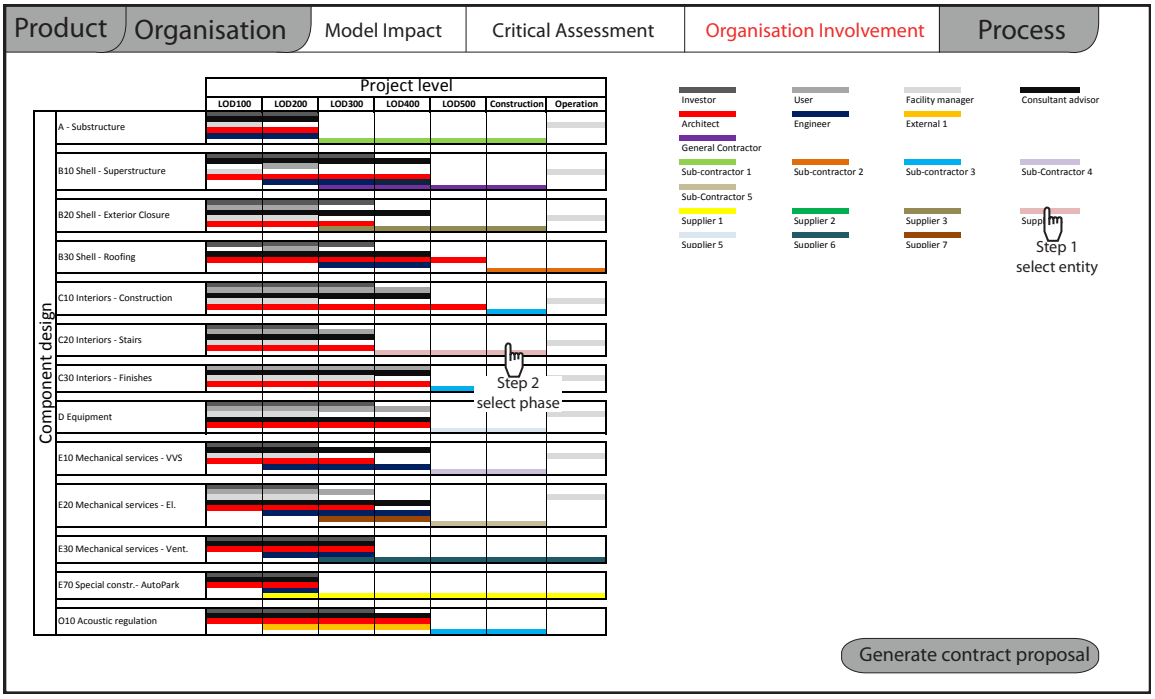


Figure 33 - User interface: *The bar at the header is used to select tools for product, organisation or process, and the tool emerges in a sub-menu on the screen. This figure exemplifies the tools of 'organisation'; an entity is selected and related to a project component phase.*

5.3.2 Relations between Information

The tools are structured in terms of POP, and each of them is seen as independent tasks. In fact, the schemes and tables are based on much of the same information, and could generally be in an even closer relation to each other. Information from the *model structure* (figure 24) is used in every other tool presented. Therefore, it is essential to operate in a database system to reuse information from the *model structure* in other tools. (figure 34)

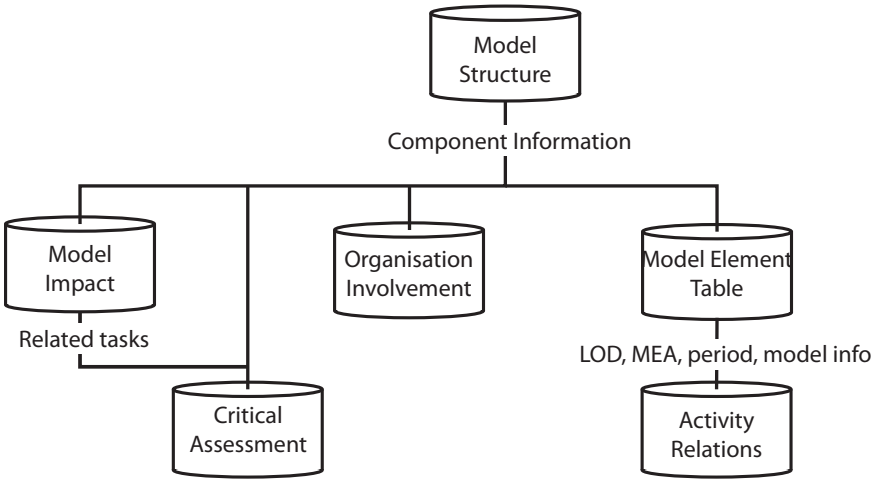


Figure 34 - Relations in information: *Information on all components defined in the model structure can be reused in the creation of other schemes and tables. Registrations in model impact can be used to define related tasks in the critical assessment. Info on model, LOD, MEA and period of time can be reused in the definitions of activity relations.*

With some programming, the *affect and affected by table* (figure 27) could automatically generate processes/tasks to be aware of in the critical decision making (figure 28). This will become a ‘drag and connect’ time schedule used to define the critical path. The *organisation involvement table* (figure 29) has the possibility of analysing the input of information, and by this propose the type of agreement suited for the stakeholder’s involvement.

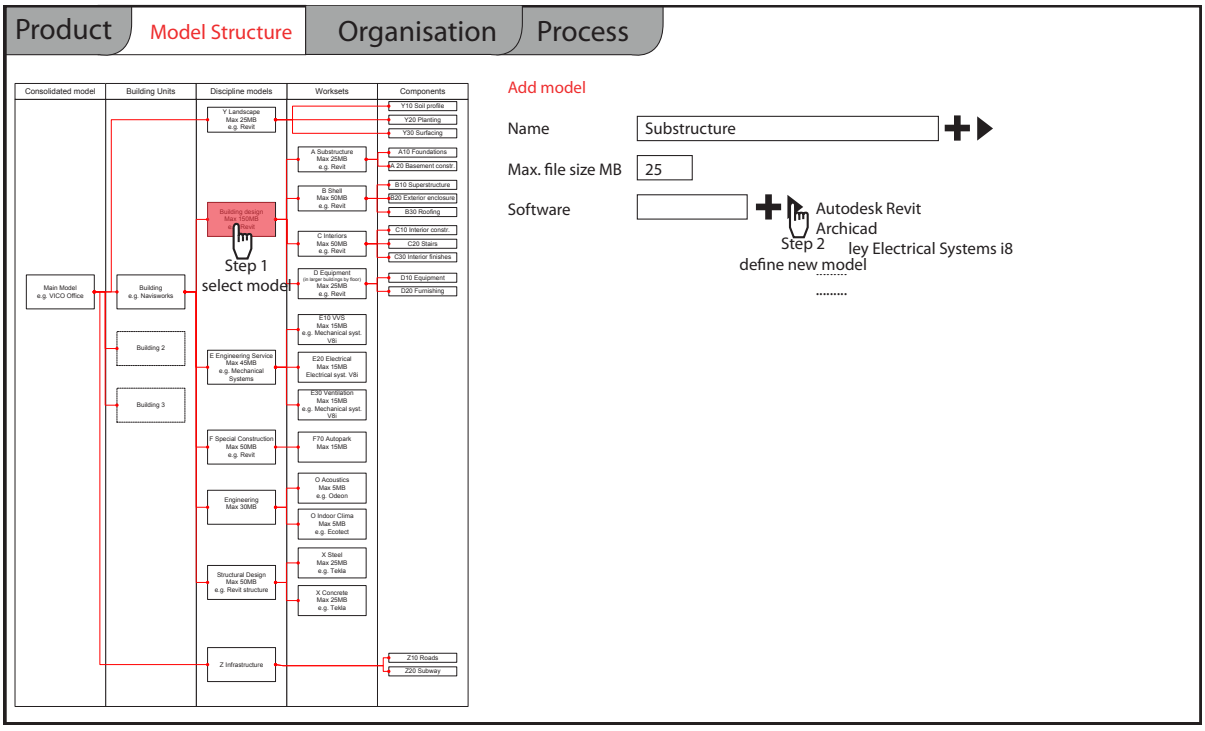
The *model element table* (figure 30) is a result of the *model structure*, where a list is created from the amount of models and a precise description of components in the building. As the scheme of *activity relations* (figure 31) is partly a product of the *model element table*, the two processes are able to support each other with information. It is then relevant to connect the two tools with parametric programming, and defining them in the same user interface, like a ‘drag or drop’ or similar.

With a database and programming, relations between the prototype tools can be used to create an efficient user interface. The easier the tools are to use, the more likely it is to apply them within the daily processes. Potentially, the tables and schemes can be used on a projector during meetings, and then become an accessory to the common structuring of a BIM based project.

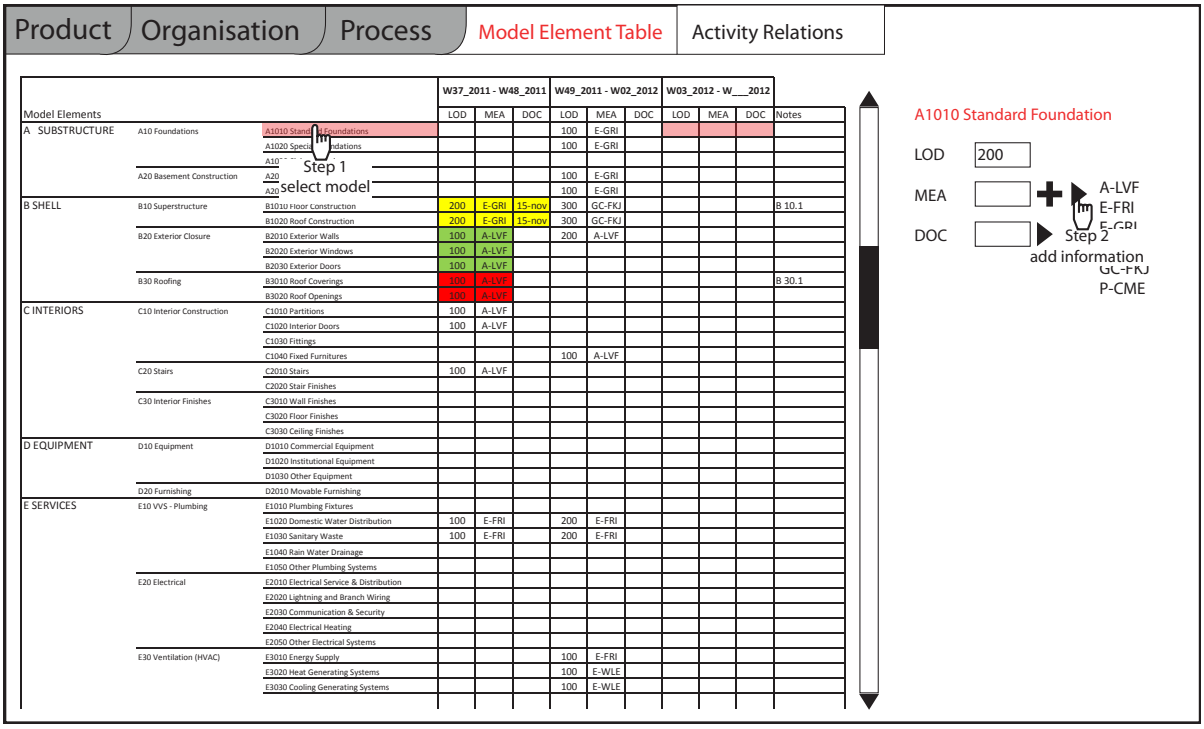
5.3.3 User Example

This example is an illustration on potential usage of the database system. An easy to access and a logical approach is essential. This example is only a visual representation on how the different tools’ user interface could be. It exemplifies how the relations could be between model structure, model element table and activity relations and how these three components will be used in the project planning.

Step 1 - defining the model structure. Start by adding a model to the consolidated model by clicking twice. A form appears to the right, where the type of model can be selected from a predefined menu, or added to the menu if not existent. Type size and select expected software to be used.

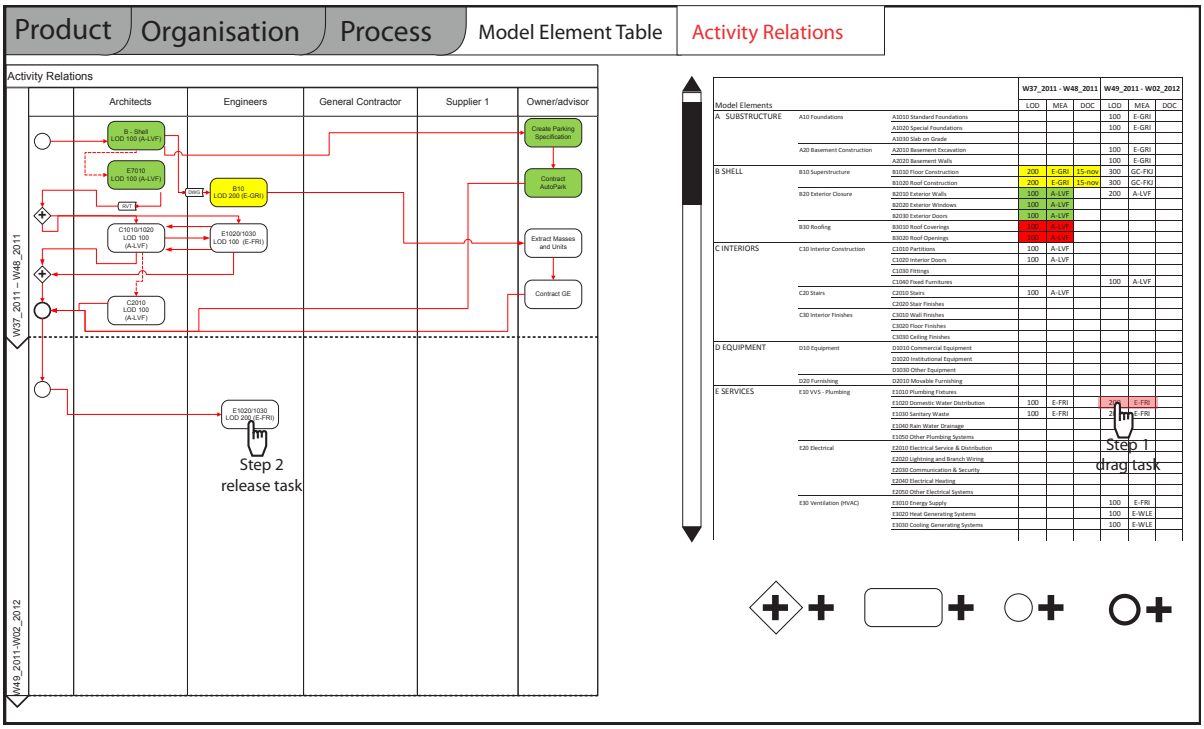


Step 2 - The model structure automatically generates a model element table. Select the model element table in the sub-menu. Add a new period, and enter required LOD, responsible MEA and DOC (if required) in the blank spaces by using the menu at the right.



Model Elements			W37_2011 - W48_2011 LOD	MEA	DOC	W49_2011 - W02_2012 LOD	MEA	DOC	W03_2012 - W___2012 LOD	MEA	DOC	Notes
A SUBSTRUCTURE	A10 Foundations	A1010 Standard Foundations				100	E-GRI					
		A1020 Special Foundations				100	E-GRI					
		A1030 Slab on Grade										
	A20 Basement Construction	A2010 Basement Excavation				100	E-GRI					
		A2020 Basement Walls				100	E-GRI					
B SHELL	B10 Superstructure	B1010 Floor Construction	200	E-GRI	15-nov	300	GC-FKJ					B 10.1
		B1020 Roof Construction	200	E-GRI	15-nov	300	GC-FKJ					
	B20 Exterior Closure	B2010 Exterior Walls	100	A-LVF		200	A-LVF					
		B2020 Exterior Windows	100	A-LVF								
		B2030 Exterior Doors	100	A-LVF								
	B30 Roofing	B3010 Roof Coverings	100	A-LVF								B 30.1
		B3020 Roof Openings	100	A-LVF								
C INTERIORS	C10 Interior Construction	C1010 Partitions	100	A-LVF								
		C1020 Interior Doors	100	A-LVF								
		C1030 Fittings										
		C1040 Fixed Furnitures				100	A-LVF					
	C20 Stairs	C2010 Stairs	100	A-LVF								
		C2020 Stair Finishes										
	C30 Interior Finishes	C3010 Wall Finishes										
		C3020 Floor Finishes										
		C3030 Ceiling Finishes										
D EQUIPMENT	D10 Equipment	D1010 Commercial Equipment										
		D1020 Institutional Equipment										
		D1030 Other Equipment										
	D20 Furnishing	D2010 Movable Furnishing										
E SERVICES	E10 VVS - Plumbing	E1010 Plumbing Fixtures										
		E1020 Domestic Water Distribution	100	E-FRI		200	E-FRI					
		E1030 Sanitary Waste	100	E-FRI		200	E-FRI					
		E1040 Rain Water Drainage										
		E1050 Other Plumbing Systems										
	E20 Electrical	E2010 Electrical Service & Distribution										
		E2020 Lightning and Branch Wiring										
		E2030 Communication & Security										
		E2040 Electrical Heating										
		E2050 Other Electrical Systems										
	E30 Ventilation (HVAC)	E3010 Energy Supply				100	E-FRI					
		E3020 Heat Generating Systems				100	E-WLE					
		E3030 Cooling Generating Systems				100	E-WLE					

Step 3 - When the model element table is structured, the activity relations can be defined. The information added in step 2, can now be used to ‘drag and drop’ into the relation scheme. When a task is dropped it can be connected to others by selecting them both pressing *shift* on the keyboard. If other processes must be defined, they can be added by the buttons underneath.



6 - Conclusion

The section of conclusion reflects on the product and concludes on the project.

Project Conclusion
The chapter concludes on the project.

6.1 Project Conclusion

Through the past centuries a significant increase in software solutions has been presented in the AEC industry. Both 2D- and 3D-software have substituted the more traditional handmade illustrations in the design and construction phases. Design and engineering disciplines have slowly adapted to the use of 3D design solutions. Today, the tools are used for construction and sustainable analysis as well as for illustrative purposes.

BIM is a process which defines how to use 3D-objects for digital information exchange between owners, architects, engineers, contractors, suppliers, etc.. The BIM ideology opens for geometry and information to be reused for more than one purpose, making the design and construction a more efficient process. Building information is used by diverse disciplines in a unified collaboration, which requires that professions within design and construction understand the needs of each other.

The aim of the present report was to define a strategy on how to support BIM as a process by solving challenges related to it. Construction projects are developed by the organisation in a collaborative process in order to create a product. The VBMs are the product of a BIM process where VBMs define geometry and specifications on each building entity.

The objective is to create a cost effective design process by involving different engineering disciplines at earlier stages in the design. Specific knowledge on structure, constructability, cost-saving-production etc., is then included in the development of the design.

Considering, that every discipline is a tool to create VBMs for building information, a structure on when to use each tool is important. Since VBMs are executed by different design disciplines, considerations on organisation and process are essential to efficiently construct a qualitative product. A need to support the structure of VBM development has been expressed by users of BIM. Considerations on POP must be made to achieve optimal collaboration between the relevant project participants.

The solution is to define the POP through a set of tools, achieving an overview of the contents of the three categories: product, organisation and product. As the three affects each other they must be considered in relation to one another. The process of the project needs to be structured from the organisation of the project and the organisation must be suited to the product of the project; the three topics are therefore considered in reversed order (product, organisation, process) and in iterative cycles.

The product must be defined in a *model structure scheme* (figure 24), based on information from the project proposal. A model structure is essential to the development of projects in BIM, caused by the unknown amount of VBMs used in the production of building information and their parametric relations. If a structure is not defined, inconsistency between models can appear.

A more precise evaluation of the project's organisation can be made when the product is defined. An organisation should support the process and must be extended if the need is present. To achieve this, the impact of building components' on each other must be evaluated (figure 27). By assessing the critical tasks related to the product progression (figure 28), a more clear structure on the involvement of participants' can be prescribed (figure 29). Precise agreements between project stakeholders can be made when their project involvement is defined.

6 - Conclusion

The process of BIM projects is structured from the need of building information. Therefore, it is essential to reconsider the traditional phases of progression. Pre-design, schematic design, design development etc. must be deselected and structuring by the LOD of each building component must be implemented. The organisation needs to be involved strategically along with the model development.

Model development within each model category must be defined to obtain a well-structured process. The *model element table* (figure 30) solidifies the progress of this development and divides responsibilities. When model information is handed over through collaboration, it must be defined for what purpose the information will be used. *Activity relations* (figure 31) between model development tasks must therefore be defined to secure the usability of the information. These are tools to be used along with the evolution of the project as a binding agreement between stakeholders of a project.

The prototype of the tools used to structure POP is found useful and project leadership will benefit from usage of these tools. Successful implementation of all tools will benefit from implementing them in a user-friendly interface. Relational databases are useful to this purpose and it is vital to apply schemes and tables in such a system to obtain a successful prototype implementation.

The final conclusion is: the AEC industry needs to consider POP when adapting to BIM, and tools are needed to do so. It is beneficial to structure the tools in a logical and user-friendly interface to maintain efficiency and obtain consistent use.

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Appendixes

Appendix A

Report - Workshop BIM/RFID at Ramboll Office Aalborg 31.03.2011

Appendix B

Case Interview with Project Leader in Board of Secretary

Appendix C

Case Interview with Project Leader for Client Advisor

Appendix D

Interview with BIM Coordinator at the Architect's

Appendix A

Workshop BIM/RFID at Ramboll Office Aalborg 31.03.2011

The worshop was arranged by Ramboll and IBM to discuss the furture of building construction, and the potential usage of BIM and RFID. Architects, engineers, contractors, suppliers and owners where all represented among the participants.

Entreprises represented: Universitets- og Byggestyrelsen, Rambøll Denmark, MT Højgaard, IBM Denmark, COWI, Sanistål, Inwido Denmark, Aalborg University, University College Nordjylland, Exigo, Tekla Denmark, Bjerg Arkitektur, Vestas Wind Systems, Spæncom, DS Elcobyg, Bygma, E. Phil & Søn, Bips, Hp Byg.

In this summary of the workshop, inputs from all participants is listed under one of those five professions they belong in.

Archiects:
The architects seldom knew what their real position in the project was, and how they preferably could add value to the total supply chain. It was claimed that a lot of work was made which had no relevanse for other parts in the value chain.

Would preferre if the value chain at some level was turned around. Suplliers could then point out what type of material they needed for their production, what the contractors needed and so on, for them to specify their work tasks in benefit of the later processes. Would save them a lot of unnessesary work.

They could clearly see the value of bringing in contractors and their task related knowledge at earlier stages. A greater value would be added if they were integrated at a level where it had influense in the project design – usually they gets involved after the design is complete.

The future role of architects were claimed to be: specifying requirements for the building and no more, contractors will do the rest in a DB-approach.

Engineers/rådgivere:
Engineers claimed that they many times where confused on what the owners actually wanted from the project.

That a lot of participants did not practise BIM, often resulted in a staggered process where old fashion practises again were practised. Information which architects and engineers spend time on designing, do not actually get used. Often do BIM models end up as automatic generators of 2D-drawings for production and construction.

Software counsellors mean that the most interesting thing is the information level of modelling, having a complete control of the production and material ability through the whole project.

Contractors:
Had the biggest ability to gain from the use of RFID, especially in the process of construction. Deliveries and localization of materials had huge financial potentials in using RFID.

BIM had great possibilities in the process of calculation and planning of the project. A video was shown of a Chineese high rise completed in 4 days, puting in perspective the ability of planning right. On time deliverys and how prefabricated structures and semi-fabricated walls are benefitting the overall process. Planning minimize on site activities in the benefit of constructors, knowing what to do and in what sequence.

Suppliers:
From the suppliers, there was a clear lack of directly usable drawings, most had to be redrawn for use in production. Happens that some concrete elements are cleared from designers and produced, but do not fit properly at site. Who to blame?

They often get told what to produce, but still have the responsibility of delivering the right elements, without having a proper description. There were no willingness from designers to co-operate further than calculating the work loads.

Supplier of steel pipes for water and gas means there is a lack of understanding from the installers, using the wrong pieces of steel at specific places, risking for the whole ting to be renovated in a short time. Supplier could really see the benefit of RFID use and permanent product information.

Owner:
Owner had a lack of interference and information flow from contractors, architects etc. They would like to get the time schedual and cost of the project updated at any time, telling what for things to cost. Would also like to receive packages including 3-dimentional models and information about the product they buy.

What they want and what they get, do not necessarily relate to each other.

Some of the owners had only interest in a facility ready for usage, while other wanted a more designed unit to be qualitative for a decade. They have two different intentions of how a building should work, why they also should take part in different constructional processes.

General:
Standards in the AEC industry was debated, where there were no clear indication of whom to do what. Salaries and work loads did not necessarily relate to the actual amount of work that was produced during different constructional approaches. Clear resemblance of situations between AECS/O, a lack of agreement on each parts responsibilty in the project of BIM. It doesn't operate well within the old standards of bips used for building construction.

Lack of a building interest, to many people aim to control their part of their project but none have the main interesst of the projects total economy. When there is one main interest, there would be more relevant to demand the use of BIM/RFID etc, as they have a clear potential benefit.

Time scheduals have the ability to automatically be developed on backround of the BIM model in software like VICO Office. Work in process was mentioned as a problem for constructional benefit of all professions.

No one is interessted in taking the costs of using BIM or RFID without beeing clear the advantage.

Also more complex projects have the ability to be broken down into bigger prefabricated units by the use of BIM, reference could be Bau How. Elements, bigger and smaller, for construction can be told where to be placed by the use of BIM and RFID.

Appendix B

Case Interview with Project Leader in Board of Secretary

Sammendrag fra interview med projektleder for bygherresekretariatet i bygherre gruppen ved et byggeproject på Aarhus havn.

Målet med interviewet var at få klarlagt anvendelsen af digitale bygningsmodeller ved bygherre. Hvorledes anvendes modellerne til præsentation og hvorledes foregår beslutningsprocesserne. Hvad baggrunden har været for at vælge BIM som foretrukket proces, og hvilke krav og forventninger det har været til udbytte af procesformen.

Interviewet var struktureret omkring en række spørgsmål, men forløb meget efter hvad situationen tilbød. Derfor vil sammendraget være en opsummering af hvad der blev sagt relateret til de specifikke punkter.

1. Må jeg få en uddybning af hvilken rolle du har i projektet og bygherregruppen?
Personen har ikke nogen byggefaglig eller teknisk baggrund, men derimod en baggrund der relaterer sig til kommunikation mellem mennesker og grupper.
Personen blev introduceret til projektet efter at dispositionsforslaget og konkurrencen var afviklet, men har været med siden projektforslagsfasen påbegyndte.
3D-modellen er personens ansvarsområdet, men anvender også i disse henseende den rådgivende ingeniør til at udføre handlinger.
Det er projektsekretariatet der står for udviklingen af huset, hvor det meste andet omkring videre brug af bygningen står i brugerens regi.

2. Hvad var baggrunden for valget af BIM som proces når projektet blev udbudt?
Idet personen ikke selv har været delagtig i denne fase af projektet, kom det ikke rigtig give svar på dette, men derimod fik jeg udleveret et notat fra udbudsmaterialet der stillede krav til BIM processen ved totalrådgiveren.
Det var et ønske fra bygherren om at anvende dette projekt som en mønsterbeskrivelse af hvorledes en BIM proces kan og bør anvendes, og hvilke fordeler der er ved valget af denne procesform.

3. Hvorledes har i som bygherre involveret jer i processen på de forskellige stadier i projektet?
Projektet er til dags dato nået til hovedprojektfasen, hvor bygherre har godkendt projektforslaget med forbehold mod enkelte dele af det der skal forbedres.
Bygherre er meget involveret i processen når det kommer til brugerinddragelse, hvor de afholder workshops etc. med borgere og ansatte for at skabe et så velfungerende byggeri som muligt. Dette skulle være lavet i regi af totalrådgiveren, men dette har således blevet anderledes. I dag bliver derfor ønsker osv. Formidlet fra bygherregruppen og til totalrådgiveren efter afholdte workshops.
Funktionaliteten af rummene er oprindeligt defineret ud fra konkurrenceforslaget, men har selvfølgelig vært drøftet i bygherregruppen og ved totalrådgivere. Udover dette ligger det største fokus ved drift, hvor de går meget op i materialevalg og holdbarheden af dette, samt hvorledes flowet i bygningen skal være.

4. På hvilken måde formår jer i bygherregruppen at drage nytte af VBM og anvendes de på nogen måde af jer som bygherre?
3D modellerne har ikke blevet brugt så effektivt som man ved bygherregruppen har haft som ønske

fra begyndelsen af. Det diskuteres tit om det totalrådgiveren leverer, opfylder de krav der har stået i kontraktforhandlingerne.
Bygherre ville gerne selv anvende modellerne aktiv, men dette har ikke rigtig forekommet. De har tilgang til de digitale modeller, men brugervenligheden af Revit-filene er meget dårlig og bremser dermed anvendelsen af dem.

5. Føler du at de digitale modeller gavner den proces som i har med totalrådgiverne, og hvorledes anvendes de konstruktivt i denne kommunikation?
Modellerne virker til at anvendes godt i et højere hierarki til præsentation af projektet, men i selve den dynamiske formidling ved anvendelse af VBM så kniber det lidt. Det har været svært at få modellerne til at fungere ordentlig, grundet computerkraft og fremlæggerens manglende erfaring med softwaret. Derimod anvendes de meget til generering af visuelle billeder og tegninger.
Bygherren havde forestillet sig at modellen kunne anvendes mere konstruktivt og aktivt i bygherregruppen.
Det er ellers tydeligt at redskaberne der anvendes af henholdsvis arkitekt, ingeniør, landskabsarkitekter etc. Ikke operer optimalt sammen, hvor de respektive bliver tvunget ud i at anvende programmer de selv ikke arbejder godt i.

6. På hvilke grundlag bliver der truffet beslutninger fra bygherres side under denne BIM proces?
Beslutningerne bliver som regel truffet på baggrund af udtræk og elementer skabt gennem anvendelsen af den virtuelle bygningsmodel. Dette betyder at der fra totalrådgiveren fremlægges tegninger og visualiseringer til at beskrive projektet og til at træffe beslutninger ud fra.

7. Kan du beskrive på hvilke tidspunkter i processen i har været nødt til at træffe de forskellige beslutninger for at processen kan forløbe effektivt og uden risiko for kostbare ændringer?
Alle funktionerne var fastlagt i udbudsprogrammet, hvilket det er anvendt meget tid på at udarbejde. Så de primære ting det har skullet tages stilling til efterfølgende under udarbejdelsen af projektforslaget, har været at få funktionerne fastlagt og placeret, samt at få klarlagt det logistiske i henhold til bygningen. Udover dette har det skullet tages stilling til energimæssige aspekter, indeklima, lys osv. Primært har det været afklaringer omkring alle overordnede træk med bygningen, men intet der senere vil kunne påvirke projektets fremdrift. Det har ikke så langt været nødvendigt at afklare anvendelsen af materialer indvendig.
Det er ingen generel oversigt over hvornår de forskellige beslutninger bør træffes.

8. Føler i at det materiale i modtager fra totalrådgiverne er bedre ved anvendelsen af BIM fremfor de andre mere traditionelle metoder?
Det er tydeligt at alle parter i projektet forholder sig forskelligt til den visuelle formidling af projektet. Den arkitektoniske vision som arkitekterne ofte lægger til sit visuelle materiale, er noget anderedes end det bygherre i udgangspunktet har behov for. Derfor er det meget materiale der ikke bliver fremskaffet fordi det er noget arkitekten synes tager for meget tid at præsentere rigtig.
Var det givet at dette var et så stort et problem fra begyndelsen af, ville der skulle være lagt afklaringer omring dette ind meget tidligere, hvor de kunne komme til enighed om kvaliteten af det materialet der bliver formidlet.
Men ellers er der ikke nogen direkte problemer, materiale der kun omhandler form og rumligheder kan typisk fremskaffes fra arkitekten meget hurtigt, men fotorealistiske billeder tager tid og er således heller ikke altid nødvendigt.
Det virker til at projekteringsgrundlaget er meget godt udarbejdet i BIM, så den interne brug af modellen i rådgivergruppen virker til at kunne fungere.

Det er ellers tegn på at kontrakten ikke er tilpasset projektets ambitioner, hvor det ikke er klarlagt hvad ydelserne skal indeholde. Kontrakterne forholder sig ikke reelt til processen der foregår, og dette burde være stemt mere overens.

9. Ser du nogle fordele/ulemper ved anvendelsen af BIM processen, og er det eventuelt noget du ser forbedringsmuligheder i?

Det virker til at have været fordelagtigt at kunne udbyde projektets første deler på meget præcise mængder, hvor der er fastlagt hvor meget stål og beton og udgravning der skal gøres i forbindelse med projektet. Virker til at have været effektivt under udbuddet med de præcise udtræk af data der kunne gøres.
Satser på at kollisionschecken kan minimere fejl og mangler i sidste ende.
Det er meget stor fordel at der hele tiden er tilgang på opdateret 3D materiale, da det for normale mennesker kan være svært at omsætte planer og snit i rumligheder. Så rumligt er det meget godt med den virtuelle model til at støtte sig op ad.
Det er meget tydeligt at de faglige interesser er meget forskellige, hvor totalrådgiver gruppen har nogle helt andre hensigter ved anvendelsen af BIM en bygherren. Dette kunne være bedre afstemt på forhånd.

10. Anvender i selv bygningsmodellerne aktivt, eksempelvis til at profilere den visuelt på nogen måde?

Modellen er i dag ved at skulle anvendes til at fremstille byggeriet på deres hjemmeside, således borgerne kan gå ind og orientere sig i bygningen, samt komme med kommentarer og forslag til funktioner i projektet, hvilket eventuelt kan anvendes konstruktivt under den videre planlægning.
Denne del vil være baseret på fasegodkendte modeller, hvor der sammensættes en model af de modeller der fås fra landskabsarkitekten, en by model og arkitektmodellen. Det er bygherren selv der står for udviklingen af denne, men med grundlag i totalrådgiverens materiale. Da fasen nu er under for projekt, vil modellen være af ren geometrisk form, men vil senere kunne blive mere detaljeret.

11. Forestiller du dig at modeller vil blive anvendt aktivt i driften af byggeriet, eller vil modellen udgå idet projektet er færdig konstrueret?

Det ønskes fra bygherre at anvende modellen til drift og vedligehold, således de kan trække meget specifikke mængder ud i henhold til udbud af rengøring, skiftning af pærer etc.

Appendix C

Case Interview with Project Leader for Client Advisor

Sammendrag fra interview med projektleder for rådgivergruppen tilknyttet bygherre på det nye byggeprojektet ved Århus havn.

Formålet med interviewet er at få klarlagt hvorledes man skal forholde sig til juridisk samarbejde i en BIM baseret proces, og om det er nogen foretrukne samarbejdsformer. Om det generelt ses nogle fordele ved anvendelsen af BIM procesmæssigt, herunder tid, økonomi, forståelse. Hvorledes man forholder sig til det materialet totalrådgiverne i denne proces fremviser, og om det er nogle bestemte krav det skal stilles til dette. Samt om det er nogen kontrol over det arbejde der udføres i BIM, og hvem der eventuelt koordinerer denne proces.

Interviewet var struktureret omkring en række spørgsmål, men forløb meget efter hvad situationen tilbød. Derfor vil sammendraget være en opsummering af hvad der blev sagt relateret til de specifikke punkter.

1. Må jeg få en generel beskrivelse af din rolle i projektet, og hvorledes du agerer som rådgiver for bygherren?
Personen er leder for bygherres rådgivergruppe på projektet byggeprojektet, og dermed bygherrens højre hånd og byggetekniske vejleder på projektet. Personen står således for styringen af det her projekt, hvilket vil pågå over 9 år. Projektet startet i 2006 og har en budgetramme på 1,9mrd, hvoraf 700mill. er støtte fra fond.
Projektet startet den gang det blev udbudt i konkurrence, hvor arkitekterne blev udvalgt på baggrund af sine indledende dispositionsforslag. 3 vindere blev udvalgt og knyttet op mod en videre forhandling af projektets udførelse, hvilket er noget unormalt. Dette skyldes at bygherre under sagkyndig vejledning ønsket at holde projektet i stram snor, og ikke lade økonomien overskride. Derfor blev de aktuelle totalrådgivere krydsforhørt i henhold til konstruktioner, opbygning, økonomiske overslag osv. I en redegørelse for projektets holdbarhed. I henhold til rådgivergruppen, har det her blevet brugt op til 12.000 mandetimer fra hver af disse for at opfylde de krav der blev stillet fra BH. Her blev de vurderet på arkitektur, konstruktion, organisering og projekt økonomi.
Det blev ikke anvendt BIM i konkurrencefasen, her var det mere traditionelle metoder i brug.

2. På hvilke måde arrangerer i det kontraktmæssige mellem arkitekter, ingeniører og bygherre i en BIM proces som denne? Er den anderledes end ved mere traditionelle projektformer? Føler du den er tilpasset projekttypen?
I forbindelse med projektets udbud er det stillet en række krav til hvorledes det forestilles at IKT vil anvendes i projektet, hvor der stilles krav til en integreret designudvikling mellem arkitekter og ingeniører i rådgivergruppen.
Det er gjort krav om anvendelse af digitale bygningsmodeller, således informationen kan anvendes aktivt projektet igennem. Det er ikke indgået nogle specifikke kontrakter, men der er tillagt nogle notater der beskriver anvendelsen af digitale modeller – notat 20 (bilag).

3. Hvilke procedurer følger i under BIM processen og hvilke intentioner har i haft ved de VBM gennem de forskellige faser?
Intentionerne omkring anvendelsen af de VBM har forholdt sig til ønsket om at holde økonomien under kontrol, og kunne gå i tidlige udbud med deler af projektet. Det har således været et ønske om at det kan foretages ændringer undervejs, som også kan være nemme og se konsekvenserne af i resten af byggeriet. Her har det handlet om at kunne få det bedst mulige stykke arkitektur, til den

bedste pris.
Dispositionsforslaget har været udarbejdet gennem sparring mellem bygherre og de aktuelle totalrådgivere, hvor dispositionsforslaget har været med til at slå bygningens overordnede formsprog fast.
Det har været vigtige parametre at få økonomi og integration mellem arkitektur og konstruktion til at spille overens.

4. Kender du noget til den proces der foregår i totalrådgivergruppen? Eventuelt hvorledes de forholder sig til BIM processen i deres design udvikling, og deres interne kommunikation?
Den proces der forløber i totalrådgivergruppen kendes der ikke specielt til, men det virker til at projekteringen går fint nok, men det hele bliver udført i programmet Revit, hvilket ikke er tilpasset de specifikke fagområder. De bruger selv Tekla i bygherrerådgivergruppen, da de selv er en så stor aktør at de er med til at udvikle softwaren. Landskabsarkitekterne har meget imod at anvende 3D specifikke værktøjer til at udføre deres arbejde, hvilket således kolliderer lidt med de andre fagretninger.
Generelt er dette et emne jeg bør drøfte med totalrådgivergruppen.
Tror rådgivergruppen samler sine modeller og låser dem en gang om ugen, for at se hvorledes deres projektering forholder sig til hinanden.

5. Er det nogen retningslinjer der sikrer det bedste udbytte af BIM processens anvendelse, hvorledes sikres det at arbejdet der udføres, også er anvendelig i de efterfølgende faser af projektet?
Det er et område som totalrådgiverne selv har bedre styr på, men det virker til at de har en struktur på hvorledes projektet bør løbe fremad internt.
Ellers er det bygherrerådgiveren der står for at sikre at det materiale der bliver fremskaffet har den rigtige værdi for resten af projektet. Specielt til entreprisedelen der udbydes efterfølgende.
En hovedentreprenør er tilknyttet udførelsen af råhus, og står for styringen af byggepladsen. De har selv været inde at granske arkitekternes tegninger lavet forbedringer i projekteringen i henhold til indehold projektmateriale.
Den struktur som totalrådgiveren går frem efter er godkendt af bygherrerådgiveren, hvor de er enige om i hvilke program projektet skal gennemføres osv.

6. Hvorledes forholder i jer til udviklingen af informationsniveauet ved en BIM proces, er der nogle retningslinjer for hvilke tidspunkter detaljeringsniveauet skal vokse?
Arkitekter og bygherre er ikke enige om udviklingen af projektet, hvor arkitekterne ofte ønsker at få større deler af projektet på plads, vil gerne BH styre projektet i det nødvendige tempo.
Projektets fremdrift er derfor ikke rigtig fastlagt på forhånd, men er lidt en løbende proces der bevæger sig efter forholdende. Normalt lægger man en linje og følger denne, men i dette projekt så ændrer stien sig med tiden.

7. Er det nogen form for struktur/planlægning af modellens udvikling, hvornår de forskellige delelementer skal være fuldført og relationen mellem de forskellige opgaver?
Det køres derfor efter et princip om last-minut afgørelser, hvor de så har en beslutning omkringhvad der skal være klart til hvilket tidspunkt, hvor dette så besluttes og fastlægges. F.eks er der lavet pålæg om at parkeringsanlægget, hvilket er fuldautomatisk, skal være noget af det første der er besluttet, således resten af byggeriet kan forholde sig til dette. Således har man også råhus og pelefundamentering for huset der skal fastlægges forholdsvis tidligt.
Derefter kan der vurderes videre hvad der er nødvendigt at tage stilling til, men eksempelvis kælderen blev der besluttet at det var økonomi til at udvide med 2000kvm, hvilket så blev ændret efter de tre tidligere last-minut afgørelser var foretaget. Således kunne der ved hurtige udtræk kunne ses hvad udvidelsen havde af omkostninger for de andre deler af byggeriet.

Hele den strukturelle opbygning kører gennem bygherrerådgiveren, der træffer vigtige standpunkter i henhold til at opnå mindst mulig risiko for projektet. Man skal gerne kunne træffe nogle beslutninger undervejs, der vil være bindende for projektets endelige udfald.

8. På hvilke tidspunkter i processen bliver de forskellige aktører indblandet, hvis vi stiller de op mod informationsniveauet i byggeprocessen? Bliver det eventuelt involveret leverandører og producenter i projekteringen?

Det er i forbindelse med råhus valgt at indgå et partnering samarbejde med entreprenøren på råhus, hvor man med et tidligt udbud har sæt det gavnligt at involvere entreprenøren i udviklingen af projektet. Her har entreprenøren således givet bud på meget præcise mængdeudtræk, hvor således det baserer sig en aftale på en enhedspris. Samtidig er de selv med til at gå igennem arkitektens projekteringsmateriale for at vejlede omkring byggeriets mest hensigtsmæssige opførelse. Det er vældig varierende fra entreprise til entreprise om det ses nødvendigt at inddrage dem i tidligere faser.

Også en entreprenør der udelukkende driver med lukning af bygninger har været indover processen fra et tidligt tidspunkt, og har været meget aktive i projekteringen.

Det er meget vigtig at være præcis med sine udbud og aftaler, da det kan give grundlag for økonomisk strid om eventuelle spild af materialer som skyldes armeringslængder eller lignende. Dette skal der helst være enighed om før aftalen indgås.

9. Føler du at de digitale modeller gavner den proces som i har med totalrådgiverne, og hvorledes anvendes modellerne konstruktivt i denne kommunikation?

Det er store fordeler i de lynhurtige udtræk man kan gøre fra modellen, og den hurtige opdatering af mængder der forekommer når der laves ændringer til projektet. Økonomien kan holdes styr på ved at man ved ændringer holder nye kalkulationer baseret på meget præcise tal.

Modellerne anvendes meget til at orientere BH og gøre udtræk af rumligheder og tegninger. Det er nemt, men resultatet er således også et meget råhus look hvor man skal lære at abstrahere fra at taget ikke altid er lagt ind osv.

10. Kan det ses nogen fordele eller ulemper ved den måde processen forløber på? Kunne den være mere effektiv eller bedre tilpasset bygherren?

Det er hele tiden en kamp omkring hvad arkitekten, ingeniøren og rådgiveren mener er nødvendigt at udføre, eller er vigtigt for deres fremdrift af projektet. Men således står BH fast på at beslutninger omkring overflader og valg af glas ikke skal vælges i dette øjeblik, men ved senere tidspunkter hvor der bliver mere klart hvilken økonomi og behov der spiller ind til de forskellige deler.

11. Hvorledes forholder BH og dens rådgiver sig til det materialet der fremstilles fra totalrådgiveren, er det bedre end ved mere traditionelle projekteringsformer? Og på hvilken baggrund træffer i jeres beslutninger omkring projektet? Bruger i bygningsmodellerne på nogen måde?

Beslutninger træffes gennem det materialet der bliver fremlagt fra arkitekten, og den successive kalkulation der forekommer ved hver ændring. Det bliver hele tiden vurderet på økonomi, og således er materialet meget anvendelig.

Det er klare fordeler i anvendelsen af BIM da materialet er mere præcist, og giver en hurtigere konkretisering af deler af projektet. Det er meget nemmere at se konsekvenser af ændringer når modellerne hænger sammen på den måde de gør. Bygningsmodellerne bliver anvendt mest til økonomiske udtræk.

Modellerne bruges til formidling, og det er også en plan om at de vil blive anvendt til den nye interaktive hjemmeside – forskellige holdninger til dette.

12. På hvilket stadie i projektet er i tvunget til at træffe de forskellige beslutninger, og

hvilken risiko ser du ved at beslutningerne skal foretages på dette stadie?
Beslutningerne træffes efter hvor risikoen er størst for forudsætte udgifter. Således er beslutninger omkring parkerigsanlæg, råhus, pelefundering osv truffet meget tidligt, og allerede i gang med at gøre klart til at bygges. Dette er beslutninger der påvirker hele det videre forløb, da de er fastlagt og kan ikke ændres. Her er således vigtigt at der ikke er glemt noget.
Denne måde at gøre det på betyder at det hele tiden er muligt at udskyde sine små beslutninger omkring materialevalg, placering af inventar osv i dette projekt. Eksempelvis er det indlagt installationsudtag i alle søjler således der kan trækkes kabler etc i disse.
Men dette betyder også de er nødt til at træffe en række forhold der skal sikre flere løsninger. Eksempelvis har der været et ønske fra arkitekten om anvendelse af sedumtag, hvilket det ikke vides om det er råd til, men alligevel har de været nødt til at forstærke tagkonstruktionen for en halv million i fald dette bliver valgt.
En række af de afgørelser der bliver truffet, betyder således også at den indre aptering skal udføres manuelt og ikke kan foretages af elementer der hejses på plads, dette er en vurdering der skal træffes på forhånd. Så man eliminerer nogle mulige løsninger ved at træffe beslutninger så tidligt i processen omkring råhus eksempelvis. Det bliver også således besluttet at ventilation, el, vvs osv vil løbe i andre bygningsdele end råhuset.
Det hele med beslutningerne bliver ren risikostyring, det er vigtigt at få truffet vigtige og store beslutninger tidligt, og få lagt disse fast for projektets videre fremdrift.

13. Som jeg har forstået så udbydes projektet i storentrepriser – er dette specifikt tilpasset det materiale der projekteres indenfor VBM/BIM? Bliver det indgået nogen form for partnering eller incitamentsordninger mellem totalrådgiver, bygherre, entreprenører i dette henseende?
Det er klart at det ikke ville være muligt at udbyde projekterne i storentrepriser på så tidlige tidspunkter uden en VBM, grundet den præcise information man kan udbyde med grundlag i. Dette har således ledt til en indgåelse af partnering samarbejde med råhus entreprenøren, hvor de så er med på at forbedre projektet, og samtidigt også ændre i projektet baseret på de enhedspriser der er kalkuleret. Det er indgået en aftale om at de enkelte entreprisedeler kan ændres med +/- 100% uden at påvirke enhedsprisen på udbudt materiale.
Alle byder på baggrund af den digitale model, men det kan blive problemer når vi kommer til underentreprenører at få dem til at følge den digitale anvendelse af 4D – tidsplanlægning gennem 3D model.
Ved at råhus entreprenøren eksempelvis har en storentreprise betyder dette at de er ansvarlig for at en stor del bliver succesful, derfor er det også muligt at få dem indover brugen af 3D-modellen til den videre projektering. Når de er ansvarlige, har de også ret til at planlægge produktionen, hvilket vil foregå gennem 4D, hvilket er et krav fra bygherre.
Integreringen af entreprenører er bedre ved BIM, således de kan være med til at ændre konstruktionen i faser hvor der er behov for dette. Dette kunne nok ikke lade sig gøre på samme vis uden anvendelsen af partnering samarbejde, da ville de gøre for store krav ved ændringer, her har de ved alle henseende en %-mæssig fortjeneste på projektet uafhængig af udfaldet.
Noget af projektet er udbudt på laveste pris, hvor det ikke har været risiko for at arkitekturen påvirkes af det arbejdet der bliver udført. På denne måde ved typisk entreprenøren selv hvor billigt det er muligt at gøre det, men dette vil ikke være aktuelt ved andre områder da indsigelser til udformningen grundet arkitekturen, kan påvirke prisen negativt.
Parkeringsanlægget har været i tidlig udbud for at skabe rammerne for bygningskroppens udformning, svært at ændre på den teknologi der bliver leveret til sådan et anlæg.

14. Er det nogle udbuds/samarbejdsformer du vil se uaktuelle for anvendelse i en BIM proces, eventuelt hvorfor? Er det nogen der er højst aktuelle og hvorfor?
Ikke rigtig nogle som er uaktuelle for en BIM proces, men det vurderes nøje hvilke entrepriser der bør indgås på hvilke måder. Kunne være udbudt som totalentreprise, men så ville man selvfølgelig

ikke kunne kontrollere noget. Synes ellers gevinsten af at indgå en form for partnering har været givende i henhold til projektets udvikling og økonomiske styring.
Entreprenørerne er eksempelvis også bedre end rådgiverne til at styre byggepladsen, og derfor får råhus entreprenøren 60 mill. for at udføre denne opgave i tillæg.

15. Hvilke fordeler ses der ved dette i henhold til BIM, kunne det eventuelt være nogen fordele ved at indgå et samarbejde baseret på partnering modellen?
Se tidligere kommentarer omkringsamarbejde med entreprenører

16. Fungerer BIM processen efter hensigten, eller er det nogle områder du mener processen eller de digitale begrænsninger halter?
Det virker til at det meste fungerer efter hensigten bygmæssigt, men det er selvfølgelig nogle forventninger til bygherrens anvendelse af modellerne der ikke helt kører optimalt. Det er nogen begrænsninger i at landskabsarkitekternes modeller ikke stemmer overens med arkitektens, men ellers så virker ting til at køre. Alt bliver udført i programmet Revit!

17. På hvilken måde ser du at BIM kommer til at påvirke byggebranchen i fremtiden, vil det kræve nye rollefordelinger for at få processerne effektiviseret? Er det eventuelt nogen erfaringer relateret til dette i det givne projekt?
Det har forløbet rigtig godt så langt med dette projekt i BIM og effekten af det har været meget positiv i henhold til tidligere projekter. Derfor ses det også som en proces der vil være fremtid i, men det er helt klart en anden arbejdsform, der kræver at det spilles sammen på en anden måde for at gavne fuld effekt.
Det skal klart træffes nogle meget vigtige beslutninger i de tidlige faser, hvilket er helt afgørende for økonomiens udvikling.
Arkitekterne bygger meget på sit eget produktionsapparat, så det vil være en tilvænning at få disse til at spille efter den processuelle fremgang der virker fornuftig med BIM. Eksempelviser det ikke nødvendigvis tid for at fastlægge alle indvendige vægge så tidligt i processen, selvom arkitekterne ønsker dette.

Appendix D

Interview with BIM Coordinator at the Architect's

Interview og samtale med BIM koordinator. Interviewets svar er direkte refereret som udtalt under hvert enkelt spørgsmål, der fra interviewers side var defineret indledningsvis. Interviewet var semi-struktureret.

1. Må jeg få en kort introduktion til din rolle i byggeprojektet på havnen i Århus, og på hvilket tidspunkt blev du involveret?

Internt i arktiektgruppen har vi en gruppe på fire mennesker som udgør BIM gruppen, min kollega ser på processer i henhold til personale. Henne og mig ser yderligere på IKT aftaler og ydelse beskrivelser etc., for å samle op på de ting som vi kan forbedre i forhold til kontrakter. Dette også i henhold til økonomi og hvorledes vi får planlagt vores ressourcer som gruppeledere generelt. Yderligere er det en kollega der kigger på bæredygtighed og kollisionskontrol i Navisworks, Ecotect etc., og som har dette som speciale, men sidder og er BIM manager på et eget projekt. En som tager sig af uddannelse til nyansatte, og fortæller dem vi har de og de programmer, prøv og kig på det – og setter op kurser, han sidder så ved siden af og har sit eget projekt han styrer.

Jeg sidder så og kigger på workflows igennem en sag, detaljeringsniveau, LOD osv. i henhold til de ydelser vi skal levere, og hvordan det fungerer når vi er i gang med en sag, hvilke ydelser er det så som er placeret på arkitektsiden og på ingeniørsiden, og hvor ligger de så henne. Vi tegner noget geometri op, også leverer vi det videre på et eller andet tidspunkt. Det er alt efter om det er det bærende, som er forholdsvis tidlig vi overfører dette til ingeniørfagene, mens mere tekniske elementer som elevatorer og lignende vil så være på et senere tidspunkt. Så jeg sidder både og supporter kollegaer i dagtimerne omkring de problemer de har tegneteknisk i Revit, supporter også de andre kollegaer der er BIM koordinatorer på sine sager. Står så for overordnet at dele projektet op, og dokumentere hvorledes vi bedst får gjort tingene.

Multimediehus sagen er så stor at der skal jeg bruge en del af min tid på at tjekke op på om vi leverer de ydelser vi skal løbende. Om tingene er organiseret rigtig og om vi får de udfyldt osv., således gå og være lidt politimand overfor kollegaerne, og om de får udfyldt det de skal, og holde dette op mod det som vores ingeniørkollegaer laver. Hvis det er nogen generelle spørgsmål omkring BIM så er det også jeg der tager dem, hvilke klassifikationssystem vi skal anvende osv.
I andre firmaer så har man måske en anden opdeling af sine BIM ansvarlige medarbejdere, alt afhængig af hvilke typer projekter man har og hvor store de er. Her har jeg 25% strukturelt på tegnestuen, 50% på sagen, og resten på support til andre, men det er svært at sige hvad der er rigtig generelt.

2. Hvilken form for kontraktmæssig aftale har arkitektgruppen med bygherre omkring dette projekt, føler du den er repræsenterende for BIM som arbejdsform?

Aftalerne er svære og styre, og det tror jeg også man kan læse ud af de afrapporteringer der kommer løbende. Vi har som rådgivere måske det bedste udgangspunkt for at vide hvad denne proces kommer til at inkludere, fordi dette er vores professionelle arbejde og vi gentager og gentager dette hvert projekt. Og vi kan se hvilke forskelle det er ved processerne fra tidligere og til nu, men dette kan selvfølgelig være lidt svært for bygherre og de aftaler vi sætter med dem. De aftaler skal jo

være tovholdere og sætte rammerne op for projektet, og der synes jeg man mangler noget før man kommer i land. Det mangler noget på ydelsesbeskrivelses siden og på IKT siden.

Det at det er holdt op på nogen gamle principper, gør det problematisk at lave de aftaler, eller i det mindste nogle udfordringer da det er vanskelig for bygherre å stille krav indenfor noget de ikke er særlig godt vidende om. Det er bare således det er, så prøver vi at lave vores overvejelser på den bedste måde i denne kontrakts proces, og gå ind at prøve at vejlede. Vi forsøger ikke at skubbe noget fra os, men ønsker bare at sikre vi får skåret kagen på den rette måde – både i forhold til vores leverance til bygherren, men også i henhold til entreprenører og rådgiverkollegaer. Fordi vi har en grundholdning om at hvis vi gør vores forarbejde og er professionelle i dette arbejde, så får vi også det bedste byggeri. Det handler ikke om at snyde nogen, men mere si at vi får italesat de problemer vi har sæt tidligere og få pillet dem ned således vi kan snakke om dem og tage stilling til dem. For hvis vi bare sier det er et BIM projekt, så har ikke bygherre forudsætninger for at vide hvad det handler om.

3. Hvordan føler du at samarbejdet mellem bygherre og totalrådgivere fungerer når det anvendes BIM styring? Er det enighed om projektets fremdrift og målsætninger?

Vi får det til at fungere, selvfølgelig gør vi det, men det er en anden opstart på projektet. Projektet i sig selv er så usædvanlig på mange måder, hvor det er indblandet både kommunale midler og private midler, og byrådet er det øverste beslutningsorgan. Det er parter på kryds og tværs, og det gør det selvfølgelig vanskelig på sin egen måde, men jeg vil si vi oplever ingen problemer vi ikke kan løse.

Uddybende spørgsmål – på et vist stadie hvor det er behov for noget information, så snakker i vel sammen om dette og hvordan i forestiller det skal være, men det er vel ikke holdt op på nogen aftaler eller noget?

Jo , det er det som kan skabe udfordringer og det gøre det, indtil – og det skal ses projektet uafhængigt – bygherren lærer hvilken proces det så er man er i, hvad er det vi skal bruge fra dem, og hvad kan de forvente af os. For vi kan jo levere alt muligt, hvis det vil betales for det. Men det er selvfølgelig en løbende forventningsafstemning, hvor vi nogen ganger er uenig, og det kan være vanskelig når vi snakker om BIM, men det er fordi det er en ny proces. For i udgangspunktet så skulle ikke det ene være mere vanskelig end det andet.

Men det sker jo at man laver nogle ting udenfor de rammer der er sat, eksempelvis en række renderinger eller tegninger, enten fordi man synes det er sjovt, eller man har lyst til at kigge nærmere på designet, eller at man har en eller anden studerende til at sidde og lave det. Og dette kan man jo også bringe videre med sig i en proces, selvom dette ikke er det rigtige at tage med videre. Så det handler hele tiden om at få det skruet ned til hvor er det faktisk vi ligger i forhold til vores ydelser osv., og disse er ikke specielt skarpt defineret - eller har været svære at fastlægge – så de aftaler der kommer derudfra bliver så også meget mudret.

4. Hvordan foregår samarbejdet mellem arkitekter og ingeniører, er det en god struktur på udnyttelsen af de digitale bygningsmodeller mellem faggrupperne? Føler du at arkitekternes og ingeniørenes samarbejde forløber effektivt ved brugen af BIM som proces? Kan jeg få et indblik i hvilke software der anvendes jer imellem?

Jeg styrer det samarbejde som kører på BIM siden, men ikke generelt på sagen. Når jeg snakker

direkte med mine kollegaer ved ingeniøren, som laver det tilsvarende som jeg gør, så kan vi hurtigt få skåret det ned til en række tekniske processer, og det er jo forholdsvis enkelt at diskutere - for os. Men det kan godt være vanskeligt at få forståelse for de forandringer der skal ske når man snakker med andre indenfor samme organisation, at det er nogen ting vi er nødt til at gøre på en anden måde. Det skal man tit, efter min smag, bringe lidt for højt op. Således at det vi snakker om bliver bundet op på nogen af de ydelser vi skal levere, og derfor medelle at det er nogen ting vi gerne vil have dem til at overtage –eks. Vis søjler elevatorer etc.. Og der skal vi ofte ind at definere ydelsernes sammenhæng med de aftaler der er gjort gennem udbud, og at de så hænger på denne del. Og det er jo fordi man nede i organisationen ikke kender processen endnu, og fordi vi i vores indledende aftaler ikke har været skarpe nok på at få dette fordelt. Det gør at vi er nødt til at hæve det hele op, for at få fastlagt hvad der er rimeligt for begge parter.

5. Da i startet modelleringen op med henblik på anvendelse i BIM, hvorledes blev dette struktureret? Har i vært enige om opbygningen, sammenkoblingen og anvendelsen af de mange modeller (bygherregruppen, arkitekter og ingeniører)?

Ja, vi har defineret opbygningen fra begyndelsen af, hvor vi har taget nogen møder hvor vi har snakket om det. Meget kan vi knytte op på allerede kendte processer. Vi skal jo definere geometrien, og når den er defineret, så kan vi begynde at aflevere denne videre i systemet. Så det er ikke så usædvanligt, men det kan være nogen af ydelserne bliver skubbet lidt frem og tilbage. Når jeg har afleveret det så forventer jeg at de retter op på det, for så har jeg ikke de objekter i min model længere, så har jeg afleveret det, også er det dig der har ansvaret. Og det er jo noget man er nødt til at snakke om hver gang det er et sådant projekt, og følge op på det, og være skarp på den proces fremadrettet. Og hvis ikke vi får afleveret til jer, så kommer de for sent i gang med sin proces i forhold til at få projekteret løbende fremadrettet.

6. Kunne i haft en gevinst i at systematisere modellen i henhold til en 'model struktur' alla denne? (Vise model structure template) Hvad er dine umiddelbare kommentarer (positive/ negative) til en sådan type strukturering? Vil det være anvendeligt/realistisk a skulle definere modellen på denne måde før opstart?

Vi definerer også vores modelopbygning fra starten af, lidt på samme måde. Men jeg vil nok af praktiske eller upraktiske hensyn splitte modellen op undervejs. Jeg har en arkitektmodel også deler jeg den op i furniture f.eks., så ligger disse i en anden fil, og når vi begynder at have fastlagt shell, så splitter jeg det ud i en anden model, men det er mere nogen programtekniske ting om hvordan de parametrisk hænger sammen og hvordan man nå gør det i archicad eller revit, det kan så være lidt forskellig. Men vi gør os tanker om det fra starten af, og har en klar tanke om hvorledes vi deler modellen op. Om det er de forskellige objekt kategorier som shell, inventar og furniture, eller om det er i bygningen som man slicer op i etage 1 til 4 og 4 til 6 og kælder, således kan man også vælge at gøre det – og da kigger vi så på hvorledes bygningen ser ud. I etager er efterhånden som man får fastlagt nogen, men så tidligt som muligt således man får placeret tingene rigtig.

Jeg vil jo ikke gå ind og styre hvorledes ingeniøren skal gøre det, men det er jo en helt anden opdeling ved faggrenser, hvor de så ligger i sin helt egen model. Hvor mekaniske elementer som pipes, vvs og el og brand vil så ligge i de forskellige fagmodeller. Men dette er lidt en naturlig ting som vi selv fosøger at tale om fra start af, hvordan vi kan gøre det her – og det er faktisk ret nemt at blive enige om. Det er noget alle kan se fordelen af, og alle kender til de der programbegrænsninger der sier at når modellerne bliver for store så skal vi have dem splittet, og hvordan kan vi så gøre dette bedst mulig med alle parters fordele. Hvis vi skal ha splittet det op så laver vi en teknisk løsning

hvor vi laver nogen groups, og linker dem ud. Så kommunikerer vi det til vores samarbejdspartnere at nu er det splittet op, og opdaterer dem på hvordan det er på vores projekt web-site, også henter de dem ind efter det.

Det fungerer fint, og alle får et overblik over tingene, men så går vi selvfølgelig lidt længere ned i vores eget arbejde og kigger på hvordan det skal deles op i worksets, og det er så efter behov. Der kan man gå meget op i om det skal være præcist sådan eller så tager vi det lidt som det kommer. Jeg prøver mere og mere at gøre det systematisk, selvom jeg meget gerne vil fastlægge alle mulige rammer så må man indrømme at man kan gøre sig en mange gode overvejelser fra start af, men hvis bemandingen ikke er klar til det så er det nogen andre ting de skal lære først, fremfor at lægge væggene i det rigtige workset. Vi lager tilpasninger fra projekt til projekt, men man er nødt til at have en generel linje.

7. Hvordan kender i til de andre aktører der er indlemmet i design/konstruktions processen, og som er involveret gennem bygherre? Har i et overblikover deres involvering og på hvilket niveau?

Vi kører efter nogle rammetidsplaner for hvornår ting skal være færdig, så den proces adskiller sig ikke fra den tidligere kendte. Det er noget man definerer fra start af når man skal have de forskellige udbud til at ligge, når man skal ha byggestart å sådan der. Det er selvfølgelig nogle ydelser som vi kontraktmæssigt og honorarmæssigt er hængt op på, som er i konflikt fordi de er lavet på det gamle skelet hvor vi nå skal bruge et andet. Men det er ikke mig der skal tage de deals. Det er nogen issues omkring hvornår vi har de forskellige leverancer.

8. Råhus entreprenøren er involveret i en incentiv aftale i projektet som hovedentreprenør – hvordan er de involveret i det design og den proces totalrådgiverne gennemfører? Er der en defineret arbejdsfordeling i henhold til udviklingen af byggeriet jer imellem?

Det er en partneringaftale som kører med råhus entreprenøren, så de tager ikke over noget af designarbejdet, de er bare med til at supplere med viden. Vi tager selve designet, også står de inde for at det er bygbart osv. og denne del tager de. Vi kan ha nok så mange gode intentioner, men hvis det ikke kan bygges, eller de mener det ikke kan bygges, eller af økonomiske hensyn mener at det er bedre at lave det på en anden måde, fordi de har nogen ressourcer som kan planeres bedre i forhold til projektet, så er da det noget man arbejder frem. Så de fungerer kun som et støttende element i selve design og projekteringsfasen.

Selvfølgelig er det forskel på om det er en totalentreprise, hovedentreprise eller fagentreprise, hvordan vores ydelser er defineret, og om det er partnering. Men jeg synes ikke så meget det adskiller sig fra hvad der ellers er, for vi skal projektere til et eller andet bestemt niveau. Så det snakker vi med entreprenøren om, og jeg går ud fra at ingeniørene gør det samme om de andre deler af byggeriet og den bærende konstruktion. Derfra optimerer vi så tingene sammen, hvis f.eks. man kan handle en bedre pris hjem med en anden betonfabrik der gør at man skal projektere noget om så må vi jo kigge på hvordan dette løses – og det er jo lidt ligt en totalentreprise situation.

9. Har det været en eller anden ide fra begyndelsen af om hvilke eksterne elementer, som entreprenører vil være involveret i processen? Og har i haft indblik i når de forskellige parter i design og konstruktions processen skulle involveres, og hvordan de forholdt sig til projektet?

Ja, det er defineret fra bygherre af, og det er ikke sådan at vi bliver holdt udenfor, men det er bygherrens beslutning. Vi rådgiver altid uanset hvilke del af processen det er og gør vores bedste uanset om det er på udbudssiden eller på det BIM tekniske eller hvad det nu er.

10. (Vise modellerne i forbindelse med organisation) Hvad er din umiddelbare kommentar til at løse organisationen på denne måde? Kunne det være til hjælp i jeres interne organisation når projekt involvering skal defineres?

Vi har forsøgt at definere de eksterne enheder der vil involvere sig i processen gennem nogle skemaer, lidt som det her med LOD, men har ikke fået fulgt op på det. Primært har dette været for os totalrådgivere imellem og de der er involveret gennem partnering, hvilke ydelser skal levere hvornår osv. Vi har faktisk snakket om at vi skal til at tage fat i det igen. Så du har helt ret med dette, i henhold til disse modeller. Man bør gå ind og definere dette, da det bringer klarhed omkring hvilke ydelser der skal leveres hvornår, med de forventninger der er parterne imellem. Det er igen efterhånden som alle bliver dygtigere til at svare på de spørgsmål som kommer, så kan man bedre gå ind og definere dette her. Og vi kan jo se nu at det bliver vi nødt til at gøre fra start af, altså være skarpere på det og få fulgt op på det – ikke ugentlig, men ved faser og opfølgende møder for at sikre at vi alle er på samme forståelses niveau. Hvad er det som skal være klar hvornår.

11. Hvad baserer i model udviklingen på?

Vi holder våres udvikling op på LOD, men bygger det op på 3D-håndbogen og den definerer således LOD og det er så det der har været at kunne støtte sig op til. Og han som har været med til at lave denne, kommer her ned på tegnestuen ugentlig for at være med til at skru disse aftaler sammen. Men vi bliver også nødt til at holde det hele op på hvad er projektforslag og dispositionsforslag, hovedprojekt og as-built projekt. Men med dette hænger LOD ret godt sammen, eller i det mindste forholdsvis sammenlignelig. Så går vi ind og kigger på hvad vi kan forvente – nogen ganger skal vi hæve det op til en større snak, men normalt kan vi holde det på et fornuftig stadie.

Uddybende spørgsmål – nå spørger jeg i henhold til udviklingen i BIM. Er ikke en del af de fordele der er ved LOD at man ikke nødvendigvis trænger at udvikle hele modellen til samme niveau parallelt? Så selvom vi taler om hovedprojekt, så er det ikke alle komponenter der trænger at være på samme niveau?

Nej det er rigtig, det behøver vi ikke. Vi er ikke dygtige nok til at få det italesat, at det ser sådan ud nu fordi vi i den fase optimerer på en ting der er vigtig, men i en anden fase vil suboptimere på noget andet. Så vi lægger noget indledende design ud, fordi det er det der skal til for at få det designet sådan rimeligt, også i to faser længere hen begynder vi at optimere på det.

Det som kan være svært at vide når man ikke har lavet en kortlægning som dette (organisations templates)fra starten af, er hvornår vi kan forvente at ingeniører eller samarbejdspartnere hiver det op på et niveau hvor det kan anvende. Det er noget der skaber problemer da vi har en forventning om at de ligger på et højere LOD end de gør, i en fase hvor vi skal bruge denne information. I et arkitekt og ingeniørfirma gøres tingene i et forskellig tempi, hvad gør at den kulturforskel der er også skal afpasses i henhold til den pågående BIM proces, hvor man i alle fald på ingeniørsiden bliver udfordret.

For vi som arkitekter kan skru det hele ned, vi har selvfølgelig nogen ydelser der har blevet skubbet længer frem, og det kan vi måske være bedre til at omstille os hvad kan skyldes ressourcemæssige

årsager. Alle arkitekter sidder og tegner, og er derfor mere omstillingsparate, mens der på ingeniørsiden ikke er sådan, selvom dette er tilfældet i f.eks Tyskland og Sverige at ingeniører her sidder og tegner. Hvis man lægger hele sin organisation ind på at det bliver lagt noget ud, også sætter vi en teknikker ind på at tegne det om, så skaber det problemer når vi nå skal bruge denne teknikker tidligere og skaber nogen uoverensstemmelser over hvilke leverancer der er hvornår.

Man skal være enige om fra start af, hvem der leverer hvad hvornår! Så det vil ligge en god gevinst i at få defineret dette gennem hvad du f.eks har lavet her. Dette er jo meget skematisk og overordnet, også må man gå ned og kigge på den enkelte sag om hvordan det så overordnet ser ud. Herunder vil det også være nogen ting man er nødt til at definere skarpere i forhold til den enkelte sag, og den projektsammensætning der er. For hvis man tegner er mindre byggeri så er det nogle andre forhold end ved et stort byggeri. Men så længe strukturen er fremlagt og klarlagt, så er dette helt klart en støtte.

Uddybende spørgsmål – men i har en helt klar ide om hvorledes dette skal skride frem, men måske ikke på papirform?

Ja, præcis det mangler lidt noget visuelt til at støtte projektlederen eller projektdirektør i henhold til de aftaler der skal gøres med entreprenører, rådgivere og bygherre for at man sikrer sig at man snakker om det samme. Man kan ikke forvente at en projekteringsleder kan gennemskue en hel BIM proces, men så skal man have en at spørge – mig i dette tilfælde – hvad kan vi gøre her og hvordan skal vi gøre det. Hvor jeg så skal vurdere om vi leverer for lidt eller for meget, og nå skal vi ha gjort dit og dat som han kan tage ind i sine overvejelser som går på andet end BIM, på ressourcer og på projektet som sådan. Og der mangler det nogle værktøjer og nogen viden som er svær at tilegne sig på ret mange andre måder end ved erfaring. Det er nemt nok at sige at vi skal skubbe ressourcerne længer frem, men det er ligesom at man skal smage blodet munden før at man finder ud at det er fakta at det bør gøres således.

12. Hvordan strukturerer i modeludviklingsprocesses i arkitektgruppen og i samarbejde med alle de andre aktører?

Når vi taler om LOD, så er vi klar over internt hvilke niveauer og hvilke forventninger det er til dette, hvilket gør at det kan laves skarpere aftaler. Det er ikke sikkert det er de forventninger vi har fra start af som bliver fyldestgørende, om hvad som skal leveres hvornår og af hvem, men så har vi i det mindste et udgangspunkt. Så har jeg en pakke jeg kan give til ham der laver kontrakten eller styrer sagen, eller til mine kollegaer der sidder og skal tegne detaljer. Jeg kan så si jeg synes de bør gøre det på denne her måde, for det har jeg undersøgt og mener passer godt. Denne udvikling er vi nødt til at holde i stram snor, da det for tiden er stor udfordring med omstillingen fra de gamle til de nye principper.

13. Hvordan vil du se på anvendelsen av disse værktøj til at styre procesudviklingen? (Legg frem model element tabel og presenter dette) Ville det være gavnligt?

Ja, det er så den tabel jeg tidligere forsøgte at forklare anvendelsen af. Det er vores helt klare målsætning at få defineret tingene, og det er lige dette skema vi har startet op men ikke fået fulgt op på siden. Det er en nødvendighed, simpelthen. Ikke fordi dette projekt ikke kan lykkes uden, hvilket vi også gør uden at skrive dem ned. Men det vil ikke være noget til hinder for at have en masterplan for hvordan vi mener vi skal gøre, hvor det bliver skrevet ned og gjort skarpere end bare i et stykke tekst. Tit skal man ind og tjekke gamle e-mail omkring hvad der egentlig blev aftalt osv. og hvordan

er det så lige vi gør. Således er det et godt værktøj, også til at følge op på.

14. Vil værktøjet også være anvendeligt som aftalevilkår?

Jo det er helt klart noget der ville være aktuelt mellem rådgiverne, og her senere entreprenørerne. Fordi at det ikke kan styres uden, da det er nemmere for folk der ikke er inde i processen at forstå det her skema. Jeg kan godt sammen med BIM ansvarlig i Alectia snakke mig frem til det her uden at skrive det ned, men jeg kan ikke forklare det ret godt til min projektleder, eller NCC eller hvem det nå er som skal gøre hvad og hvornår. Igen når det er en proces man ikke kender har man behov for at få den lagt frem på en måde som man kan forstå – det er lidt mere spiselig når den bliver sat op i et sådan skema her.

Grunden til at vi ikke har fået fulgt så godt op på det som vi ville, er nok at det kræver meget tid og det er hele tiden nogen andet man skal have gjort. Selvom intentionen var der fra starten af, så opstår det altid noget andet der er sjovere eller vigtigere. Hvis det er en aflevering neste uge, arbejder man så 80 timer for at få denne klar eller setter man sig ned at kigger på denne fordeling af ydelser. Det er klart at hvis man har en aflevering, så er det det man laver. Hvis jeg får i opgave at lave det her, så skulle jeg også gerne få dette givet i tidsfordelingen internt fordi man sier det er dette som er vigtigt. Det er jo så noget man må gøre op med sig selv på tegnestuen.

Vi har også nogen ting som vi ikke får klarlagt lige fra start af omkring bygherreydelser, hvad skal vi have af informationer fra bygherren. Ikke kun fra programmet, men hvilke byggeydelser skal vi levere og på hvilket LOD skal vi levere as-built som typisk ikke er på samme høje niveau som udbudsmaterialet. Det har det i alle fald været på alle de projekter jeg har været med til, hvor vi så går ind i samtale med facility management omkring deres krav og behov. De er ikke de samme, også bliver man nødt til at optimere i forskellige retninger. Det kan være svært når man har med en bygherre der ikke har arbejdet med BIM tidligere, at få de til at give svar på de her spørgsmål.

Vi skal således ind at tage denne kamp fra begyndelsen af, hvor vi kan tilbyde flere services, selvfølgelig mod en betaling. Det er nødvendigt da det nu er et materiale vi skal levere, men hvis jeg føler at bygherre ikke får noget ud af at få alt for meget materiale, så er det så op til mig at finde ud af hvad han er bedst tjent med. Så udover at have rådgiver faserne som løber gennem projektering og udførsel, så skal man faktisk også have facility management koblet på, da de har et eget krav om LOD. Gøre klart hvilke klassifikationssystem er det de bruger, DBK/SEB. Vigtigt at vide hvad der skal afleveres også i sidste ende.

15. Som et supplement til selve tabellen har jeg dette relations skema, som definerer hvorledes opgaverne hænger sammen. Tror du det vil kunne give et klarere overblik over hvad jeres informations udvikling skal bruges til, og hvem i skal generere information til?

Det er altid et samarbejde pågående mellem flere parter, men udover de ydelser der er, så har vi også et ansvar i en periode for en bygningsdel. Denne periode kan være lang eller kort, for at definere noget for den anden part. Fra vores side, vil det leveres videre til en anden fase. Vi starter med at definere hvor søjlerne står, også leverer jeg det til ingeniøren. Jeg definerer på et LOD og ingeniøren så på et andet LOD når de overtager det.

Min sunde fornuft giver mig et overblik over hvad den anden part vil have, men det er fordi det er det jeg laver. Men det er noget af det som er den store udfordring at hvis man arbejder sammen med nogen der ikke har den samme forståelse, hvordan er det så man får det til at fungere. Det der er det svære ved BIM, det er at man ikke kun skal vide hvad man selv skal, men også hvad de andre kan, skal og gør. På et BIM teknisk plan så omhandler det hvilke processer er det vi kører med vores

samarbejdspartnere og hvorfor kan ikke de levere til de givne tidpunkt, og det hænger jo sammen med at vi ikke leverer det vi skal til dem.

De kommer her ind, også skal vi levere noget til dem. Også skal vi snakke sammen om det under nogen teknikker møder eller projekteringsmøder.

Supplerende kommentar - Det er så de krav der stilles hele vejen igennem jeg forestiller mig kan sættes i et sådan skema, for at undgå at der bliver udført mere arbejde end der er anvendelig til formålet? Men det er det du sier at det bliver drøftet på møderne, og skrevet ned i referater?

Ja, det gør det. Men det ville da være en fordel at kunne visualisere dette ved en sådan relations sammenhæng. Men det er svært at definere en sådan noget fra start af, nogle af de andre modeller kan man godt lave fra start af og jeg kan godt se fordelen også i det her, men jeg tror måske ikke vi er parate til det. Jeg tror dine grundtanker er det helt rigtige.

Supplerende kommentar – tanken er ikke at alt skal defineres fra begyndelsen af, men tages efterhånden

Man bør i alle fald kigge på den kritiske sti, og det varierer fra sag til sag. I dette projekt er tagskiven kritisk, da den både påvirker økonomi, udførelsesdetaljer, grænseflader mellem parterne, både rådgivere og udførende. Det er altid nogle kritiske punkter, forskellige fra projekt til projekt, men det ville klart være en fordel at få defineret disse visuelt så alle var klar over hvorledes det forholdt sig. På den måde får man alt frem i lyset, om det så skal være et supplement til referater eller andet så er det det. For det kan være svært at sidde og tegne bokse under mødet.

Et andet punkt er at vi begynder at skulle levere mængde betegnelser, men for at undgå at gøre billedet mudret, så kunne det være fornuftig at definere hvad modtageren skal have. Vi leverer jo det hele, og så kan det være svært for modtageren at vurdere hvad der er vigtig at kigge på i henhold til helheden. Måske er det vigtigere at kigge på facaden end de indvendige vægge når det handler om kritiske mener i økonomien. Om det er 20 kvm mere gips er nødvendigvis ikke det som vælter budgettet, men om vi har fået klarlagt grænsefladerne og at man ved når de andre parter kommer ind. Vi bruger her et økonomisk system udviklet af Steen Lichtenberg ved Aalborg universitet, for at finne hvor der størst risiko er for at budgettet sprækker. Der er man nødt til at have nogle værktøjer til at hjælpe en.

De her processer, enten det handler om økonomi eller at nedbryde i BIM, det er nogle ting som skifter fra sag til sag, noget der er med til at gøre det vanskelig. Så er man jo nødt til at gå ind og kigge på den kritiske sti. Om det er noget man gør indledningsvis og får defineret hvad man skal gøre herfra og videre og videre, eller om man tager det hen ad vejen og med jævne mellemrum i henhold til løbende IKT aftaler det er så det. Man er nødt til at tage problemerne løbende, så har man de her LOD og den kritiske sti som dukker op på møderne løbende.

Det digitale byggeri har nogen problemer med at det er nogen gode intentioner omkring IKT og Bips aftalen osv, men de har måske villet det for godt. Så må man jo gå ind og revidere dette, og si at på disse tidspunkt så må vi have de og de ting, for de vil hjælpe os frem til det neste. I BIM aftalen er vi nødt til at definere hvilket LOD skal vi levere på og hvornår. Og ikke mindst hvad skal vi levere til facility management i sidste ende for at kunne sige at vi har afleveret vore projekt på den rigtige måde. Så må man jo tage problemerne når de kommer og kigge på hvad er det så som er kritisk her.

16. Hvordan bliver fremdriften af projektet planlagt? Er det noget i definerer på tværs af deltagerne eller er det en individuel vurdering af hvad neste skridt i processen er?

Det er en hel branche der skal arbejde sammen, og det er ikke fordi nogen ikke prøver at gøre deres bedste – alle vil gerne levere det bedste byggeri til den bedste pris. Vi ville ikke have det arbejde hvis, det ikke var det vi gik op i. Det er ingen som er ude efter at snyde andre, men man kan nogen ganger have behov for lidt hjælp til at finne ud af hvad vi kan gøre bedst for hverandre, og få lagt vægt på hvad det er man vil have. Det i sig selv er vanskelig, fordi vi har det aftale grundlag som vi har, så det vil tage nogen år før vi endnu er der hvor dette vil fungere.