

# **Model Based Cost Estimations**

- An International Comparison

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## Abstract

- Title:** Model based cost estimations – An International Comparison
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- Problem:** How has the work with model based cost estimations affected the scope of work for the estimator and the designer? Has it led to any gains for a specific actor and what gain would that be? How is the need for different levels of detail in the estimation handled? To start using a completely new process when making estimations, a suitable business model has to be developed, how has this been done internationally?
- Aim:** The study aims to clarify in a qualitative way how the implementation work of model based cost estimation is proceeding internationally. A comparison of the BIM-use in Sweden and abroad was performed.
- Methodology:** To identify critical topics and questions, a national study among Swedish actors was conducted. The pinpointed target areas were then used as a basis for the qualitative interviews with international actors from the Nordic countries as well as the Netherlands and the USA. No statistically verified conclusions can be extracted from the results but the study should be seen as an attempt to define the frontier of development.
- Conclusions:** Model based cost estimations are currently used to a very limited extent. Large benefits have been revealed, but also a number of obstacles that needs to be overcome. Cost information is not available in the early phases of the project since the contractor is not yet procured. This is one of the major obstacles. By extracting quantities from the model safe

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and accurate lists can be produced. If these are then linked directly to an estimation, a superb traceability in the estimations can be achieved. The main requirement for this to function is a high quality model, which can only be created if demands and guidelines of BIM and the use of the models are established already in the project initiation. Business models for the designer who have to create the model are hard to define. The common opinion in all countries visited is that the design consultants must see this as a weapon of competition, not as a tool for timesaving. A number of new services have already begun to influence the market, that is where the actual benefit lie for the consultants.

**Keywords:** Model based cost estimations, BIM, value engineering, IPD

## **Preface**

This thesis is the result of a very rewarding and enjoyable cooperation between the authors and Tyréns, one of the leading construction consultant companies in Sweden.

The idea started as a trembling attempt from the authors to explore something new and inventive regarding the use of building information modelling. With the aid of Tyréns we stepped down from our high horses and decided to focus on one, perhaps narrow and hard to define area within the concept of BIM, model based cost estimations or 5D BIM-use as some prefer to call it.

To help us define the scope of our work we fortunately had our very dedicated and helpful supervisor from the Division of Construction Management, Kristian Widén. Without all the inputs from him, both regarding details in the subject and also general recommendations about how this study should be performed, it would have been very hard to achieve the results we did.

The authors would like to show our gratitude for the pleasure of working with the staff at Tyréns' offices in Malmö and Stockholm. We would like to thank Peter Tenggren for his daily support and recommendations, Pål Hansson for making it possible to perform vital international interviews, on-site across Europe just to increase the quality. Olle Samuelsson and Dag Wingstrand contributed with valuable guidance when deciding what this report should deliver.

Unfortunately we cannot name all of those who have taken their valuable time to meet with us whether by phone, Skype or in person. The interviews have given us an extraordinary chance of getting to know interesting people all over the world and to take part in their valuable work. All interviews are confidential which forces us to just say this to all participants, thank you!

Lund February 2011  
Carl Bylund & Andreas Magnusson

## **Abbreviations**

VDC – Virtual Design and Construction

BIM – Building Information Modelling

ROI – Return Of Investment

R&D – Research and Development

DB – Design Build (Totalentreprenad)

DBB – Design Bid Build (Utförandeentreprenad)

IPD – Integrated Project Delivery

IAI – International Alliance for Interoperability

PBS – Product Breakdown Structure

WBS – Work Breakdown Structure

CBS – Cost Breakdown Structure

VE – Value Engineering

TVD – Target Value Design

PPA – Public Procurement Act (LOU in Swedish law)

GMP – Guaranteed Maximum Price

GML – Guaranteed Maximum Liability

PDA – Portable Data Assistant

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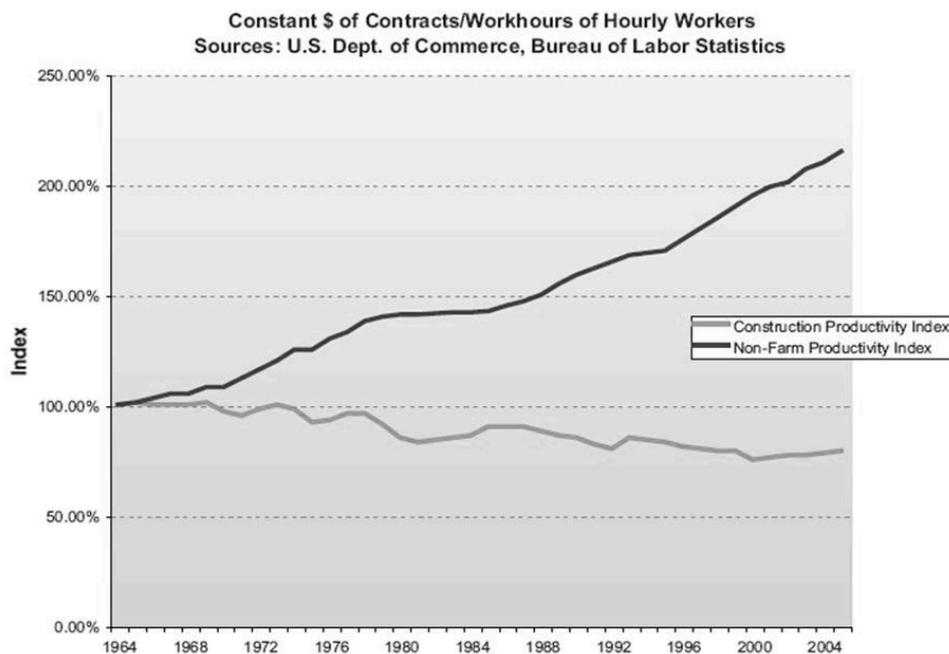
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# 1 Introduction

## 1.1 Background

Building information modelling (BIM) could be one of the changes needed for the construction industry to increase its productivity. Labour is currently approximated to represent 40 % - 60 % of the total construction cost. Since 1964 the labour productivity has actually decreased by 10 %. In the same period of time, the non-farm industry has increased its labour productivity by over 100 %<sup>1</sup>.



Reference: Paul Teicholz, Ph.D., Professor (Research) Emeritus, Dept. of Civil and Environmental Engineering, Stanford University

Figure 1, Productivity index for construction and non-farm industries<sup>2</sup>

In the Nordic countries public clients are starting to define their requirements due to the use of BIM in their projects. E.g. Statsbygg, a Norwegian public client demands BIM in all of their projects since the beginning of 2010<sup>3</sup>. In Denmark the public organization “Det digitale byggeri” has defined variable BIM-requirements due to the extent and cost of the project<sup>4</sup>. Similar demands exist in Finland where Senaatti is one of the largest public actors.

There seem to be a transition going on in the construction industry today worldwide, perhaps as comprehensive as the one in the early 90’s where CAD tools were

<sup>1</sup> Eastman C et al., (2008)

<sup>2</sup> Eastman C et al., (2008)

<sup>3</sup> Statsbygg.no, (2011)

<sup>4</sup> Det digitale byggeri, (2011)

introduced to the market. Although the implementation of BIM should be even more profound since not only the ways of visualization is about to change, but also the interaction between all actors in the project. The project phases will be blurred and the order in which projects are conducted will possibly change.

The first logical step of implementation of BIM is to use the benefits of visualization. This thesis however focuses on model based cost estimations. This is often referred to as the “fifth” dimension (5D) even if that expression’s validity is somewhat discussed. Even so, there are a number of benefits expected with model based cost estimation and quantity takeoffs, such as:

- More precise quantities through all project phases.
- Changes create immediate updates in the list of quantities and cost estimations.
- Possibility to very precise planning of material delivery with thorough scheduling.

Extracting quantities from 2D-drawings can take up as much as 50 %- 80 % of the estimator’s time in a project<sup>5</sup>. With a building model the time usage for making estimations is expected to decrease.

This together means that the estimator could redistribute his time so that more time and effort is put into evaluating different design alternatives rather than assessing 2D-drawings and writing manual spread sheets.

## 1.2 Goals

The authors’ have the intention to answer and have a discussion around the following questions and topics:

- How is the use of quantity takeoffs for model based cost estimations affected depending on who is setting the requirements of BIM-use in the project?
- Have the scope of work for the estimator and designer changed due to the use of cost estimations? If so, in what way?
- How do the estimator and designer manage the need for different levels of detail in the cost estimation due to project phase?
- Which actor has the largest economical gain of model based cost estimations and how did that gain evolve?
- What does the business model look like for those actors providing model based estimation services today? Is there a difference between these business models and traditional models and types of compensation?

Besides these clearly defined target topics, the study aims to clarify and roughly map the situation for the entire business when it comes to the implementation of BIM.

## 1.3 Purpose

Today there seem to be a common, not very substantiated opinion about how different actors and countries are adapting to the new technologies and processes of work that BIM brings. The authors’ opinion is that the people involved with R&D questions have a point of view of the implementation of BIM that might differ relatively much

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<sup>5</sup> Sabol L, (2008)

from the common opinion in the industry. However, the purpose of this thesis is not to establish a situation report in general for the construction industry today, but to clarify where the solid edge of development and use of certain BIM-features lies.

Since the industry probably is or has been approaching the same implementation issues in most places regardless of geographic location, an international study would give a more valid idea of the current situation. Finally the intent of the thesis is to clarify the general situation in the BIM-adopting industry in Sweden as well as in Norway, Denmark, Finland, USA and the Netherlands. Focus will lie on the use of model based cost estimations and how this feature has changed the roles of the participants of the project. Although to reach an understanding about cost estimations, certain aspects of BIM, such as the technical process on which the estimations are created and the organizational requirements, have to be studied. One critical aspect companies always tend to focus on is the return of investment (ROI). Therefore the business models for design consultants will be evaluated.

When this is done a comparative analysis will be performed where the Swedish industry is matched against the foreign. This way the writers hope to be able to clarify in which areas implementation approaches differs and hopefully be able to pinpoint foreign experiences that might be of use.

#### **1.4 Limitations**

Currently several thesis are written with focus on general knowledge and implementation on subjects such as e.g. BIM, VDC and IPD. The main focus in our work will be on model based cost estimations and quantity takeoffs. These two features of building information modelling will be evaluated according to technical, organizational and economical values. Even if the project processes involve a number of different actors, the view of perspective will be the one of the design consultants.

Areas that will not be studied in detail in this thesis:

- Building information modelling, merely an overview will be presented.
- The shape and functions of the building industry itself in general.
- Technical aspects such as specific software and limitations in those.
- Actual cost and timesaving measurements. Only some subjective opinions will be presented.

Using the designation “BIM” requires a clear definition. However, in this thesis, the authors take the liberty to use it to describe a concept of how construction projects could be managed with regards to organization, processes and software tools, as well as a more simple use of somewhat intelligent 3D-models.

#### **1.5 Method**

To achieve the transparency required in a master thesis and for the reader to be able to create an own opinion about the credibility of the report, this chapter will address the method of work. The method used will be presented in detail to ensure that the report will be considered trustworthy and that the study has been conducted in a scientific way.

### **1.5.1 Workflow**

To be able to work efficiently when writing a thesis it takes a well defined structure of the workflow as well as a clear intent and goal. A master thesis may have different purposes depending on the nature of the project:

- Describing (How something works or was done)
- Exploring (A deep analysis of how something works)
- Explanatory (Explains a causation or how something works)
- Problem-solving (An identified problem is engaged and solved)

This thesis is both the problem-solving type and the describing type. Several problems in the implementation of BIM have been identified; they are to be resolved if possible. To do this, an understanding of the processes around the actual problem have to be achieved, thereby the describing type.

Information about the problem can be collected in many different ways. To ensure that the information is collected in a structured way and to ensure that a comparisons can be made between different data and to analyse the results of it, the correct “tool” has to be used. Different tools are recommended depending on how the problem formulation is set up.

With a broad question, a mapping or survey is suitable to establish the current situation in some areas. If a deeper analysis is needed a case study can be used. That means that one or more objects, e.g. construction projects, are evaluated in a more narrow area of interest.

A project can consist of several phases, which perhaps need different evaluation methods. E.g. to identify specific problems may require a survey of some kind, while the solving of the problem might need a case study.

To achieve the best possible result in this thesis, the following workflow has been chosen:

- Planning and choice of structure
- Study of literature on the topic
- Mapping of target topics of interests by interviews within Tyréns AB
- Analysis of the answers from those interviews
- National study by qualitative interviews distributed among the entire building industry in Sweden
- International study in the same way as the national
- Comparative analysis between the national and international study

### **1.5.2 Studies of literature**

To comprehend which questions have to be asked to extract the correct information, a deep understanding in the subjects of BIM is required. Typically, regarding what BIM actually is, what happens and who is affected when BIM is put in the context of a true construction project.

If the literature studies are well performed, unnecessary rework can be avoided by using information already published. However the reliability of the sources used have to be validated to be able to base assumptions and conclusions on their content. The following questions should be answered before considering a source trustworthy:

- Has the material been revised and in that case by whom?
- Who is guarantor of the credibility of the source?

- Is the method in which the material was created credible?
- Are the results processed in a context relevant for my own questions?
- Have the results been confirmed or have led to a scientific recognition or used in other credible contexts?

These suggestions above also apply to the reader of this report. That is why the transparency of the work is vital and in the attempt to achieve this, sources are revealed whenever possible and the processes of the studies performed are described.

### **1.5.3 Gathering data through interviews**

Interviews as a way of gathering information require some level of structure to be credible. The choice of structure depends on the purpose of the study and the topic discussed. Normally three techniques are applied with different approaches regarding how the questions are presented and thereby how the answers will be formulated. The open and directed interview lets the interviewed person speak freely around a subject or a specific question. The answers will be qualitative and the interviewer must make sure that the interview stays within the subject. A semi-structured interview is a mixture of questions, where the interviewed person speaks freely around questions with fixed alternatives of answers. It is important to perform different interviews within one study exactly the same way and with the same formulations so that the interviewed is not affected in any direction.

A structured interview can be seen as an oral survey with fixed answers.

### **1.5.4 Choice of interview technique**

This study can for many reasons be criticized because of its lack of scientific approach when performing interviews, choice of participating individuals and the ways the gathered information is assembled and presented. However, this study's aim was not to establish any statistically verified material. The main focus in the thesis is to identify the critical topics and areas of interest when implementing BIM. The idea of how this is done most effectively was to start by interviewing people currently involved with BIM in Sweden at Tyréns AB, establishing a few main topics of interest. These topics would later provide the base for the sheet of questions used for both the national and international interviews.

The main topics are:

- Perceived current status of implementation and work with cost estimates
- Organizational queries
- Business models
- Roles of responsibility

The results displayed here are merely the authors' reflections of the interviews. No general assumptions about the work of a certain company or country can be made out of the material since it only represents thoughts and ideas of individuals. All persons are as already mentioned involved with BIM-questions in their daily work and can therefore be assumed to have a personal commitment in this question. The interviews have been conducted in a very open way in the attempt to extract as much information as possible within the subjects.

The interviews have been recorded when possible. To ensure that what is reproduced in the report is credible and true; summaries were written after each interview based

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on the recorded material. The interviewed person was then given the opportunity to comment on the summary to ensure its correctness.

## 2 Theory

### 2.1 Building Information Modelling (BIM) – Definition & Challenges

*This chapter gives a general description on the use of Building information Modelling (BIM). It will also cover the most frequently addressed benefits and challenges that the AEC industry stands before in the adoption of BIM.*

#### 2.1.1 BIM Definition

Digital files are generated by all kinds of CAD systems. The older CAD applications used only graphical information such as vectors, line-types etc. to describe a building object. These systems were then developed to allow for more information to be added such as blocks of data and text. When 3D modelling started to gain more popularity even more information could be added with complex surfacing and advanced definition tools<sup>6</sup>.

With this development towards more information based drawings the focus changed from solely drawing and images towards the data itself. Today's BIM tools are object-based meaning that they not only show multiple views of the model in 2D and 3D but also allows for properties to be stored within every single object.

According to "The BIM handbook" BIM is defined as:

"A modelling technology and associated set of processes to produce, communicate, and analyse building models<sup>7</sup>."

A building model is then characterized by:

- **Building components** that are represented by objects that "know" what they are and can be linked with data attributes, graphic and parametric rules. In this way a door will "know" that it is a door and that it can for example only be attached to a wall and not to a roof.
- **Consistent and non-redundant data**, meaning that a change made in one view will be represented in all other views as well.
- **Components that include data that describe how they behave**, for analyses and work processes, e.g. specifications, quantity takeoffs and energy simulations.
- **Coordinated data**, so that all views will be represented in a coordinated way<sup>8</sup>.

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<sup>6</sup> Eastman C et al., (2008)

<sup>7</sup> Eastman C et al., (2008)

<sup>8</sup> Eastman C et al., (2008)

### **2.1.2 Collaboration and file protocols**

In a building project it is of great importance to easily be able to import and export information between different actors. One of the main focuses of BIM is to increase this interoperability between actors. When using BIM software there are mainly two primary approaches to make this work. Either stay within one software vendor's product range and use his specific file formats or use software from various vendors that can exchange information using a standard protocol. The first alternative makes interoperability between actors easier since there is no need for export and import between file formats. The second approach however allows for more flexibility and does not force any actor to use certain software. The file protocol most frequently used is, Industrial Foundation Classes, (IFC), which is an open standard developed by the international organization, International Alliance for Interoperability, (IAI), since 1996<sup>9</sup>. This standard allows for building objects to be exported from one BIM software and imported into another one. The use of an open standard is particularly important in public projects where the client might be unable to exclude actors from the procurement, because of the use of different software. This is regulated in the Public Procurement Act (LOU).

### **2.1.3 Challenges in the adoption of BIM**

#### *Cooperation*

Good collaboration is essential to the success of every building project. In a BIM project however the necessity of cooperation within the project group is even more important.

Determining which method should be used for sharing model information between actors in the project team is a major issue. If the design is made in a traditional way with 2D drawings it might be necessary for the contractor to build the model, to be able to use it for e.g. quantity takeoffs, cost estimations and clash detection. This adds cost to the project but may be justified anyway because of the great advantages of using the model at the construction site and in the procurement etc. If the project team members use different modelling software, tools for moving and combining these models are required. This can add difficulties to the project and is an issue that has to be addressed. One way to reduce these problems might be to use IFC standards for the data exchanges. Another method is to use a model server that uses e.g. IFC to communicate with all BIM applications<sup>10</sup>. Model servers are used to store and manage the model either at a host site or on an internal network/server. Today, the use of BIM together with model servers is not fully developed, since many servers still only provide access and storage at a file level. Today's BIM projects typically have an assigned model manager who manually integrates and creates project model files<sup>11</sup>.

#### *Legal concerns and documentation ownership*

There are legal matters regarding in particular the right of the project outcome and documents. Who owns the documents and for what can they be used etc.? These

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<sup>9</sup> Gustafsson M, (2006)

<sup>10</sup> Eastman C et al., (2008)

<sup>11</sup> Eastman C et al., (2008)

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issues are often handled differently in each country since laws and regulations vary, but there are professional organizations such as the BuildingSMART that are developing general guidelines for the contractual writings regarding BIM. When client's and owner's level of knowledge and experience of BIM increases they will most likely want to use the model for maintenance, operations and renovations of the buildings. This will even further require clear agreements and contracts to avoid misunderstandings and conflicts<sup>12</sup>.

### *Changes in practice and information usage*

In most building projects it is desirable to have the construction knowledge from the contractor available early on in the project, since this will help to reduce errors and complications as the project develops.<sup>13</sup> The benefit of this will increase even more in BIM projects, since the contractor is one of the actors who are likely to use the model most frequently. If integrated in an early stage the contractor can then give the design group valuable input on how the model should be created to suit his requirements for usage.

Companies who are able to coordinate all stages of the design and integrate the knowledge from construction in an early phase will have the largest benefits of BIM<sup>14</sup>.

The shift from 2D and 3D CAD design to a BIM approach will also require considerable more than just upgrading software and training personnel. To use BIM successfully almost every aspect of a companies business will have to change. It will require a detailed understanding and a well-prepared plan of implementation before the conversion can start. It will not be sufficient to simply do old things in a new way. Of course the specific changes made to each company will depend on the different activities performed. Some general steps that should be considered include:

- Assigning top-level management the responsibility for developing a plan for BIM implementation.
- Start using BIM on a few smaller pilot projects to be able to compare and evaluate results.
- Use results from pilot projects to continue to educate personnel and keep senior management up to date with progress and problems.
- Start new collaboration based projects that allow building information to be shared in early stages.

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<sup>12</sup> Eastman C et al., (2008)

<sup>13</sup> Gustafsson M, (2006)

<sup>14</sup> Eastman C et al., (2008)

## 2.2 Budget management and cost estimation

*A construction project's origin is almost always an idea of a person or organization with a need for a conceptual or functional building or facility. In the earliest phase it is nothing but an intention about how the future could look like. To be able to reach that future with available resources is the true challenge of the construction industry. In this chapter the methods used for steering and controlling the project's resources and budget along its development are presented.*

### 2.2.1 Cost management and development of cost estimations

When a project is in its earliest phase, the expected cost is of utmost importance, especially to the client since he is the one who will have to bear the cost in the end. To be able to measure the economical success or failure in an on going or finished project some kind of factors of measurements must exist. The project budget is the most important factor for such an evaluation<sup>15</sup>.

For the client to engage in the intended project, economical analysis have to be made to ensure that project cost will be refunded in a certain number of years. This can be done by a Net Present Value (NPV) calculation, which takes future project cash flows into account<sup>16</sup>. When this is done the client's maximum budget is decided due to the NPV. Budget management later on is about keeping the project cost below the budget at all phases<sup>17</sup>. It is in the early phases of a project that the possibility to influence the total project cost at a low cost exist. However, in the industry today, cost management is the contractor's tool to a higher degree, which means that focus often is set on the construction phase.<sup>18</sup>

Traditional budget management means that the client sets a maximum cost for the entire project or parts of the project<sup>19</sup>. At each design phase initiation, an updated cost estimation should be performed. Unexpected events and discrepancies from the budget may then be found in time. An important feature of the collaboration between the designer and the estimator is the possibility to alter between and to evaluate different design solutions<sup>20</sup>.

At a building project initiation very little is known about the actual building. The level of information increases as the architect and designers develops design solutions and products to be used and installed. Parallel with their work the estimator uses the information of the designers as inputs to create cost estimations, most often called Product Breakdown Structures (PBS).

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<sup>15</sup> Winch M G, (2010)

<sup>16</sup> Hendrickson C, (1998)

<sup>17</sup> Winch M G, (2010)

<sup>18</sup> Sundaram V, (2008)

<sup>19</sup> Winch M G, (2010)

<sup>20</sup> Sundaram V, (2008)

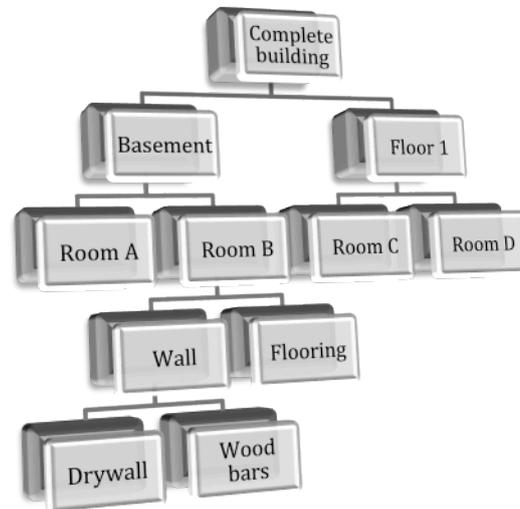


Figure 2, Example of Product Breakdown Structure

The PBS is used for early phase estimations and focuses on the materials and products used in the building<sup>21</sup>. Instead of this parallel work, an integrated method of work where the cost estimation is used as a design tool is desired, primarily to avoid late discoveries of budget overruns<sup>22</sup>.

As more information becomes known the uncertainty in the estimations decreases to finally be zero, as the project is complete and delivered.

This inaccuracy in the cost estimates is one of the reasons why design and site-construction is separated in the project life cycle. By using different contracts for design and construction the client has a better ability to evaluate the building costs before the actual construction phase is initiated. To increase the accuracy of the estimations in these early stages, a database with previously conducted project's tender prices would be of great assistance. One must then keep in mind that the building price is not the same as the project cost and therefore use database figures carefully when evaluating situations<sup>23</sup>. This is supported in a report from 2007 where the ability to re-use quality historical cost data for similar projects is pointed out as a factor that could heavily increase the accuracy of cost estimation<sup>24</sup>.

One problem in modern construction industry is the connection between early cost estimations and actual construction performance on site<sup>25</sup>. It is relatively common that the estimators active in the design phase, on the account of the client, have limited experience from actual construction. Neither have they access to valid unit costs etc. collected from previous projects<sup>26</sup>. A PBS concentrates on the components of the building and by that generating a construction cost using unit prices for each

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<sup>21</sup> Winch M G, (2010)

<sup>22</sup> Sundaram V, (2008)

<sup>23</sup> Winch M G, (2010)

<sup>24</sup> Liu L, Zhu K, (2007)

<sup>25</sup> Winch M G, (2010)

<sup>26</sup> Sundaram V, (2008)

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component. In the earliest phase this might be a standard value cost per apartment or parking space. That estimation is then refined to e.g. cost per square meter in the actual building and then it is finally based on a bill of quantities. Often these types of estimations are used for setting target prices for incentive contracts.

Since the contractor is going to be in charge of the process of actually assembling all the components included in the PBS he needs another way of estimating his costs. The method used is often referred to as a Work Breakdown Structure (WBS) and involves the components in the PBS, inserted in the context of the process of assembling them. When the transition from the designers/client's PBS to the contractor's WBS takes place, a redistribution of responsibility often occurs from the client towards the contractor<sup>27</sup>.

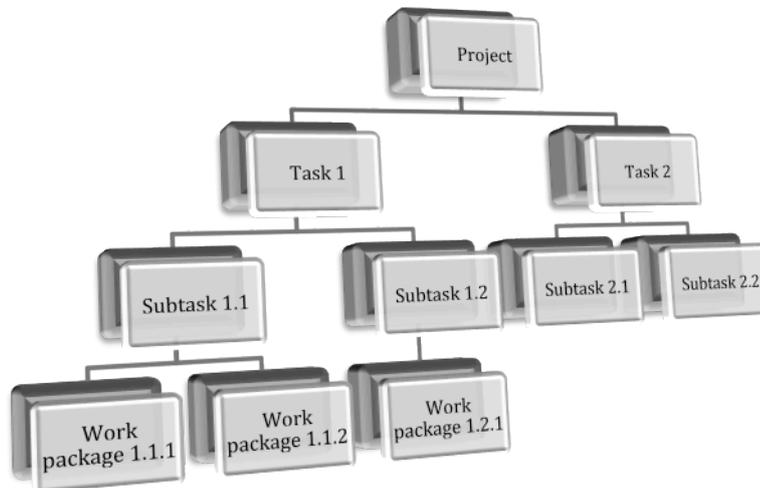


Figure 3, Example of work breakdown structure, modified from NetMBA Business Knowledge Center, “Work breakdown structure”

In an attempt to create more cost effective projects, value engineering is used, often in the form of a work-group who in collaborative workshops re-evaluates the designer's proposals. Their work is supposed to minimize unnecessary costs to meet the intended budget cost. There are questions about the effectiveness of this type of value engineering since it means an extra cost for the client to hire this third-party resource<sup>28</sup>. Especially in times with large market fluctuations and in recesses the first thing clients tend to focus on, is lowered fees for design services in the design phase, therefore neglecting the need for continuous value engineering<sup>29</sup>. It also means that designers and architects experience a loss of motivation of creativity since the VE-group might change or delete their work in order to trim the project cost<sup>30</sup>.

Instead a more effective approach might be that the designers have an incentive contract instead of the fee-based variant. For the designer to already in the early

<sup>27</sup> Winch M G, (2010)

<sup>28</sup> Winch M G, (2010)

<sup>29</sup> Grace M J, (2010)

<sup>30</sup> Winch M G, (2010)

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phases have the value engineering in mind and to use the knowledge from those who have experience and expertise in realizing projects, i.e. the contractor could be of great importance. Working in this way instead of the traditional could mean that waste and safety hazards are decreased and productivity and quality are increased<sup>31</sup>. There are however thoughts about internal cost control or value engineering within the design team. With new tools such as software used for BIM-purposes quantity takeoffs can be done in lesser time and with better accuracy. The danger is supposed to lie in the event that inadequately experienced users from the client's staff makes estimations based upon assumptions and unit prices from general contractors, subcontractor or suppliers. Therefore the roll of the value engineer as a third-party actor is recommended<sup>32</sup>.

Once the construction phase is engaged, the project manager typically handles the main control of the budget. They often use an even more refined estimation method, Cost Breakdown Structure (CBS). In the CBS each element from the WBS is broken down into three sub categories, labor, materials and plant required for executing the task, e.g. assembling the component or mounting of a window<sup>33</sup>.

The nature of the cost estimation changes when the project enters the construction phase. In the design the estimation is predictive of a future build cost. When in the construction phase the estimators focus on estimating the present in a reactive way. This meaning that the estimator must react to changes generated by the owner or other project contingencies and keep the estimation updated. The value engineering should take place continuously with the cost engineers and the designers involved. This way pro-active cost management will be possible and proposals of design solutions with higher quality or cost effectiveness could be presented. These optimizing changes are sometimes mentioned as Value Engineering Change Proposals (VECPs)<sup>34</sup>.

In this traditional way of managing project cost and budget with the aid of repeat estimations the focus is always on “what does this design cost?” and the estimation is created by the current information available. By using a part of the lean construction methodology called Target Value Design (TVD) this is could be seen from a different perspective. The engagement of a project starts with agreeing on a target price for the client. Then the resources available decide what and how things get designed. This means that the design team needs to be fully aware of the cost of the intended design and for them to receive fast feedback from the cost estimator. To achieve this, model based estimations are used where quantity takeoffs are made directly from the intelligent 3D model. This method of value engineering has been fully applied in some large healthcare projects in the USA where integrated project delivery were used as a delivery method<sup>35</sup>.

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<sup>31</sup> Winch M G, (2010)

<sup>32</sup> Grace M J, (2010)

<sup>33</sup> Winch M G, (2010)

<sup>34</sup> WBDG Cost –Effective Committee, (2009)

<sup>35</sup> Tiwari S et al., (2009)

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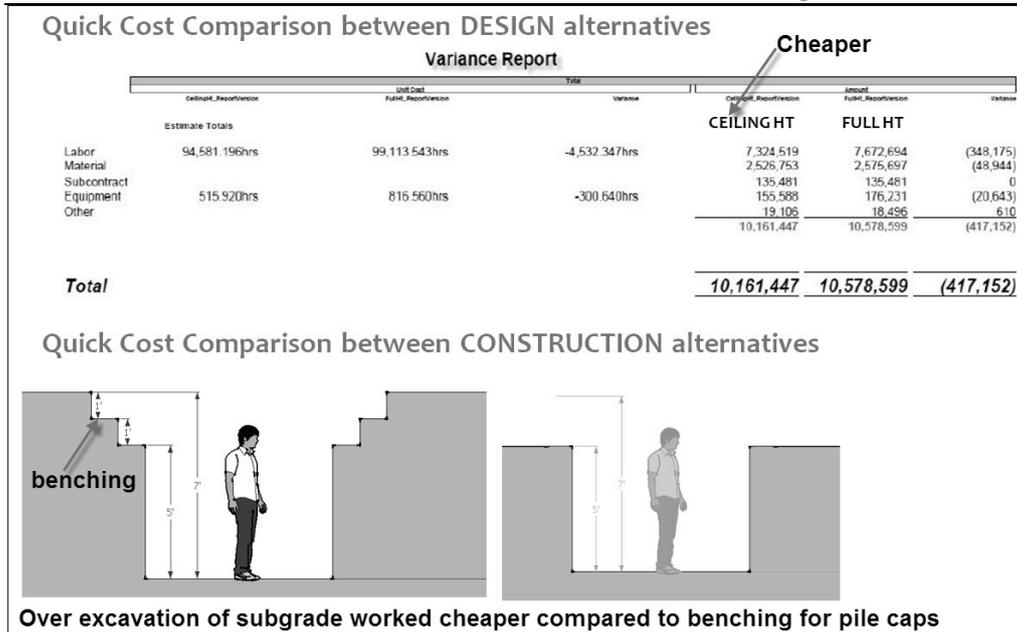


Figure 4, Example of evaluation of design solutions, AECbytes

If a fast and reliable loop of cost feedback involving the design team and the cost estimator can be established and realized, a tool for iterative design solution evaluations has been created<sup>36</sup>.

### 2.3 Quantity takeoffs

Quantity takeoffs are often used as a basis for cost estimations during a project. The reason for doing a quantity takeoff is mainly to translate drawn objects to lists. These lists will then contain information about e.g. the amount of building material, appliances and building goods in the project. With the use of today's modern BIM software it is possible to do quantity takeoffs directly from an object model. These lists can then be connected with cost recipes to get an estimate of the project cost and create PBS and WBS reports.

In the current situation the cost estimates are not entirely customized for actors doing production based calculations, which can cause some difficulties. In the future when model based cost estimates will be improved and done more efficiently it is most likely that the traditional way of manually calculating quantities will diminish<sup>37</sup>.

When doing quantity takeoffs it is very important to measure the objects in the same way otherwise it will be difficult for other persons to get involved in the work or take over the tasks with the quantities. If for example the area of a wall has been calculated, it is essential to know whether the area includes door openings or not. Clear rules and norms are therefore essential<sup>38</sup>. This is also important to bear in mind

<sup>36</sup> Tiwari S et al., (2009)

<sup>37</sup> Hansson B, Olander S, Persson M, (2009)

<sup>38</sup> Eastman C et al., (2008)

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when different BIM applications are used in the project, since not all software measures quantities in the same way. For example the length of a wall might be measured from the centreline or the outside resulting in a somewhat different area when calculated. Furthermore some applications gives the user the flexibility of modelling objects in different ways though quantification does not work with all of them. An example of this is when modelling openings using e.g. Revit. Openings could be modelled using an “opening tool”, an “edit profile tool”, an “opening family tool” or a “void extrusion”. However the only way the opening gets quantified is if they are modelled using the opening tool or opening family tool<sup>39</sup>.

Quantity data can be divided in different ways depending on in which way they are calculated:

- Actual quantities are quantities measured on site.
- Generalized quantities are also those measured on site, but with lower accuracy than the actual quantities.
- Theoretical quantities are measured from the drawings.
- Hypothetical quantities are estimated at a stage when there are no defined metrics to work from.

Quantity takeoffs are in general done for the first time in the procurement phase when the contractors are about to leave their bids. However, in some projects the client might choose to calculate quantities already in the design phase<sup>40</sup>.

Today there are several companies specialized in doing quantity takeoffs. The benefit of using these companies is mainly that the contractor can save time and focus more on pricing the bids. In some cases the price for calculating the quantities will even be lower if a consultant is doing the work, since he can sell the same quantities to several contractors<sup>41</sup>.

If the client decides to do a quantity takeoff in the design phase it can be used in the procurement of the contractor in a DBB project. The quantities can then be used as a legal binding contract that the contractor can leave a price on or they can be used as a reference number to increase the accuracy of the bids. Since all the contractors will be leaving their bids on the same quantities the price will be determined by more soft parameters. The reference numbers could also be used by the contractor to check the reliability of their own quantities.

If the client chooses to make the quantities legally binding the contractor typically leaves a fixed price. This is usually done by taking a list of unit prices and multiply with the given quantities. The list with unit prices can then be used to correct for changes and additional works.

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<sup>39</sup> Tiwari S et al., (2009)

<sup>40</sup> Hansson B, Olander S, Persson M, (2009)

<sup>41</sup> Hansson B, Olander S, Persson M, (2009)

Besides the benefit of more accurate bids from the contractor, there are more benefits for the customer from doing quantity takeoffs in the design phase.

The documents will most likely have a higher level of detail and quality if they should be a basis for quantity takeoffs. The client will furthermore get an improved control over whether the estimated costs are correct. One disadvantage of doing early quantity takeoffs is that the time for the design phase is likely to increase<sup>42,43</sup>.

Legally binding quantities submitted by the client will affect the contractor in several ways:

- The risk will be decreased since the contractor does not have to calculate quantities himself.
- More balanced competition between contractors since bids will be submitted on the same basis.
- Reduced costs since no quantity takeoff has to be made.
- Some contractors will still be forced to do quantity takeoffs to be able to use it in their cost calculation system. Within these companies the motivation to leave a bid might decrease.
- Increased risk for the client to receive bids from unscrupulous contractors who actually lack the capacity but still place the bid since it is now cheaper<sup>44</sup>.

As stated by a British KPMG study as much as 10% of the turnover of a contractor is used for tendering. This means that a significant amount of time is being spent on calculating quantities and doing cost estimates. Being able to do this more efficiently and with a greater quality could therefore possibly save both time and money<sup>45</sup>.

## 2.4 Cost estimations

Cost estimations are done in all building projects and are a way to control the project costs. In early stages the estimate is typically done based on unit cost per square meter, but as the project develops the estimate can be done more accurate and in detail forming a PBS<sup>46</sup>. Later on the contractor will transform the PBS into a WBS to suit his requirements of an estimate.

The classic method of doing a cost estimate implicates manual counting and measuring by the estimator. This is a very time consuming activity and as all human activities it is also subject to errors and mistakes<sup>47</sup>. According to a survey performed

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<sup>42</sup> Hansson B, Olander S, Persson M, (2009)

<sup>43</sup> Eastman C et al., (2008)

<sup>44</sup> Hansson B, Olander S, Persson M, (2009)

<sup>45</sup> Winch M G, (2010)

<sup>46</sup> Eastman C et al., (2008)

<sup>47</sup> Popov V et al, (2009)

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by a Dutch consultant as much as 60% of the estimators time is taken up by calculating quantities<sup>48</sup>. With building information modelling it is now possible to count quantities, areas, volumes etc. from the model and use this as a basis for cost estimates<sup>49</sup>. This quick connection between design and cost will significantly increase the designer's potential of value engineering, considering and valuating different design solutions while designing<sup>50</sup>.

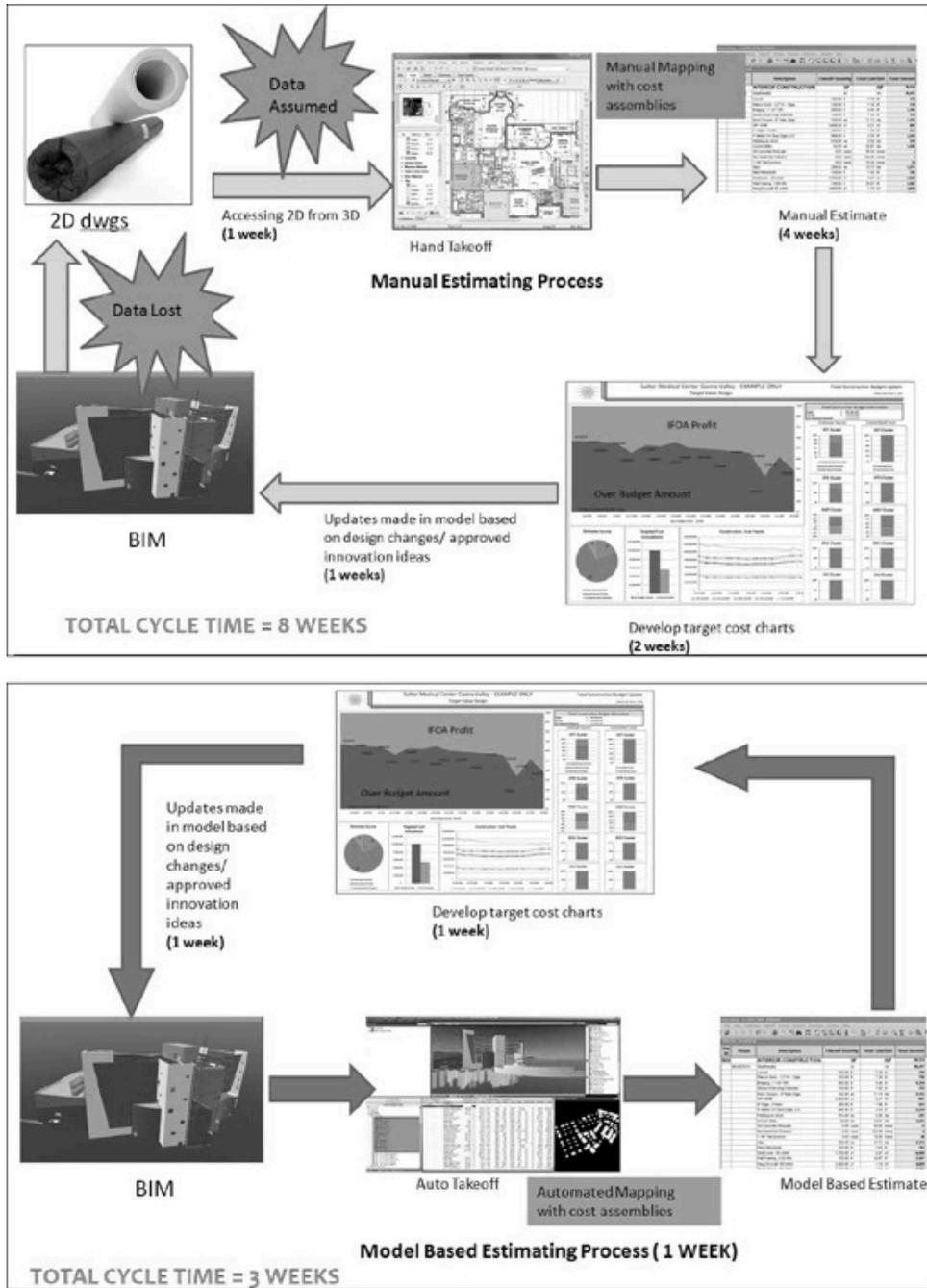
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<sup>48</sup> Hendriks H, (2010)

<sup>49</sup> Eastman C et al., (2008)

<sup>50</sup> Edgar J-O, (2002)

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Figure 5 The manual estimating process compared to the modelbased estimating

<sup>51</sup> Tiwari S et al., (2009)

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Value engineering throughout the development of the project allows for better evaluation of the building design. It is also most likely more effective than the traditional practice of managing the budget by removing cost items at the end of a project, when the easier change is often prioritized ahead of the more effective<sup>52</sup>.

To create a calculus it is necessary to first do a quantity takeoff from the model. The quantities taken from the model are then linked with recipes to estimate the cost. The total price for e.g. a window includes not only the material price but also a cost for delivery, mounting etc. In that way it is possible to estimate a total cost for the building, or divide it by levels, apartments etc. if that is preferred<sup>53</sup>.

A cost estimate typically needs to be made in numerous stages of a project. In the conceptual stage, rough key figures are needed to determine whether a project is feasible or not. Later on in the bidding and construction phase more accurate estimates are required to control budget and tendering processes<sup>54</sup>. The accuracy of construction cost predictions is largely depending on the amount and quality of historical cost data and the experience of the estimator among other things. In the early stage of a project a lack of information might force the estimator to make assumptions about the project design that appear to be incorrect as the project evolves<sup>55</sup>.

A way to measure the quality of an estimate is by the accuracy level. A comparison done by Liu & Zhu shows that the accuracy level hardly have changed at all for the last four decades, remaining at around 10%. Ranging from 30-50% in the early stages of a project when the experience of the estimator is crucial, to around 5% in the preconstruction stage when a lot of focus is on the costs<sup>56</sup>.

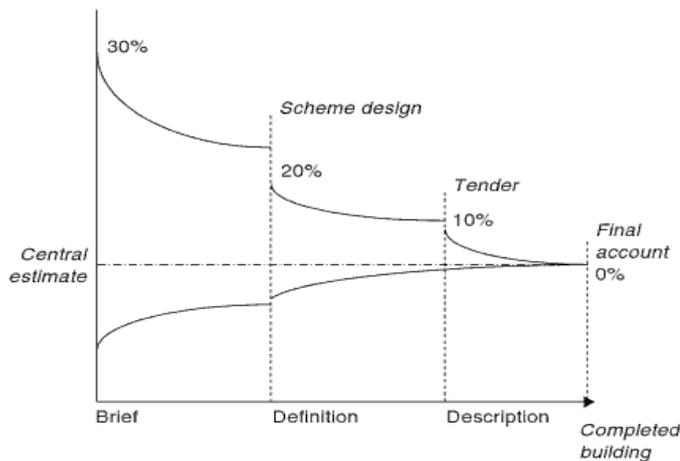


Figure 6, Accuracy of estimates during project development<sup>57</sup>

<sup>52</sup> Eastman C et al., (2008)

<sup>53</sup> Edgar J-O, (2002)

<sup>54</sup> Liu L, Zhu K, (2007)

<sup>55</sup> Liu L, Zhu K, (2007)

<sup>56</sup> Liu L, Zhu K, (2007)

<sup>57</sup> Winch M G, (2010)

It is obvious that the benefits of an early cost estimate will have several positive effects on the project. Instead of waiting until the design is finished to make changes, these can be done as the project develops. More accurate cost estimates during the project will allow the designer and client to make more informed decisions, improving the projects' cost control<sup>58</sup>.

Equally significant is that a BIM approach can reduce the time required to get a high quality project by improving design and construction collaboration as well as accuracy in quantity takeoffs.

In the early design stage, there is usually a lack of quantities and the only ones available are associated with volumes and areas such as boundary lengths, types of spaces etc. These quantities will be depending on the building type, e.g. number of floors, area of each commercial space etc. Unfortunately this information is in general hard to extract from early design packages e.g. SketchUp, since they do not define objects. Moving the information from this kind of software into BIM tools early on in the process is therefore important to facilitate the extraction of quantities and cost estimates<sup>59</sup>.

During the development of the project it will then be possible to use more detailed information from the model. The quantities extracted from any BIM package are typically more than adequate for cost estimations. However there may arise problems when the contractor needs to use the quantities if they are not defined in the same way as he desires. This is a problem that can be addressed with early involvement of the contractor in the project<sup>60</sup>.

It is essential to note that even though building information models provide good basis for quantity takeoffs, the role of the estimator will not be replaced<sup>61</sup>. The estimator plays a key role and should continuously monitor the design decisions that affect the costs, and inform the designers of the impact the changes will have at the earliest possible time. This way, design options can be altered without great difficulty<sup>62</sup>.

The process of estimating is a complex procedure that involves assessing conditions, such as infrequently used joints, unique assemblies and challenging access situations. This information cannot be estimated in a feasible way by today's BIM tools. The estimator should therefore consider the use of BIM software mainly as a way of reducing the uncertainties regarding quantity takeoffs. The timesavings acquired could be used to better evaluate conditions and optimize prices from subcontractors and suppliers<sup>63</sup>.

The U.S construction company DPR, have in an article described that they can currently extract approximately 86% of the quantities from their self-performed work. This counts for roughly 15% of the total project cost, which shows that there is still a large amount of the quantities in a complete project that cannot be taken from the model for various reasons. The best way to increase this is according to DPR to bring

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<sup>58</sup> Eastman C et al., (2008)

<sup>59</sup> Eastman C et al., (2008)

<sup>60</sup> Tiwari S et al., (2009)

<sup>61</sup> Sundaram V, (2008)

<sup>62</sup> Sundaram V, (2008)

<sup>63</sup> Eastman C et al., (2008)

in a cross functional team of designers, general contractor and subcontractors early on in a project, with an incentive to collaborate and optimize the project<sup>64</sup>.

## 2.5 Project organizations

*A large part of the implementation work of BIM is predicted to require or to be dependent on the coalition structure chosen for the project. To start using BIM means that traditional processes will change. Aspects of those changes are also dependent on how the rolls and relationships between the participating individuals look like. In a Dutch research study, the national culture of collaboration is mentioned as one of the main complications for implementing BIM<sup>65</sup>.*

*Therefore it seems relevant to in this chapter present both traditional coalition structures and relatively newly developed delivery methods.*

### 2.5.1 Mediated coalitions

The organizational structure called mediated coalition is often called design-bid-build (DBB)<sup>66</sup>. DBB is the most used deliver method on the market today. In the USA about 90 % of the public buildings and 40 % of the private building projects were executed with this type of organization<sup>67</sup>. The first tendering process means to establish a contract between the client and a group of designers<sup>68</sup>. The client has besides the contract with the consultants, only one contract regarding the construction project. That is the one with the contractor<sup>69</sup>. In other countries than Sweden e.g. in the USA, the client often contracts a construction manager responsible for directing and managing the project<sup>70</sup>. The design consultant's main purpose is to create a specifications document for the entire project according to the client's requirements. The level of detail of such a document may vary between different projects and clients. Examples of requirements from the client may be number of floors, total square meters and energy efficiency. Based on those requirements the group of designers, which often consists of several different companies, produces detailed planning and tendering documents for the contractor to bid on<sup>71</sup>.

Once elected, the contractor is responsible for tendering and control of the subcontractors. It is quite common that the contractor, in his bid, has requested prices from a limited number of subcontractors. Those prices often change from the tender process to the actual writing of the contract. This is a risk management question that can either mean a higher profit for the contractor or an actual loss<sup>72</sup>.

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<sup>64</sup> Tiwari S et al., (2009)

<sup>65</sup> Straatman J, Pel W, Hendriks H, (2010)

<sup>66</sup> Winch M G, (2010)

<sup>67</sup> Eastman C et al., (2008)

<sup>68</sup> Nordstrand U, (2003)

<sup>69</sup> Nordstrand U, (2003)

<sup>70</sup> Winch M G, (2010)

<sup>71</sup> Nordstrand U, (2003)

<sup>72</sup> Söderberg J, (1998)

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The tendering process where the contractor is to be selected varies whether the client is a public or private actor. A private client has no obligation to follow any particular regulations except the general Swedish law regarding writing of contracts. A private contract is often based on a description written by the consultants in the design group. The document “Administrative Regulations” (Administrativa Föreskrifter, AF), describing general rules and guidelines for how a project should be performed has been created by the organization “The Building Contract Committee” (Byggandets Kontraktskommitté, BKK). In the year of 2000 they distributed that document since the “in-house” competence with the clients did not always comply with the demands for controlling a project. The pre-defined document AF is written so that it will suit any contractor with no regards to used delivery method. The document can be used just as it is, unlike the more general document AMA that regulates and prescribes a project in a more case-specific way<sup>73</sup>.

A public client is far more restricted since he is forced to follow European regulations and the Public Procurement Act, PPA (LOU). Depending on the total cost of the project different models for procurement is to be used. The models regulate how advertising, content in tendering documents and how the procurement itself should be performed<sup>74</sup>.

In the bidding process the most advantageous tender may not always be the one with the lowest price. Soft parameters are also considered e.g. reference objects, offered competence and project resources. They are evaluated and given an economic value and are then added to the bid. The most suitable contractor is chosen and are thereafter to be considered the main contractor in the project, by that it means he is responsible for the production of the intended building by following the documents he receive from the client. The contractor is not involved with the design of the building and is only contracted to the client and subcontractor. The communication between the designers and the contractor are supposed to go through the client, but most often there are a shorter way of communication between the contractor and designers<sup>75</sup>. In cases when an external project manager is used, he is often responsible for distribution of project information<sup>76</sup>.

In the DBB contract it is hard to take advantage of the competence and the experience of the contractor in the design phase since he is not selected yet. Though there are cases were the procurement of the contractor has been done earlier before the design phase is complete in order to receive a better feasibility in the project. In the typical case the construction documents that the contractor receives from the client are strictly applicable. Every change and fault discovered in them means extra work for the contractor and will cause an extra charge. Therefore it is of outmost importance that enough time and effort is put in the design phase for the project to function smoothly. If the contractor is procured earlier in the design phase as mentioned above, the responsibility of the construction documents’ quality have to be contracted<sup>77</sup>.

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<sup>73</sup> Byggedarna, (2007)

<sup>74</sup> Nordstrand U, (2003)

<sup>75</sup> Nordstrand U, (2003)

<sup>76</sup> Winch M G, (2010)

<sup>77</sup> Nordstrand U, (2003)

### 2.5.2 Integrated coalitions

Integrated coalitions are also known as Design Build (DB)<sup>78</sup>. Together with the DBB the design-build, here called DB contract form represents the majority of the project on today's market<sup>79</sup>. In a research paper published 2003 on the behalf of the Finnish "Road Management Organization" (Vägförvaltningen) an evaluation of delivery methods used in the Nordic countries is described. The delivery methods are evaluated regarding project cost, share of the total of all project costs and share of the total number of projects executed. The trends in the use of delivery methods were also investigated. Because of the too large differences between definitions of delivery methods only Finland and Sweden were evaluated in the same way. An important notice is that the results only reflect the projects conducted by Finnish and Swedish road management organization and not the general business<sup>80</sup>.

There is a difference in systematic use of coalition structures. Finland favour's the DB structure to a far higher extent than Sweden<sup>81</sup>. In both countries there was a clear relationship between project size and used coalition structure. Design-build was used for larger projects than DBB. Four percentage of the total number of the projects conducted by the Swedish Road Management Organization was done with DB; the corresponding number in Finland was 21 %. This is to be compared to the use in the USA where about 40% of the projects use DB and there is a clear trend of increasing use of design build coalitions<sup>82</sup>.

The largest difference between the DBB and the DB is the responsibility and the contractor's obligations towards the client. In the DB the client has only one counterpart to write a contract with. The contractor is responsible for the entire design process and the construction of the building. Therefore it is the contractor who is in charge of the procurement of the design consultants. To only have one contract to focus on can be advantageous for a less experienced client. In a strict design-build project the client specifies certain requirements, e.g. total area in square meters, architectural design or number of car parking spaces<sup>83</sup>. The requirements are then to be fulfilled by the contractor. He is therefore forced to evaluate and produce a model for the project and price it for the client. This means the contractor has to put in a lot of time and effort into a project he is not sure to get. The client gets an advantage of this since he is approached with several different design solutions and prices. Although there are also negative aspects of this since it can be hard for an inexperienced client to decide which alternative is the most advantageous in total. The documents this far is not ready for construction and are in general only conceptual.

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<sup>78</sup> Winch M G, (2010)

<sup>79</sup> Nordstrand U, (2003)

<sup>80</sup> Ranta-aho A, (2003)

<sup>81</sup> Ranta-aho A, (2003)

<sup>82</sup> Eastman C et al., (2008)

<sup>83</sup> Nordstrand U, (2003)

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The alternative found most attractive is selected, and the contractor is contracted by following the same procedure and regulations as described in the chapter above<sup>84</sup>. Even though there are many positive effects of the DB tender procedure there are also some negative aspects. For example, the bid from the contractor will and must be based on the least costly design solution that fulfils the client's requirements. It is a fact that the documents produced in the design phase before the tendering does not have to be as complete and covering as the document delivered from a client to the contractor in a DBB. The contractor in a DB only has to buy drawings and description detailed enough for him to be able to start the execution of the project. This also means that the design phase and the construction phase sometimes may run parallel instead of serial like in a DBB.

To secure the quality of the project and to ensure that life cycle costs etc. are not rising, clients sometimes require reference objects as a parameter in the tendering documents. As long as the quality of the project is not reduced, these effects of the DB might actually be a benefit worth regarding since it may reduce the costs of the entire design phase due to the lower level of detail required on the design documents<sup>85</sup>.

When selected, the contractor is responsible for the entire project. As long as the client does not make any changes in the project, the contractor alone is responsible for the outcome of the project. He is therefore forced to produce the building in an as effective way as possible since he then increases the difference between the cost for the project and the price he offered the client<sup>86</sup>. This is mentioned as a risk for the client since it is obvious that the contractor might select low quality solutions to reduce project cost. To avoid this, the client's requirement specification must be thorough and well defined<sup>87</sup>.

The contractor himself selects subcontractor. They often have full responsibility for their areas of work. That means they design their own solutions due to requirements received from the contractor. To avoid conflicts, both the contractor and his sub contractor should create requirements and demands that are possible to measure, e.g. energy consumption per month, isolation values and relative humidity in materials.

The most common scenario today is a slightly modified version of the DB where the requirements in the procurement with the contractor are more detailed than described above. The contractor then leaves a bid on a partly finished design and then takes over the responsibility for the project and the design. The roles of responsibility can be unclear in this type of contract since the requirements are partly set when the contractor takes over. Another disadvantage is that the contractor is less involved in the design phase. The positive aspects are that the client has a more uniform selection of design solutions and tenders to choose the contractor from<sup>88</sup>. As mentioned above, to reduce the risk of forcing the contractor to certain design solutions and thereby miss the benefit of different designs and design optimization, reference objects is a healthier way then pre defining the project in detail<sup>89</sup>.

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<sup>84</sup> Nordstrand U, (2003)

<sup>85</sup> Söderberg J, (1998)

<sup>86</sup> Nordstrand U, (2003)

<sup>87</sup> Söderberg J, (1998)

<sup>88</sup> Nordstrand U, (2003)

<sup>89</sup> Söderberg J, (1998)

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The production phase is quite similar in the two alternatives. The contractor is fully responsible for all communication to the client and to the subcontractor<sup>90</sup>. Before engaging the construction phase, building permits must be provided. Since it is the responsibility of the contractor to produce documents for such permitting, delays to the construction phase might be created if the processing time with the building committee is long, compared with the DB organization<sup>91</sup>.

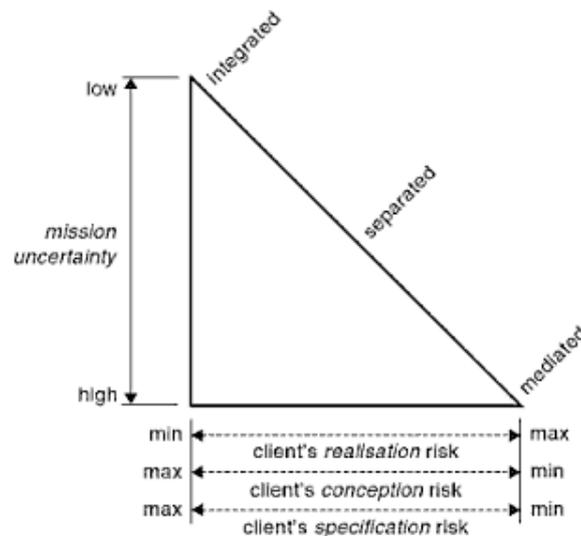


Figure 7, Client's risk dependency with delivery methods, Winch G M, 2010

### 2.5.3 Partnering

In the past years actors in the Swedish construction industry have been subjected to the public debate where the quality of projects and the over-all costs are discussed. Internally the actors also express a feeling of dissatisfaction with the ineffectiveness in construction, attitudes and low profits. Within the sector there are also concerns about the transfer of knowledge inside projects.<sup>92</sup>

The Swedish construction industry is in general described as harmonious and informal in comparison to other countries, both Anglo-Saxon and Nordic countries. The Swedish mentality and personality traits are defined by<sup>93</sup>:

- Communication apprehension
- Conflict avoidance
- Social independency
- Reluctance of displaying strong emotions
- Tendencies to search for rationality
- Practicality is considered honourable
- Puritanism, in the meaning that rules and regulations are to be followed.

<sup>90</sup> Nordstrand U, (2003)

<sup>91</sup> Söderberg J, (1998)

<sup>92</sup> Rohdin A, Rohdin Anna, "partnering in Swedish construction projects – analysis of processes and structures", Sundsvall,

<sup>93</sup> Daun Å, (1996)

- The report also mentions that there are tendencies to egalitarianism, equal thinking concerning people and a decentralization of power

The mentality characteristics described above together with the fact that informal collaboration is preferred and the way that conflicts are handled in Swedish construction industry separates us from other countries. This might be one of the reasons why partnering as a delivery method does not fit the industry in Sweden since partnering was developed according to Anglo-Saxon preferences<sup>94</sup>.

In the Anglo-Saxon parts of the world partnering was developed in the mid eighties as a reaction to the same dissatisfactions that were mentioned above regarding Sweden. Considerable research and practice have been conducted mostly in the USA<sup>95</sup>. The purpose of partnering is amongst others to create a more open and collaborative organization in a project. Along the way the word “partnering” has gained a lot of different meanings; here is how the Swedish central of nomenclature defines “partnering”:

*“Partnership is the management practice that is used between client and supplier to interact and inform each other according to the contract, in order to achieve a better common result of a project. Basic components of the partnership are founded on mutual goals, understandings about problem solving techniques and active cooperation for continuous measurable improvements”*<sup>96</sup>

(Freely translated by the author)

The traditional delivery methods are based on well-defined structures that define areas of responsibility for the different actors. Large amounts of energy are used defining what is expected of each actor inside the project. Once established, no actor has any gains of reaching outside his area of responsibility. Partnering searches for a multi-disciplinary project organization where key actors form collaborative groups to ensure that competence and experience do not vanish as a result of the described structure of boundaries between actors<sup>97</sup>.

By forming a group of all key actors including the client, collaborative goals can be defined. The requirements of the client are discussed from the different views and hopefully a consensus is achieved about the way the project should be performed and what the goals are<sup>98</sup>.

There are several studies performed that proves the effectiveness of partnering. One study where 209 projects were evaluated depending on level of integration of the project organization showed that there was a significant difference between partnering and traditional delivery methods. Among the 209 studied projects 63

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<sup>94</sup> Kadefors A, Kadefors Anna, ”Collaborative approaches in Swedish construction projects – four case studies”, Göteborg

<sup>95</sup> Rohdin A, (2002)

<sup>96</sup> Rohdin A, (2002)

<sup>97</sup> Rohdin A, (2002)

<sup>98</sup> Rohdin A, (2002)

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where typical partnering projects. The study showed that those projects' results were higher in three of four measured parameters:

- Cost
- Time schedules
- Changes and design faults

In another qualitative study where 400 projects (200 partnering projects) were evaluated it was possible to prove that in projects worth over 5 million dollars, partnering projects surpassed the traditional ones in all thirteen evaluation criteria, e.g.

- Additional costs
- Time extensions
- Number of ordered additional work
- Costs due to conflicts
- Downtime, calculated as a percentage of the total project cost.

Some actors, mostly contractors and subcontractor are not used to these collaborative ways of working and might see the required meetings and work shops as ineffective<sup>99</sup>. The parameters of project outcome mentioned above can also be used as a measurement system for evaluating the success of the cooperation and the overall project outcome<sup>100</sup>. It is of great importance that such measurable parameters are set to be able to evaluate a project from other aspects than economical. For the staff to understand what worked well, as well as where the failures came from, there have to be a more precise way to measure the level of success within the project organization<sup>101</sup>.

To be able to work collaborative in an effective organization e.g. partnering, it is of utmost importance that regulations and contracts are written in such manner that each actor is totally comfortable with his roll in the project and his area of responsibility. Procurement and tendering are normally handled in the same way as for a traditional contract. That means the regulations and the prescribed documents can be used rather unedited. The purpose of this type of project structure is to be able to work cross-sectional from start to end. To be able to share ideas, competence and experience in order to optimize design and project goals is the great advantage of partnering. These benefits are much depending on the social structure and that everybody have to chance to express their opinions in matters affecting them in a later stage<sup>102</sup>.

In an analysis of four construction projects ranging between \$2 million and \$35 million, strengthening and weakening factors were pinpointed in seven different interaction processes. One process manages the early phase when common goals are to be set. To include as many actors as possible in the decision making phase regarding the goals and to have a pre-defined plan for how to select the goals and

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<sup>99</sup> Rohdin A, Rohdin Anna, "partnering in Swedish construction projects – analysis of processes and structures", Sundsvall

<sup>100</sup> Rohdin A, (2002)

<sup>101</sup> Johansson O, (2004)

<sup>102</sup> Rohdin A, (2002)

achievements are stated to be reinforcing the partnering organization<sup>103</sup>. It is also mentioned that actors with a lower level of participation in the goal-defining phase is weakening the project structure<sup>104</sup>. Therefore it is important to choose actors with suitable attitude towards collaborative delivery methods.

Setting the project goals collaboratively may cause issues when partnering is used with public clients where the Public Procurement Act (PPA) has to be followed. To stimulate the open market and for all actors to be free to participate in the tender process, the design has to be established to some extent. This counteracts with the philosophy of partnering since many of the major decisions already are taken when the contractor is selected. It can also mean some uncertainty with the client, how detailed do the information in the tender documents have to be? Seen to the juridical aspect of the PPA, there are no obstacles for using partnering as a contract for public clients. What is important for the client is to be able to set the right requirements in the tender documents for stimulating the procurement process and later the collaboration between client and contractor/designer. To achieve this may seem hard; the contractors must have well defined information to base their tenders on, at the same time, as much as possible should be worked out within the project group. One possible way for the client to achieve both proper bids and the ability to use as much of the contractor's influence in the project group as possible is by determining the projects required functions instead of focusing on the architectural design and given technical solutions. By letting the contractor base their tenders on written requirements, as many benefits as possible can be extracted. This is due to the positive effect the collaboration in the project group between the contractor, designers and the client has<sup>105</sup>.

#### **2.5.4 Integrated Project Delivery (IPD)**

*In this chapter, a non-traditional delivery method will be presented, IPD. However, this thesis does not focus on or is meant to be an IPD-guide. IPD is currently not a common way of working in any part of the world. The reason for presenting it in this chapter is because of its strong development recently and since it can be considered as a delivery method and as an extension of building information modelling. Only aspects of the delivery method that the authors believe are of importance for the reader, to understand the result and analysis later in the report will be presented. Facts such as actual contracts available, structure of organization and suggested workflows will not be presented in detail.*

IPD is a delivery method and an organizational structure. Like partnering, the goal is to use as much of the potential of the project organization as possible. The difference between IPD and partnering is that IPD is supposed to be an even more integrated

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<sup>103</sup> Rohdin A, Rohdin Anna, "partnering in Swedish construction projects – analysis of processes and structures", Sundsvall

<sup>104</sup> Rohdin A, Rohdin Anna, "partnering in Swedish construction projects – analysis of processes and structures", Sundsvall

<sup>105</sup> Johansson O, (2004)

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structure that allows the use of new ways for communication and interaction between the actors involved. To get IPD working, all actors in the complete chain of value are supposed to be involved in the organization from the start<sup>106</sup>.

In a case study of six IPD projects in the USA the following criteria was used to define whether the projects were integrated enough to be called to use IPD<sup>107</sup>:

- Early involvement of key participants
- Shared risk and reward
- Multi-party contract
- Collaborative decision making and control
- Liability waivers among key participants
- Jointly developed and validated project goals

Key participants are here defined as the owner, architect and the builder, who signs the primary contract. Vital design consultants and subcontractors with joining agreements are also considered key participants since they too share risk and reward<sup>108</sup>.

According to UKOGC (United Kingdoms' Office of Government Commerce) results from IPD projects have been reported where as much as 2-10 % was saved depending on the level of experience from IPD with the actors. In cases where IPD has been used in a series of projects results showed that as much as 30 % of the total project cost could be saved<sup>109</sup>. These results are also found in the case study where all six of the evaluated projects met or exceeded the financial goals. One practical example mentioned several times in the case study is the flexibility of the overall project budget. To be able to re-distribute resources and money is a great benefit e.g. cleaning of the construction site can be performed by lower-wage workers during the night or the same lift can be used for several trades<sup>110</sup>.

Even if the economical benefits naturally speak for themselves in these cases, the other benefits should not be overlooked. A large portion of energy is put in the matter of increasing the overall quality of the project outcome. To be involved in an IPD contract requires that each actor accept the need for cross-sectional collaboration with all other actors. This can achieve a synergetic effect, meaning that created documents and products hold a quality and value that no individual actor could have produced<sup>111</sup>. For example when the key participants collaborate in such way that the architect is working with support from the contractor who provide actual and current unit costs and constructability inputs. Along with this, the structural engineer creates the building structure in a flexible way that allows multiple design solutions to work. That way, for example, design solutions are evaluated from an economical aspect and the number of contingencies and delaying obstacles in production are proven to decrease<sup>112</sup>.

For the client the transparency and the financial structure with "open cards" are beneficial since it not only allows him to have a better control during the project; but

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<sup>106</sup> AIA National, (2007)

<sup>107</sup> Cohen J, (2010)

<sup>108</sup> Cohen J, (2010)

<sup>109</sup> AIA National, (2007)

<sup>110</sup> Cohen J, (2010)

<sup>111</sup> AIA National, (2007)

<sup>112</sup> Cohen J, (2010)

it is also supposed to create an attitude of goodwill and mutual respect within the different project groups.

Since a lot of the total amount of work done by the design consultants is concentrated to an earlier phase than in a traditional project, they can be used for more qualitative measurements such as e.g. energy efficiency, life cycle costs or more extensive cost control. As for the contractor, the largest benefit might be the possibility to a far more effective and leaner production phase. To be able to visualize the whole project with the inputs from all leading key actors and subcontractor, already in the earliest phase will reduce the amount of faults, changes and rework<sup>113</sup>.

When blurring the boundaries between the works of professionals with long experiences from working in traditional ways, of course mixed opinions are to be expected. Some mentioned that they were able to reduce the level of detail in the design documents since the builder already knew what was supposed to be constructed and in what way. Thoughts about the contracts displayed both positive and negative feelings. The idea with the collaboration based contract or the design-build contract but with addendums regarding the collaborative aspects, was that it is not always the right way to dictate behaviour as it could have the opposite effect. In general the opinion was that as many of the vital participants as possible should be active in the project group and meetings regarding daily activities and design to gain most benefits<sup>114</sup>.

Early and intense design effort allows a higher level of prefabrication since the project is much more complete when the construction phase begins than in a traditional project. Although benefits such as cost control or scheduling etc. often are thought to be a client's tool, it is naturally also a powerful tool for the contractor. As already mentioned the design consultants' roles in an IPD project are slightly different from the traditional way of working. In an IPD project the work of the consultants are concentrated to the design phase and the early phases to a higher degree than in a traditional project, this is presented in the figure below. The time consumed for each document should be less than normal because of the support from the design team and BIM tools. Although the total time spent in the design phase will probably be longer since more attention is paid to the completeness of the construction documents than traditionally.

The increased cost of consultants are thought to be corresponded by the shortened and more effective construction phase since it is much more expensive than the design phase<sup>115</sup>.

This is also confirmed by some of the persons interviewed in the case study, one person mentions that the total amount of hours for the designer did not change, it was only redistributed. As the bidding/negotiation phase never existed, those hours along with some from the creating of the construction documents were placed in the early design. That allows, and is crucial, for the client to get the transparency and cost insight he needs to stay updated with the project. The great efforts in the early project phases also decrease the number of changes of design scopes and extra work. In all of the six projects evaluated, the number of design scope changes not made by the owner

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<sup>113</sup> AIA National, (2007)

<sup>114</sup> Cohen J, (2010)

<sup>115</sup> AIA National, (2007)

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were very few or none<sup>116</sup>. For the contractor the same fact applies, or as Tocci Construction's Jack Short put it when discussing their early involvement that decreased their risk by increasing the certainty about what is to be built<sup>117</sup>:

“As builders we're used to doing very well on seven projects and getting killed on three. We'd much rather make our client happy and earn a reasonable profit on all ten.”

As mentioned above, the transparency of the project organization is vital. Risk, reward and responsibility are components that are shared amongst the team members. Therefore there must be a well-defined structure for how information is to be distributed to create an open atmosphere that allows team members to trust each other. For this, building information modelling is an excellent tool. To create such knowledge centres and databases of information allows each actor to participate in the creation and use of design plans, scheduling, and cost control by model based cost estimations and continuous follow-ups. Effort should be invested early in the project about how the model should be used and define areas of responsibility, levels of detail and expected deliveries<sup>118</sup>.

In a large healthcare project it was reported that the cost engineers spent three months during design to plan and structure the model based cost estimate together with all of the disciplines of the design team. After that they could produce a fully updated cost estimate in just two days. This was done every two weeks to keep track of the target cost of the project<sup>119</sup>.

In another case study the importance of interoperability between different software was highlighted. The file formats and software versions were not always compatible and this caused collaboration obstacles within the project groups<sup>120</sup>.

The terminology in today's industry with expressions such as BIM, lean construction, IPD etc. have caused confusion. IPD is to be seen as the entire way to conduct a project, including all processes. To achieve an effective IPD project, a set of tools is necessary; such tools might be BIM and lean construction<sup>121</sup>.

The more detailed the planning and defined structure of the project is, the less risk of disputes and legal issues in the later phases exists. To create ways to avoid and solve disputes among the team members are important in every project. Early, before the actual project is engaged, a side-function of the project organization should be formed as the “Decision Making Body”. Their only interest lies with the well being of the project; they should therefore consist of a well-balanced mixture of the participants of the project<sup>122</sup>.

The IPD organization should preferably consist of at least two defined groups of actors where each group has a pre-defined area of responsibility. The primary participants may be the group with representatives from the client, architect and the

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<sup>116</sup> Cohen J, (2010)

<sup>117</sup> Cohen J, (2010)

<sup>118</sup> AIA National, (2007)

<sup>119</sup> Tiwari S et al., (2009)

<sup>120</sup> Cohen J, (2010)

<sup>121</sup> Cohen J, (2010)

<sup>122</sup> AIA National, (2007)

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contractor. It is useful to have a more active group with more participants involved in the daily planning and production. The key supporting participants form this group; representatives from all active actors, e.g. architect, contractor and design consultants. The roles of these two formal groups may vary depending on the nature and specific need of each project. In general the primary participants are responsible for overall decisions concerning project financials and major design options. The second group, the key supporting participants, has a more continuous and active role in the project. They are persons with a daily involvement with more discrete tasks of both basic and advanced nature<sup>123</sup>. In practice the number and structure of project groups are created with regards to project nature and individuals involved. Two or three groups have been used in all cases with different set-ups and tasks. A structure including three groups where the second level group is in charge of decisions that cannot be taken in the third level group where daily activities are discussed. The first level often consists of senior participants and their task is to settle disagreements and disputes arisen among the lower levels<sup>124</sup>.

The set-up of actors in the different groups are not always consistent, they may very well vary with the nature of the project. For example, a structural engineer probably would not be involved with the primary participants in a project concerning a smaller office or an apartment building. But in a bridge-project, his role is different since he is involved with all major decisions regarding the design of the bridge. Therefore it might be appropriate to include him with the primary participants.

The decision making body in an IPD project should contain members that have the right ambition and the required level of competence for quick decision making. The group has the final saying in most questions and is to be considered omnipotent<sup>125</sup>. In many cases liability waivers are included with the multi-party contract or written separately. The waivers may have different meanings, from “no-sue” formulations, perhaps with exception for fraud and gross negligence, to agreements that arbitration by a third-party should be used when conflicts arise. In most cases the typical insurances was still demanded from each actor<sup>126</sup>.

At the use of new contracts and structures in the project organization, there will be questions and uncertainties regarding legal aspects, who is responsible for what, how should the contracts be drafted, etc. In traditional projects, contracts are written to define boundaries between project participants. In IPD collaboration, boundaries are not wanted in the same way, the boundaries should be more fluidly constructed. The designers are working close with the contractor, which could mean that the contractor is responsible for mistakes done during the design phase and the other way around. Today, a lot of effort is put into the writing of general contracts for entering IPD and other collaborative project structures. The American Institute of Architects (AIA National) for example is one such organization. Still, since precedents are missing, contracts must be written to define the roles of participants and how the relations between actors should look like in each unique project. The areas of work are not to be described in the contract since that limits the chance of gaining that synergetic effect possible from the collaboration and team spirit within the group. This does not

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<sup>123</sup> AIA National, (2007)

<sup>124</sup> Cohen J, (2010)

<sup>125</sup> AIA National, (2007)

<sup>126</sup> Cohen J, (2010)

mean that the roles of responsibility have to be unclear; on the contrary, the responsibility and delivery expected from each actor should be clearly defined to make sure that participants are comfortable in their role in the project organization.

### 2.5.5 Collaboration based delivery methods in Sweden

*A lot of focus in this report, both in the chapters above and in the result and analysis will be on delivery methods and organizational issues where the level of integration and collaboration are vital parts. To be able to compare and to understand organizational methods and traditions in the countries evaluated during this study the authors believe that a chapter about the Swedish mentality and how collaboration works in the Swedish industry of construction is essential.*

Due to cultural and historical heritage, roles and responsibilities of actors differ between countries, even within countries in the same geographic area. This of course affects the way people are working together and how informal and formal relations are structured<sup>127</sup>. As mentioned in the chapter about partnering as a delivery method the Swedish mentality is considered to contain a number of certain personality traits. The way the industry in Sweden today collaborates and functions have been studied and analysed from an historical perspective. The strong influence of the centralised state control together with the lack of strong professional identities have contributed to form an industry where the type of collaboration in many ways separates Sweden from other countries<sup>128</sup>. The Swedish industry's heritage originates from the merging of the older guild system where experience and knowledge was transmitted tacitly on the construction site, and the military engineering with clearly defined roles and articulated organizations<sup>129</sup>.

This together with the Swedish mentality has evolved into an industry with a considerably low level of open conflicts in comparison to other countries, even to the Nordic ones<sup>130</sup>. Even if conflicts are considered fewer than in other countries, they are seen as a factor causing inefficiency and adversarial roles in the construction sector<sup>131</sup>.

It is not only the level of conflicts that differs the Swedish industry from others. There are also considerable differences in how the decision-making process function. In a comparative study including Sweden and Great Britain it was concluded that the Swedish decision-making includes more contributing persons than in the UK. People are more likely to have strong opinions about the outcome of the decision in Sweden, but on the other hand, in the UK, strongly opposing views are more often expressed<sup>132</sup>. In Britain it is more likely that one of the alternatives presented in its original form is finally chosen. In Sweden there is a strong and solid culture of

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<sup>127</sup> Bröchner J, Josephson P-E, Kadefors A, (2002)

<sup>128</sup> Bröchner J, Josephson P-E, Kadefors A, (2002)

<sup>129</sup> Bröchner J, Josephson P-E, Kadefors A, (2002)

<sup>130</sup> Kadefors A, Kadefors Anna, "Collaborative approaches in Swedish construction projects – four case studies", Göteborg,

<sup>131</sup> Björkman, Kadefors, Ranhem, (1999)

<sup>132</sup> Axelsson R et al., (1991),

compromising, therefore the final choice is often a mixture of the alternatives presented. This is also known in most decision-making groups, why everyone counts on being forced to compromise to achieve progress. One interesting discovery in the study showed that the time from the initial idea to the start of the decision process is about twice as long in Sweden as in the UK. Other countries such as Canada and the Netherlands also showed the same results as the UK in the matter. The decision process itself is also almost twice as time-consuming in Sweden. The report mentions that Sweden at the time for the study had taken many decisions regarding large technological investments, which might have affected the results. The authors of the report still consider the results to be valid<sup>133</sup>. The study referred to above applies for decision-making in general and not only in the construction sector.

When researching this question within the building industry a different image appears than the one in the comparative research. The Swedish contractors are described to have a “cowboy-mentality” where “acting rather than asking” is rewarded<sup>134</sup>. Concretely this is also seen at the construction site where the design consultants seldom are consulted. Quick decisions are preferred, sometimes at the cost of long-term qualities<sup>135</sup>.

One of the larger differences in the comparative study about decision-making processes is the composition of the groups and the search for information. In Sweden it is more likely that the persons contributing to the discussion also delivers information about the decision and the task. More people contribute with information, which prolongs the process. This suggests the meaning of rationality among Swedish managers. It is believed that more information creates more secure decision-making. It is also stated that more protests occur in the decision arena in Sweden; the protests do not however affect the time for the decision-process<sup>136</sup>.

Partnering as a delivery method has not gained the same attention in Sweden as it has in the Anglo-Saxon and the Nordic countries<sup>137</sup>. In Sweden there are two main actors, the client and the contractor. Between these two actors, conflicts are often solved within the informal collaboration.

Instead of pronounced guidelines for collaboration in construction projects, the Swedish model appears to be based on the design-build delivery method where a fixed price is the foundation. The tendering documents are often rather specified, in accordance with the description of the chapter about the design-build contract<sup>138</sup>. Hand in hand with the statement about the “cowboy-mentality” in the projects goes the allegation that competent people on site should establish the relations between project participants, and that the bureaucracy following explicit planning is

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<sup>133</sup> Axelsson R et al., (1991),

<sup>134</sup> Hellgren, Stjernberg, (1995)

<sup>135</sup> Kadefors A, Kadefors Anna, ”Collaborative approaches in Swedish construction projects – four case studies”, Göteborg

<sup>136</sup> Axelsson R et al., (1991)

<sup>137</sup> Kadefors A, Kadefors Anna, ”Collaborative approaches in Swedish construction projects – four case studies”, Göteborg

<sup>138</sup> Kadefors A, Kadefors Anna, ”Collaborative approaches in Swedish construction projects – four case studies”, Göteborg

considered ineffective<sup>139</sup>. The spontaneous relations on site may be seen as effective, but they are also a risk since the loyalty between individuals may overtake the loyalty towards the project or the employer<sup>140</sup>.

So instead of the partnering contract, “trust-based contracts” or “negotiated-contracts” are used where the contractor often is a long-term partner. This requires that the project is somewhat standardized and possible to predict regarding project cost etc. Larger, more complex project with schedules and timetables not suitable for traditional delivery methods have been conducted in a more pronounced partnering way, and the interest are increasing.

## 2.6 Drivers and business models for design consultants

*Since this thesis is written in cooperation with a design consultant company. The authors’ main focus regarding the adoption of building information modelling will therefore lie with the designers. This chapter will discuss the financial processes, both traditional and new, that exist in the construction industry. The purpose of this is to create a foundation to base assumptions on regarding the ways for designers to create profit, economical or other, out of BIM and to evaluate IF there are any profit to be made.*

### 2.6.1 The implementation of BIM for design consultants

It is clear that the scope of work for all design consultants will be affected and probably dramatically changed with the implementation of BIM. Or as stated in “BIM Handbook, A guide to Building Information Modelling”:

*“Building Information Modelling can be considered an epochal transition in design practice. Unlike CADD, which primarily automates aspects of traditional drawing production, BIM is a paradigm change.”<sup>141</sup>*

One of the main problems in the transition between traditional scopes of work and new processes is the measurability of benefits. For a contractor or a client the visualization tools and the possibility to increase the productivity in construction create clear economical incentives for implementing BIM. For design companies the benefits are not that easy to define and the profit to quantify<sup>142</sup>. Although it is a fact that construction costs are merely a small part of the life cycle cost of a project, much focus tend to lie with productivity during construction<sup>143</sup>.

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<sup>139</sup> Kadefors A, Kadefors Anna, ”Collaborative approaches in Swedish construction projects – four case studies”, Göteborg

<sup>140</sup> Kadefors A, Kadefors Anna, ”Collaborative approaches in Swedish construction projects – four case studies”, Göteborg

<sup>141</sup> Eastman C et al., (2008)

<sup>142</sup> Eastman C et al., (2008)

<sup>143</sup>The Office of Government Commerce, (2010)

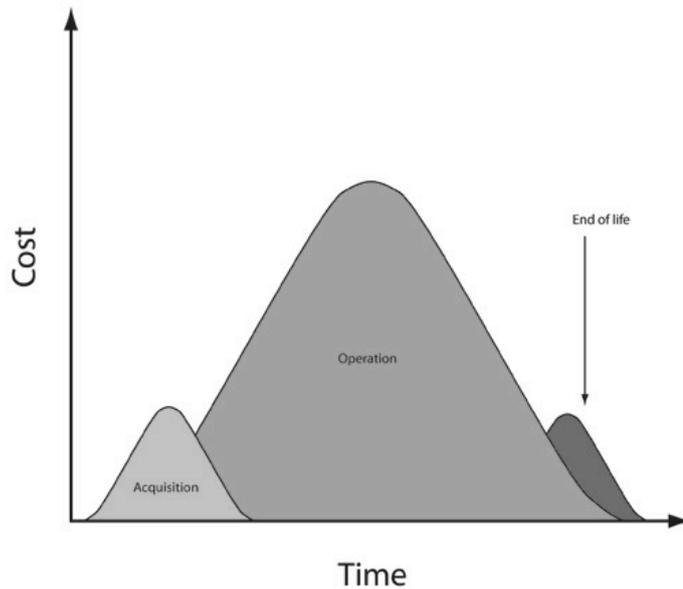


Figure 8, Life cycle costs<sup>144</sup>

As seen in the figure above, design services affecting the life cycle costs of the project have larger potential due to client finances than services increasing productivity. Design quality can therefore be considered long lasting. The general benefits for the design consultant might be considered as the ability to perform analyses and design optimization, which increases the value and quality in their product. The problem still exists with the trouble to quantify intangible outcomes. The challenge for the design companies will be how to quantify and charge the increased level of quality<sup>145</sup>.

When the market becomes aware of the benefits with BIM, the pressure on designers will increase. The implementation phase will not be free, staff must be educated, and licenses for software must be purchased. The question has to be asked if the investment in these matters will be worthwhile. Today the design companies who have transitioned to work with BIM find the largest reward within the own organization to be the increased productivity with construction documents<sup>146</sup>.

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<sup>144</sup> oge.gov.uk

<sup>145</sup> Eastman C et al., (2008)

<sup>146</sup> Eastman C et al., (2008)

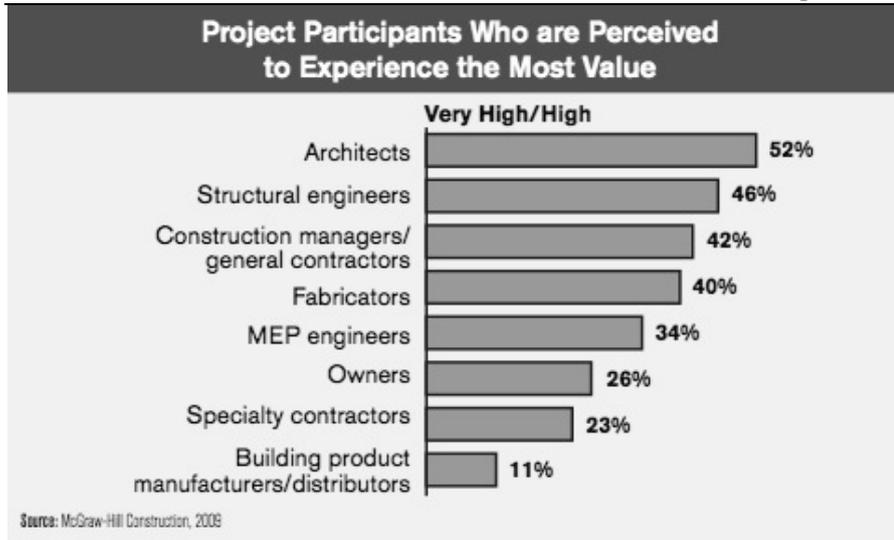


Figure 9, Percieved BIM-value among project participants, source McGraw-Hill Construction 2009

According to the McGraw-Hill Construction Small Market Report consultants are among those who have the largest benefits of BIM<sup>147</sup>. This combined with the fact that BIM allows for a more effective design work makes it important which form of compensation the consultants use.

An integrated project organization which is recommended to gain most benefits of BIM requires adjustments to today's contracts and ways to set fees<sup>148</sup>.

In Sweden compensation for consultants normally is charged by the hour<sup>149</sup>. This is also applicable abroad<sup>150</sup>. Since the opinion is that BIM reduces the time consumed by drafting it means that there is a challenge for many consultants as they feel that they will have to acquire more projects to be able to charge an equal amount of hours.

<sup>147</sup> McGraw-Hill Construction Smart Market Report, (2009)

<sup>148</sup> Eastman C et al., (2008)

<sup>149</sup> Liman Lars-Otto, (2007)

<sup>150</sup> Winch M G, (2010)

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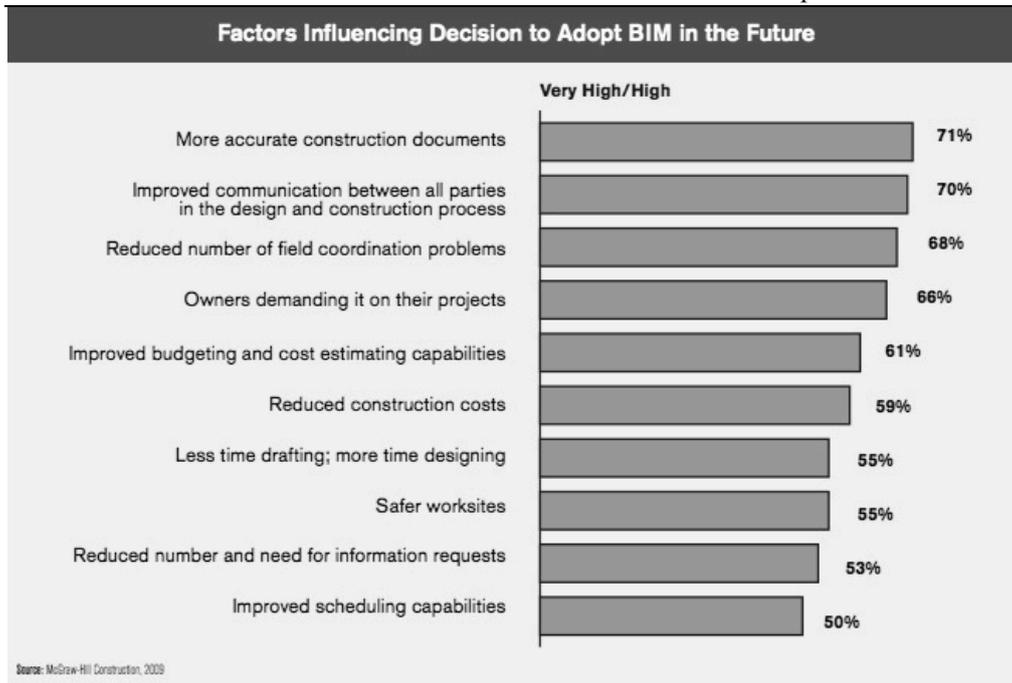


Figure 10, Factors for BIM adoption, McGraw-Hill Construction

### 2.6.2 Procurement methods of design consultants

As already mentioned, the ways for tendering and compensating architects, structural engineers and MEP-designers will have an impact on the implementation of BIM. Today three general strategies for tendering suppliers (in this case designers) exist:

- Appointment
- Concours
- Competitive tendering

#### *Appointment*

This is the most common way of procuring design services in most countries. In the earliest phase of the project the level of information required producing tendering documents might not be available. The designer company is then chosen based on their previous achievements and reputation. The client can of course involve several different companies in the discussion, but the process is not as transparent as in competitive tendering. Using appointment means that the cost for search and selection will be low and that trusting relations can be established with design companies. To only use a small number of suppliers on long-term basis means lower competitions, which might cause a decreased level of productivity or increased pricing. There is also a danger in getting into too deep relations with suppliers since personal relations between actors can lead to corruption<sup>151</sup>.

<sup>151</sup> Winch M G, (2010)

*Concurs*

In similar with appointment, concurs are widely used for procuring design services or project management resources. The selection is here based on the quality of the design documents. A competition is advertised with the client's initial requirements. This method is often used when the final result is a building or plant, which are supposed to have a symbolic value as well. The design solutions are then more ambitious and the paramount aspects of choice are other than the project cost.

The use of concurs allows involvement from actors normally not in the close-by network. To have a jury evaluating the solutions contributed means that other design professionals can leave their opinions. On the other hand, the process is rather expensive, especially if the contributing designers are reimbursed. A danger also lies with the fact that the aesthetics of the project can be prioritized at the expense of other aspects<sup>152</sup>.

*Competitive tendering*

This is the most used procuring process used when choosing the supplier of construction services, e.g. the contractor. The client establishes tendering documents with various levels of detail and descriptions. Then suppliers create cost estimates, which are the base for their tenders. There are regulations for how competitive tendering must be handled when the client is a public actor. This is described in the chapter about mediated delivery methods. The competition keeps the prices low and the possibility for actors to contribute decreases the risk for cartels. The method can be considered as costly, as much as 10 % of the turnover of a contractor is used for tendering according to a British KPMG study. All actors in the competition are basing their bids on the same information, this along with the fact that the price is by far the most important selection criteria, creates a situation where the winner often has made a miscalculation or left something out. This may lead to a situation in the construction phase where the contractor has to search for changes and additional work in a non-healthy way to compensate for the miscalculation<sup>153</sup>.

### **2.6.3 Contracts for compensation**

*Fee-based contracts*

When the types of service and resources needed are known, but the extent of the work is unclear, fee-based contracts are often used. This means that fee-based contracts often are used in high-uncertainty projects and situations. Typically, design services such as architects and engineers are procured in some sort of fee-based contract. There are basically two different fee-based contracts, cost-reimbursable and a percentage fee. With the cost-reimbursable contract the supplier is compensated due to the time spent in the project according to a set hourly rate<sup>154</sup>. This way the client does not have control over the final project cost<sup>155</sup>. A more common way of contracting outside Sweden is for the designer to get compensated by a percentage of

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<sup>152</sup> Winch M G, (2010)

<sup>153</sup> Winch M G, (2010)

<sup>154</sup> Winch M G, (2010)

<sup>155</sup> Söderberg J, (1998)

the cost of the site-work. This is often managed by national regulations, e.g. The German federal Honorarordnung für Architekten und Ingenieure (HOAI) where nine different project phases are identified and a pre-set percentage of each phase are decided. Additional services are however often charged by the hour<sup>156</sup>.

A problem with fee-based contracts is the situation where the supplier can increase his profit by generating more work. Generally fee-based contracts are the ones with the least incentive for an economical production<sup>157</sup>.

#### *Fixed-price contracts*

To be able to set a fixed price for a service or product, a larger amount of information is required. Therefore fixed-price contracts can be used in situations when the uncertainty is lower than with fee-based contracts.

The contract is either a lump-sum price based on the information available at the point of negotiation or an after-measurement where the actual price is known. When procuring the construction services done by the contractor this type of contract is most often used. As with the fee-based contracts, there is a moral danger in fixed-price contracts. A high project price favours the supplier, since the profit increases with higher price and lower cost<sup>158</sup>.

This type of contract where the supplier bases his tender on the client's information means that the level of information has to be relatively high. The more uncertainty there is in the tendering documents the larger is the amount the supplier has to add to his bid to cope with eventualities later on in the project<sup>159</sup>.

#### *Incentive contracts*

Incentive contracts can differ greatly in shape and function, but they are most often based on a mixture of fee-based contracts and a fixed price. The main reason to use them is to unite the actors involved through gain sharing during the whole project.

Often the contractor leaves a target price, which is to be considered a fixed price. The incentive consists in the chance for the contractor to take part as a percentage of the cost savings if he manages to end up below the target price. Should he on the other hand exceed the target price he have to accept to pay a percentage of that difference. It is however not always this simple as described above; to manage the risks of the client and the contractor a "guaranteed maximum price" (GMP) is used to ensure that the client's risk it not unlimited<sup>160</sup>. Using a GMP often means that the price will be higher than corresponding fixed price because of the risk the supplier engages. But the contract also stipulates collaboration between the client and supplier for economical gains<sup>161</sup>. For the contractor there can also be a "guaranteed maximum liability" (GML), this limits his part in the exceeding cost of the project<sup>162</sup>.

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<sup>156</sup> Winch M G, (2010)

<sup>157</sup> Söderberg J, (1998)

<sup>158</sup> Winch M G, (2010)

<sup>159</sup> Söderberg J, (1998)

<sup>160</sup> Winch M G, (2010)

<sup>161</sup> Söderberg J, (1998)

<sup>162</sup> Winch M G, (2010)

*Choosing an appropriate contract type*

The suitable type of contract for a given situation is controlled by the client's will to distribute the risk of the project.



Figure 11, Responsibilities with different contracts, Winch G M, 2010

The fixed-price contract moves the majority of the risk to the supplier, even if changes or eventualities beyond the supplier's control still are the client's responsibility. Fee-based contracts shifts more risk to the client. In the cost-reimbursable contract the supplier can charge a number of hours, which is very hard for the client to audit. Therefore this type of contract requires rigorous time-sheet management. The percentage-fee contract is safer to the client since the supplier is not able to influence the percentage of the fee.

The incentive-based contract distributes the project risk more equally between the client and the supplier. With a GML the risk is shifted towards the client and the opposite with a GMP<sup>163</sup>.

<sup>163</sup> Winch M G, (2010)

## 2.7 Legislations in Swedish building projects

*The legal responsibility for Swedish building consultants is stated in ABK09 (Allmänna Bestämmelser för konsultuppdrag inom arkitekt- och ingenjörsvetenskap av år 2009). ABK09 replaced the older ABK96, which was valid until December 2009. This chapter will explain the mayor changes made in ABK09 and how the current rules will affect the use of virtual construction in building projects.*

### 2.7.1 ABK09

ABK09 defines the rules that should be followed in a general contract between a building consultant and other actors e.g. clients and contractors. However these rules can be changed if another agreement is made between the parties<sup>164</sup>. ABK09 describes in which order the documents are legally binding:

1. Contract
2. Changes made to ABK09 which appear in a special compilation
3. ABK09
4. The order
5. The order confirmation
6. Tender
7. Specifications
8. Other documents<sup>165</sup>

ABK09 also regulates who should be responsible for documenting agreements. When an agreement is made between the consultant and another party it is the consultant who has the responsibility to document, that which has been agreed. This includes the extent of the assignment, the quality level of the object as well as the level of detail. It should also be decided which file format that should be used for the delivered documents. The consultant is furthermore responsible to raise questions about how and for what the delivered material should be used and how the archiving should be handled. If nothing is written about the use of the documents, the client is permitted to use these for the intended purpose of the project<sup>166</sup>.

It is no longer mandatory for the consultant to have an archive with old projects. This change has been made possible since the client now is allowed to make his own copies of the project material. If the client lacks the capacity for archiving it might be appropriate for the consultant to do this. It should then be agreed on which files that should be archived, how this should be done and for how long. ABK09 also states that if there is conflicting information in the specifications, the consultant should calculate his tender on the information that entails the lowest cost for him<sup>167</sup>.

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<sup>164</sup> Liman L-O, Lundenmark L, (2010)

<sup>165</sup> Svensk Byggtjänst och Byggandets kontraktskommitté AB, (2009)

<sup>166</sup> Liman L-O, Lundenmark L, (2010)

<sup>167</sup> Liman L-O, Lundenmark L, (2010)

### 2.7.2 Responsibility

ABK09 has a chapter describing how the responsibility for the consultant should be handled. In general ABK09 states that if the client has showed that damage has occurred and made clear that it is likely that the consultant is responsible it is up to the consultant to prove the opposite. However to be able to make a claim at least three conditions have to be met.

1. There must have been a damage. The damage should be expressed in money.
2. There has to be causation between the error and the damage.
3. The consultant must have caused the damage through negligence<sup>168</sup>.

### 2.7.3 Legal right of documents

A frequently discussed subject when talking about the legal aspects of BIM is the legal right of the design documents. As stated in earlier chapters the client is allowed to use the building documents for the intended purpose of the project. To avoid misunderstandings a comment to ABK09 mentions that it is of great importance that the actors make clear and agree on what the exact purpose of the project is<sup>169</sup>.

The client is also in general allowed to use specific solutions from the project in other tasks. However if the documents are protected by immaterial regulations, these rules have to be followed. Since it is common that both architectural and structural drawings are protected in one or another way this most likely means that the consultant's admittance is required in most of these cases. Since the immaterial regulations are in general dispositive meaning that they can be ruled out through an agreement, the contract will always be the document of greater importance in these matters<sup>170</sup>.

With the use of BIM the interest from the owner for using the produced digital files should increase. Instead of only using the files during the construction phase the documents can now also be used for facility management during the whole lifecycle of the building. An important legal aspect of this is that there is nothing stated in ABK09 about who is the legal owner of the database. Because of this the Swedish organization OpenBim has developed a model agreement ("Avtal för digitala leveranser 2010") specifically for BIM projects. The form covers all potential aspects regarding a BIM project and can be a helpful tool in these matters<sup>171</sup>.

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<sup>168</sup> Liman L-O, Lundenmark L, (2010)

<sup>169</sup> Svensk Byggtjänst och Byggandets kontraktskommitté AB, (2009)

<sup>170</sup> Liman L-O, Lundenmark L, (2010)

<sup>171</sup> Nilsson G, (2010)



## 3 Results of national study

### 3.1 Interviews within Tyréns AB

*In this part of the results the information received from the interviews performed with employees at Tyréns AB will be presented. A total of seven interviews were conducted with persons involved in different business sectors such as project management, structural engineering and information management.*

#### 3.1.1 Brief presentation of Tyréns AB

Tyréns is one of Sweden's leading consulting companies in urban and rural planning. They provide client-based services in the areas of infrastructure and urban development, building design, as well as the real estate sector. Their operation is nationwide and organized into four regions, all with full access to every one of the other areas of competence. Since being founded in 1942, they have developed into a group of companies employing just over 1000 co-workers in more than 20 offices around the country. Tyréns constitute a driving force in research and development, continuously working in close co-operation with Swedish universities and colleges. Their goal is to create better communities for people<sup>172</sup>.

#### 3.1.2 Cost estimates

Today Tyréns are working on a national basis with the implementation of BIM within the organization according to a specified development program. 3D drafting is performed in several projects on a daily basis. Some pilots have been conducted in the past years with model based cost estimations. However the results were not entirely positive and e.g. the software used to connect the model to the estimate were perceived as complex and the profits were hard to explain to the client. Nevertheless quantities have been extracted from the model in a rather large number of projects with good results. The greatest benefits from BIM today, is considered by most interviewees to be the increased quality in visualization and the use of clash controls. At the moment it is usually the design consultants who have to introduce BIM to the clients, even though the contractor is regarded to have the largest benefits. However some of the respondents state that this is about to change and that especially the larger contractors are using BIM frequently. A few interviewees pointed out the importance of which of the actors who took initiative to use BIM. If the client did, everybody had to adapt and acknowledge this new way of working. Although the danger of excluding the smaller companies with less resources from the market competition due to requirements of advanced software and expensive development costs is pointed out.

All the interviewees were interested in the use of model based cost estimations and a more iterative way of designing where design solutions could be evaluated from an economical aspect.

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<sup>172</sup> tyrens.se

However there are some obstacles to achieve this. One problem that is mentioned is that several models have to be modelled which will take much more time for the consultants and might be hard to get compensated for.

There also seems to be a lack of understanding and knowledge among estimators today, this is however considered a transitory issue since the development is moving fast within the area. One difficulty that is mentioned about model based cost estimation in the early phases where perhaps several different models would be evaluated, is the lack of information from the subcontractor. Their prices will change due to the change in design, sometimes in a way the general contractor cannot predict. One of the structural engineers interviewed stated that they frequently are asked to create flexible structural systems that will allow for more design changes later on in the design phase without changing the framework of the building. This is an important feature when evaluating different design solutions.

### **3.1.3 Organizations**

The interviewees have a very similar way of reasoning around the most preferred organization in a BIM project. To gain the most, actors must own as much of the value chain as possible and own their own process. Almost everybody is considering the contractor to have the largest benefits at the moment from both BIM in general and the use of model based cost estimations. All the interviewees believe the DB organization to be best suited for BIM use, since it means that the experience and information from the contractor can be used for design efficiency. Another reason for DB to be well suited for BIM use is that the contractor then has a large part of the value chain. It also means that requirements for the BIM use can be established between the contractor and designers directly. A rather large percentage of the interviewees mention that BIM probably will not create any economical benefits for the client when using DB since the contractor is likely to use BIM to increase his profit by reducing his costs but not the project price.

Working in some form of collaborate project organization is attractive to the majority of the interviewed persons. Some form of partnering, formal or informal should together with an incentive for all the key actors be the most beneficial delivery method for BIM. From their own experience two persons mentioned that the practical use of this collaborative way of working might not be as advantageous as believed. The required transparency in project financials is very hard to achieve. Actors find it difficult to abandon the traditional thinking of boundaries, where everyone searches to gain the most for themselves.

In the projects where model based cost estimations have been used a need for a transition in work for the estimator has been discovered. In the traditional way he enters rather late in the design phase, typically when the contractor is procured. To get the use of cost estimations from the model to work, the estimator has to be present right from the start, creating the structure of the estimation and then evaluating the given design solutions. This has been met with some resistance from the estimators because of the large difference towards the traditional scope of work.

### 3.1.4 Business models

All the persons interviewed acknowledge that there must be a clearly defined business model for all actors in the project. The gains for the contractor are rather clear and well known. It currently seems, as if it is hard for the consultants to see any benefits for themselves, using BIM.

The general opinion is that the time for creating descriptions and documents will decrease. It is also believed that the overall quality will increase in those documents. This in combination with the lack of measurable benefits for e.g. a client makes it hard to convince the client of any benefits worth paying for, creating a situation where the designers have to reduce their price in each project since they charge by the hour. This has caused a problem in the market since the consultants are reluctant to make the necessary investments in technology and proper training of the staff.

When discussing specific work with cost estimations and quantity takeoffs, problem also crystallizes. The major issue is that no one is ready to pay for the services or improvements that these features bring. There are some who mentions that this might be a maturity problem and that it will vanish as the level of awareness rise among clients. For the consultants today, building a model and delivering quantities and cost estimations cannot be compensated only by the normal charge per hour since it means that the responsibility is moved from the contractor to the consultant.

For a design company today the most beneficial scope would be if they could handle a larger portion of the project and integrate the cost estimation work within their own organization with the project managers.

New possible business models are discussed widely and the one that seems most interesting is to change the way to charge the client/contractor. If a lump-sum contract were used, the consultants would be forced to work in an as effective way as possible to maintain or increase their profit. To implement BIM into their scope of work could be a tool for this. However, a few persons mentions that it is currently very difficult to estimate the extent of a project since the limitations and the use of BIM often is vaguely defined and no great experience in drafting really exists.

Together with new organizational ideas, new business approaches follows. To be able to work in a collaborative way where the key participants are jointly involved with an incentive based on project outcome seems advantageous to almost everybody. Although there are practical complications to such a project structure mentioned in the chapter above.

The most frequently mentioned way to create more value in the design consultant's work is the possibility to create a set of new services with related to BIM e.g:

- Clash controls
- Quantity takeoffs
- Simulations like acoustic, energy or constructability
- Project management where consultants are using BIM to streamline the project
- Information distribution through a Project Information Officer

These are all services mentioned during the interviews. Some are already used on regular basis, e.g. clash control and the PIO service. An interesting comment regarding clash controls performed by consultants were when the business ethics were brought into discussion. It could be seen as though clash control should be seen as self-control of the quality of the own work and not a service towards the client. This because of the fact that the client ordered functional documents and is expected to get

it. However by delivering a clash control basically what you are saying is that “we did some errors while designing the building, but for an additional fee we could remove most of them”.

### **3.1.5 Roles of responsibility**

The question about whether the roles of responsibility would change or not and in that case how they will change is clearly an important area of interest. It was brought up during all interviews as a critical topic, even though the opinions were slightly split. The majority of the persons in the study mention that there are problems, particularly regarding quantity takeoffs. One opinion is that the situation will not change very much from the current state. Companies who are specialized in quantity takeoffs seldom take economical responsibility for the delivered quantities. Even if they do, explanations as “ we did not receive the correct information” or “the information sent to us has been changed” is not uncommon which have resulted in the fact that contractors seldom proceed with claiming compensation for miscalculated quantities. Those who doubt that the roles will remain as they currently are, point out that the responsibility for the quantities lies with the one who makes the quantity takeoffs. Traditionally the estimator at the contractor takes over the responsibility from the designer. If the consultants now start to perform these tasks themselves, the quantities delivered are their responsibility. Especially in the situation where someone else drafts the model or perhaps parts of the model it becomes a large risk to sell the quantities.

The client or the contractor is not ready to pay for this kind of service and shift of responsibility.

A few persons mention that the problem might not be the actual roles of responsibility itself but merely the uncertainty of it. Clear contracting should solve this.

## **3.2 National Interviews**

*This section of the results will present the information received from ten interviews with Swedish contractors, technical consultants and clients. Six of these interviews are made with major contractors; three are made with consultants and one with a large Swedish client.*

### **3.2.1 Cost estimates**

#### *Contractors*

All the participating contractors were using BIM as a tool in production, some more than others.

Typically, BIM was being used for visualization and clash controls but some contractors were using model based quantity takeoffs in the daily work. The quantities were then primarily used for tendering.

The connection to cost estimates have been tried in pilot projects with good results but is not being used to any great extent. One contractor believed that the benefits of using model based cost estimates was not that great for contractors.

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All the contractors could see several benefits of using BIM. These benefits were often large enough for the contractor to motivate making an own 3D model if only 2D material was delivered from the designers. To save this time some contractors were requiring 3D models from consultants in all of their DB projects.

The largest benefits from quantity takeoffs and cost estimations were regarded to be more accurate quantities in less time, better understanding of the economical effect of changes and better visualization/traceability of quantities.

To be able to use model based cost estimations in an efficient way it is important to get the contractor involved early in the design phase so that the model can be created in an accurate way. This was mentioned to be one of the reasons why cost estimations were not used that much at the moment. Another reason was that early estimations require large cost databases since the model is not detailed enough at that stage. One contractor stated that he believed the use of model based quantities and cost estimates to be used mainly by external companies that already perform quantity takeoffs. They have large databases with the contractor's recipes and can use existing material to link quantities to cost management software.

All contractors agreed that they were usually the driving part in BIM implementation. However clients were starting to make more demands of BIM, a fact that would make it easier for the contractor to use the model in e.g. DBB projects. Nevertheless one contractor argued that more demands from the clients was not entirely positive, since the demands could be made to static and only based on a few successful projects. That would reduce the possibilities for a good collaboration between the contractor and the client.

#### *Design consultants*

The general level of BIM use for the consultants interviewed, was mainly 3D modelling and in some projects clash detections. Pilot projects on model based quantity takeoffs and cost estimates had been conducted with good results although one consultant described some problems with the interoperability between the quantity takeoff tool and the drawing application. Furthermore the estimator lacked some competence in using these tools as well. The quantities extracted from the model had mainly been used as a reference number to make the contractor's bids more uniformed and not as legal binding quantities. Extracting quantities from the model was mainly seen as an extra service to the client and nothing that could be charged a lot of money for.

All the consultants interviewed saw several benefits of starting to use BIM. Drawings could probably be produced faster when the knowledge in the new BIM applications increased and errors could be found earlier through e.g. clash detections. This would increase the general quality of the consultants work. Most consultants believed that the estimator's role would be more important in BIM projects since various alternative designs could be evaluated economically in the early stages. The major concern for technical consultants was instead to be able to get paid for this higher quality. For contractors this is easier since they often own the whole process themselves.

This issue has made some design consultants start discussing to change their business model into managing the whole process from designing to constructing. The consultants all agreed that it is the contractor who has been the driving part in the

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BIM implementation so far, probably because they reap the largest benefits out of BIM at the moment. However many consultants had noticed increased demands from clients to use BIM.

Regarding file formats and interoperability issues, many consultants agree that the open file formats such as IFC probably is the right way to go. However the technique is not working well enough at the moment.

### *Clients/Owners*

The public owner interviewed was at the time for the interview working actively on implementing BIM in the organization. A proposal for making object-based models of the whole property portfolio was being discussed in the company board. Since the owner were involved in the entire building lifecycle from early drawing stages to the demolition, several benefits were expected from the use of BIM, especially in the design phase but also in management and operation. Regarding cost estimations, more effective and less time consuming estimates, better visualisation/traceability of quantities and easier re-use of estimations were considered to be the main benefits.

Some projects had already been conducted with BIM. In these projects an individual consultant was used to make object based quantity takeoffs, cost estimates and schedules, mainly with good results. Some problems were encountered mainly because of the lack of early demands on the model. The owner stated that external consultants will be used for doing quantity takeoffs also in the future. The only change will be that demands will be made that the takeoffs should be done from the model instead of from 2D drawings.

The owner believes that it is the contractors who are the main driving part in the BIM implementation. However there have been requests for clearer demands from clients in BIM projects. Because of that, effort has been put into developing BIM-manuals and specifications.

Since the owner in this interview is public, open file formats are necessary in all their BIM projects. Today mainly IFC and .xml are being used.

## **3.2.2 Organizations**

### *Contractors*

Almost all contractors interviewed believe that DB is the best organization for BIM projects since it makes it easier for them to make demands on design consultants and subcontractor. However more collaboration based organizations were also used frequently, especially by one of the interviewed companies who stated that they saw increased profits in those projects compared to DB. In that case incentives were typically used between the contractor and the client but it was desirable to also get the other actors engaged by an incentive, to make all actors work towards the same objective. There was a general belief that it was difficult to get the subcontractor involved in an incentive due to the open project economics required. In today's industry there is a tradition that makes this openness difficult to acquire. For example the contractors agreements with suppliers is central for their business and nothing that is of interest to disclose at this time.

Many contractors agree that evaluating different designs in an early stage of the project would provide great benefits. However there is usually a lack of time in today's tendering process, which could make these evaluations difficult to realize.

The opinion on who should set the conditions and make the demands for BIM varies between different contractors. Some believe that the client should make the demands and some that it is better if the contractor does this.

#### *Design consultants*

Most consultants agreed that a DB organization was best suited for BIM projects at the moment. This was mainly due to the early involvement of the contractor. However the benefits of BIM will be important in all organizations only that they will be harder to achieve if the knowledge of the contractor is unavailable in the design phase. One consultant mentioned that the general knowledge among consultants was poor regarding the requirements the contractors usually had on the model.

Furthermore if the model is to be used in management and operation it is important to get the information from the contractor to be able to update the model from “as planned” to “as built”. Early involvement of the estimator is also significant for the project if model based cost estimations are to be used. Obviously early participation of various actors will increase the project cost initially, but many consultants believe that the benefits will make up for this cost. One consultant mentioned that it is in general challenging to get all actors engaged in a BIM project, why an organization with few participants would be desirable.

However partnering and more collaboration based organizations are regarded to be an interesting organization type for BIM, by most consultants. Since partnering demands a high level of honesty and cooperation many consultants agree that it is important to have the right control in these kinds of projects. One consultant mentioned that making all actors in a partnering project sit in the same room to discuss questions and make all decisions, was an efficient way to work. To first develop the objectives of the project and then customize the technique to reach those was regarded to be the right approach by most consultants.

To successfully implement BIM in an organization’s corporate culture was mentioned to be important. If there are too many obstacles and regulations within the company the change that BIM requires will be much harder to achieve.

#### *Clients/Owners*

The owner interviewed believed that a collaborative approach to BIM was likely to be successful. If the decision makers e.g. the client and the project manager are in the same organization as the design team, faster and more accurate control over the project could be achieved.

### **3.2.3 Business models**

#### *Contractors*

Most consultants believe that higher prices for the consultants are the wrong way to increase profits, since the competition will drive down the prices. What is being mentioned as possible business models is instead more fixed or budget based prices. In that way the consultants could streamline their own process through the use of BIM and get more time for other projects. However this demands that labour supply is good. One contractor believed that BIM as used today was mainly a way for the contractor to increase his profits in a project by working more effectively. For the

owner the main benefits would rather be in the management and operation phase and for the consultant it was more of a competition tool.

#### *Design consultants*

The design consultants generally believe that there are some difficulties for them to get a part of the potential profit of using BIM. One problem is the business model of charging the client by the hour, since they are now providing a model with a higher value in less time. A model that has been tried with good results is to leave a fixed price and then streamline the own process through BIM, however this has only been done in some less complicated projects where the designer's cost was easier to predict.

Most consultants agreed that they got a higher profit in projects where BIM was used compare to traditional projects.

A potential way to increase profits was mentioned by one consultant to be new services. For example an estimating service with incremental estimations through out the whole project could be an attractive feature for a contractor. To the client a more complete responsibility with streamlined project management through the use of model based cost estimations and BIM could be offered.

One consultant believes that there is too much focus on immediate increase in profits through BIM and that important features also includes; better working environment, higher quality and attractiveness as an employer.

#### *Clients/Owners*

The owner interviewed mentioned that the use of BIM and cost estimations would possibly make new services necessary, such as model coordination specifying requirements. Consultants could probably perform some of these new services.

### **3.2.4 Roles of responsibility**

#### *Contractor*

Most contractors believe that the responsibility for quantities is not a large issue. The companies specialized in calculating quantities today often have contracts stating that their economic responsibility is very limited. This makes it difficult for contractors/clients to direct claims at these companies. Similar contracts could be used if a design consultant was to do the same work.

A more current issue for contractors is the use of the building model. According to present regulations 2D drawings are still to be regarded as the legally binding document and not the building model, meaning that the contractor cannot use information from the model without taking on the full responsibility. Some contractors have decided that it is worth the risk and take their own measurements sections etc. from the model, while other contractors instead ask the consultants to put more measurements on the 2D drawings.

#### *Design consultant*

An important question for many consultants is which actor should have the responsibility for the quantities extracted from an object model. However most consultants agree that the best solution would be to let the estimator be responsible for the quantities. In that way the estimator would be responsible for checking and

verifying the model, which means that small, or no changes would have to be made from today's process. One consultant who had experience from object based quantity takeoffs believed that the responsibility for consultants was no actual issue since it was almost impossible to direct claims against the estimating firms today. That would not change just because the consultant did the estimations.

*Client/Owner*

Results from the owner regarding responsibilities are not available due to lack of information.

### **3.3 National summary**

*The national summary is a brief summary of the most vital and most often mentioned topics. All that is presented in this chapter also exist in the previous chapter in its full extent. The text is fully impartial and is only the reflection of the answers received during the national interviews.*

Summary of national study

- Visualization and clash detection are the most frequently used BIM features
- Quantities from the model are often used for tendering
- Model based cost estimation has been tried with positive results
- No extensive use of model based cost estimates by any actor at the moment
- Great benefits from BIM have been achieved by contractors, even advantageous enough to create own models from 2D drawings
- Quantity takeoffs results in higher accuracy and better understanding of projects
- Higher transparency and traceability of quantities are possible when using model based quantity takeoffs
- Lack of early involvement of the contractor leads to decreased accuracy in estimations
- Contractors are the driving part of BIM development in Sweden
- Client demands of BIM are not entirely positive since they might become too static and only based on only a few successful projects
- Designers use BIM mainly as a 3D visualization tool with clash detection
- Non-interoperability between quantity takeoff tools and drawing application is a problem
- Using model based quantities may lead to more uniform tenders from contractors

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- The role of the estimator is predicted to become more important in the near future
- Iterative design evaluation in early stages are likely to increase
- Designers are starting to discuss other business approaches where a larger part of the value chain is handled by the designer
- Clients see the use of model based cost estimates as an important management tool
- Demands and requirements must be established early to create a high quality model
- Every contractor believes DB to be the most effective organization for BIM use
- Incentives involving the client and contractor have been used for attempts to increase collaboration with good results
- The transparency of partnering organizations are hard to achieve, contractors are not likely to reveal their supplier agreements and discounts
- Design consultants typically believed DB to be most suitable for BIM projects
- Consultants in general have little understanding for the contractors' needs regarding the model
- Increased initial costs of early involvement of the contractor will be returned over the project due to less faults and rework
- For the design team to work together in the same room is efficient
- Fixed prices for the designers' work could be a better business model than hour rates
- A general disbelief exist with the designers about their benefits of BIM
- Some consultants however report of increased profits in their BIM projects
- New services like cost estimating could mean higher return of investment for designers
- Not only economics should be discussed but also higher value of product and better working climate and attractiveness as an employer
- Most contractors believe that the roles of responsibility will remain as today
- The model is considered additional information, the 2D drawing is the legal document

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- Contractors find it hard to use the model in construction due to responsibility issues
- Designers believe the distribution of responsibility to be a vital question when managing quantities
- The estimator should be responsible for the quantities and the designer for the model



## 4 Results of international study

### 4.1 International interviews

*The international study is based on a total of fourteen interviews with actors from the Nordic countries, the USA and the Netherlands. Four of the interviews are with contractors, nine with design consultants and one with a public client.*

#### 4.1.1 Denmark

*The information in this section is based on merely one interview with a Danish BIM consultant. The interview was performed at two different occasions, on site, in Denmark.*

##### 4.1.1.1 Cost estimations

###### *Design consultants*

According to the Danish consultant the work with BIM in Denmark is very limited. 3D modelling exists as a way for architects to present their design suggestions to the client. The projects that are conducted with BIM involvement or 3D modelling are considered pilot projects and are rather few. The connection between the model and cost estimate has also been tried in some pilot projects but not on regular basis. During one of these projects an attempt to create more accurate early phase estimation by altering the level of detail in the model was made. The idea was to create a very detailed model where e.g. the floor tiles were modelled exactly. The purpose was to extract information that would help create key numbers for early evaluations. In the model they were able to calculate how many percentage of the tiles that had to be modified to fit the building, e.g. in corners. Since those tiles will be more expensive to mount than the regular ones they will have a larger impact on the cost estimation. The actual size of the impact was calculated and a key number was received based on the area of the slab and the number of irregular shapes, e.g. corners. On later attempts the accuracy was evaluated and was discovered to be very good.

To be able to increase the level of detail without creating a too heavy model and to reduce time for drafting, details such as mounts for windows was added as external information to the window instead of drafting them. This way it was possible to involve the details in the cost estimation without having to add them graphically or by manual adding in the estimate.

The consultant also mentions one way to facilitate the issue with large and hard-to-handle models by creating different models with different levels of detail depending on their purpose. One model could be built for visualization, one for estimation and another for scheduling.

The largest benefits of BIM that have been used are visualization tools. In some case scheduling was aided by the fact that one person on the construction site were marking the finished processes in the model, that way it was easy to display the progress of the overall project. This method is however met with split opinions since

it will be harder for the contractor to control his cash flow when the client will be able to see exactly what work has been finished. A better control of the finished processes will of course be a significant benefit to the client.

#### *Organisations*

The role of the architect seems to differ from Sweden. In Denmark about 80 % of the time used by architects is spent on project management. This of course has effects on their view on a new way to manage and conduct projects through BIM.

#### *Business models*

There have not been any changes in the business models for consultants in Denmark. However it is very likely that the hour rates for designers will increase when starting to implement BIM and 3D modelling. The most important thing for the consultants and especially the architects is to keep up with the development in the market. A danger for the architects is that their role as project managers will be weakened if they do not adapt to more modern ways of organizing projects.

To start selling new services is another way of approaching new working methods. Services like PIO has not been seen in Denmark yet, but a similar role where coordination and review of the models are the main tasks exist. The consultant represents the client and the purpose is to, during the project's design and construction phase, create an as-built model for the client to use for maintenance.

#### *Roles of responsibility*

According to the interview, the roles of responsibility are quite clear. As a BIM-consultant you charge the client for the review of the models and for the integration of them. If the contractor would like to use the model he have to pay for it and then the responsibility remains with the BIM-consultant. However the quantities are fully adjustable which means that if a fault would be discovered the project cost would not exceed what it should have been from the beginning. The contractor can in that way not rely on an extra profit from change orders.

### **4.1.2 Norway**

*In Norway four interviews were conducted on site with the distribution of one contractor, two architects and one owner. All of them had experience from actual BIM projects and their work was represented all over Norway.*

#### 4.1.2.1 Cost estimations

##### *Contractors*

At the moment the main use of cost estimations revolve around quantity takeoffs. No projects have been performed with a direct link from the model to the estimation. Today the quantities are manually added to the estimation via a spreadsheet. At the time for the interviews some projects were planned where model based cost estimations were to be used.

The main reason and the largest perceived benefit of using BIM and model based cost estimations are claimed to be the ability to share information visually within the project and to increased the quality of project documents. To be able to economically

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evaluate design solutions and to perform energy simulations are also mentioned as important features.

In the current situation there are issues that have to be resolved. The consistency of model object iteration must be improved for estimation use, otherwise estimations becomes unreliable since review of the model will be hard.

In Norway some large clients have started to set demands for BIM use in projects. Guidelines fit for clients do not always comply with the required specifications of the contractor. This weakens the use of the model and BIM in general.

To motivate the personnel to start using BIM in projects, the strategy is to make sure that the first encounter with model work is positive and not to overwhelm the project team with new features and responsibilities.

One contractor states that to start using BIM is no problem since the worst-case scenario is that it does not help you. However as soon as you base your cost estimations on the model, there is a large amount of risk.

### *Design consultants*

According to the design consultants the development of BIM use in Norway is completely depending on the clients. The contractors have been starting to realize the benefits and have started to implement it in their organizations.

A few larger projects have been conducted under pilot like circumstances where new technology and processes have been tested with mixed results. By using a set of software tools, checking of room objects has been done. This way the reliability of the model can be checked so that no rooms are “stacked” on top of each other and that the room definition is correct. Also quantities have been extracted from a rather immature model and then used for early model based cost estimations. However, the results were somewhat halting. The objects in the model must be more standardized and the cost information must be easier to access in an accurate way. If this would improve the main benefit of these fast estimations would be the ability to present different design options to the clients with “easy to change” estimations.

To get BIM working properly industry wide the reliability of the model must be increased. This way the model could change from additional information to be used as the actual construction documents.

### *Clients/Owners*

The clients’ main focus is not primarily on the economics when trying to adopt BIM into their projects. That is more considered to be a natural consequence of the contractors learning to streamline their work. The contractor will start increasing their profit on the expense of the client, however when the industry matures the market forces will make the prices decrease.

The main benefits for the client today is claimed to be more exact and even distributed tenders and that the overall project quality increases due to less faults by the contractor/designer.

Future gains would be cost estimations and quantity takeoffs that are trustworthy and create traceability in the documents.

An important discussion that has occurred is the negative view on BIM since not every feature is possible to use in a satisfying way today. The current benefits are so great that it is best to use what we can. Even if the cost estimates lack some

information like the sub contractor's prices, it is still very usable to cost control the projects.

It is important to realize that the implementation of BIM is not done over night and that actors must have the chance to adapt in a reasonable time. In all projects descriptions and regular documents are the legal documents and the model is considered additional information, that way no contractors are excluded from the tender process because of inadequate BIM-experience. This can also be seen as a danger, e.g. when quantities are easy to extract with little effort. Contractors that normally would not get involved in the tender for large projects are tempted to try projects they might not have capacity to manage.

Along with the opinion that no actor shall be excluded from the market because of BIM, the use and requirement of open standards and file formats really are pointed out as mandatory.

An interesting comment when discussing some unclear questions about BIM was that almost every question that are being asked in the business today can be solved by asking one self how things are done today. It is just that the documents exist electronically.

#### 4.1.2.2 Organizations

##### *Contractors*

No information

##### *Design consultants*

Much emphasis is put into the fact that the use of BIM will not be a technological issue but an organizational one. Today the traditional project coalitions are used like DB and DBB. The one most preferred is DB since it allows the designers to engage the project with the inputs from the contractor. However DBB has been used with very good results, mainly because of the good relationships between the actors that were involved. Early involvement of the contractor is pointed out as very important since he often have opinions about design solutions that might look insignificant to the designer but that will be very expensive to build in reality. The danger in working in this way is however that focus tends to stay entirely with the costs. To avoid this, contracts are being developed that will allow a contractor to be involved with the design phase even if the final contractor has not yet been procured.

In Norway it is often the architects responsibility to produce the project descriptions, which potentially could make them more involved with the project then in e.g. Sweden.

A problem is that even when actors get involved early in projects, they do not start to build their models until a large amount of decisions already have been taken. This makes early phase cost estimations from the model hard to perform.

All consultants interviewed believed that more collaboration is a key feature to increase the BIM use. A flat organization in some form of partnering contract would be the best project organization. To create an incentive for highest possible quality, maintenance for a number of years could be included in the contractor's contract.

*Client/Owner*

According to interviews the organizational questions are claimed to have little to do with BIM use. It was as important to achieve good collaboration in a project before BIM existed. Focus today seems to be to involve the contractor early but this could also have negative effects. The main reason for early involvement would be increased feasibility. This means that it is only the knowledge of the contractor, not the contractor himself that is wanted. Early involvement could mean decreased competition and a chance for the contractor to affect the project to his own gain. To avoid this, clients are starting to employ construction engineers to work with the design teams.

The main opinion is that the preferred organization depends on the nature of the project. If an opera house were to be built the client wants as much control as possible and a DBB would be preferred. In less complex projects, DB could be better suited since the contractor then takes the risk.

4.1.2.3 Business models

*Contractor*

Since the general use of BIM is relatively low no change of the consultants' business model have been noticed. They are now leaving fixed prices in general. In the pilot projects the designers have been very enthusiastic and considered the perhaps higher cost as a development investment. The long-term prices however will in general not be affected of BIM.

*Design consultants*

The business models of the design consultants will probably change in some way. To increase the hour rate will probably not work since the market forces will keep the prices down through competition. Instead lump sum contracts have been tried in some cases and works well. The designer can increase his profit by working more efficiently while the client moves his risk to the designer. This should be a profitable contract for all parts. It has also been discussed that the architects, since they are already involved with description and documents, should take part in what is traditionally the contractor's work, e.g. scheduling and cost estimations. This may require that the architect have access to the object libraries and prices from the contractor.

*Client/Owner*

For a consultant to be able to charge more just for using BIM in his scope of work is not reasonable according to the interviews. A comparison is made to the time where CAD was first introduced to the market. The consultants are not making less money now than before even if the time for each document is less now. The same applies for the implementation of BIM. As long as the market is doing all right and there is work to do, each consultant is able to take on a larger number of projects.

#### 4.1.2.4 Roles of responsibility

##### *Contractor*

According to the contractors interviewed the roles of responsibility have not changed when using BIM. However it is still an important question since uncertainties about boundaries makes collaboration hard.

The 2D drawings are still the legal documents but when the contractor receives a model, quantities can be calculated from that. This means that the contractor takes on the responsibility for those quantities, just like in the traditional way.

When the contractor is involved with contracting designers, the guidelines and requirements of the model binds the consultants to the model. The contractor has the main responsibility when using the model for production and estimations, but the consultants can be held responsible for faults. To avoid conflicts in production, all changes from “as planned” to “as built” are made by the original designer.

##### *Design consultants*

The roles of responsibility are not meant to change because of the use of BIM. This is stated clearly by the consultants spoken to. Each designer should be responsible for his deliveries, just as today. Also the order of legal documents should remain the same, descriptions first, 2D drawings and then the model.

In one project the contractor saved a large amount of time (2-3 hours compared with 7-9 days) in making model based quantity takeoffs and therefore accepted to take over the responsibility of the model.

##### *Client/Owner*

The general opinion is that the roles of responsibility will not change from the present situation. The quantities are often fully adjustable, that way it will always be the client who have to pay for any inaccuracies. The only difference will be that feedback from eventualities will be of higher quality since the traceability is higher. Making it easier to learn from previous mistakes and improve the accuracy in future projects.

### **4.1.3 Finland**

*In Finland three actors took part in the interviews. Two of these were from large contractors and one from a consultant company; unfortunately no client/owner was available for an interview.*

#### 4.1.3.1 Cost estimations

##### *Contractors*

Finnish contractors use BIM in especially residential and own developed projects. In commercial projects BIM is not used to the same extent. Both of the contractors interviewed had used model based cost estimations in several projects often with a good outcome. Typically the model was used in early stages together with rough key numbers to create an accurate estimate. This process needed to be supervised by

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experienced personnel to match the current market prices. This was regarded to be the largest benefits and was also used to get accurate data for investment analysis.

Especially one of the contractors used the cost estimates to evaluate different design solutions with the aim not to exceed a “target project cost”.

Another contractor mentioned that the early estimates usually done from the architect’s model would count for approximately 60% of the total information needed for the estimate at that stage. After the detailed design is done it is usually harder to perform an accurate estimate since models from subcontractor has to be combined as well. What was desirable to do was to use the architectural model and create an estimate and then use the more accurate quantities to increase the level of detail in the model. The accuracy of the quantities was regarded to be the largest benefit since it was a powerful risk management tool that would allow the contractor to reduce the margins on quantities in the estimate.

### *Consultants*

The consultant interviewed believed that the main user of BIM in Finland today was the contractor, who used it in primarily project developments or in larger projects such as shopping malls. Finland has a large public client Senaatti, who has made demands for the use of BIM and developed own BIM guidelines. However this has not had a large impact on the development of BIM. The driving part is the contractors and that is where the largest progresses are being made, according to the consultant. The most efficient way to increase the use of BIM would be to get more demands from owners, although the demands of course have to be made in a way that suits the other actors involved.

In Finland the companies are in general smaller compared to e.g. Sweden, this fact has made the implementation of BIM faster since small companies have easier to change their processes and practices. It is also frequent that external companies sell services like model coordinator and PIO to the larger firms. Making guidelines for BIM is not a large cost, and takes in general only a couple of days of consulting work, but it is of great importance to be able to use the model in an efficient way later on for e.g. cost estimations. The consultant clarifies that model based cost estimations is not the same as automatic cost estimates. There always have to be an estimator to verify the estimate and add the manual posts. For example the subcontractor prices are difficult to include in the estimate and typically have to be added by the estimator.

The largest benefiter from model based estimates are according to the consultant the client or project owner, mainly due to the increased quality. However one problem has been to convince the clients of this increased quality. It has also been difficult to present any numbers on increased return.

### 4.1.3.2 Organization

#### *Contractors*

Both contractors agree that DB is where the largest benefits are at the moment and that early involvement from the contractor is vital for the project outcome. Partnering and IPD are also mentioned as potentially good ways of collaboration in BIM projects. However these are not used to any great extent today. To be able to work

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successfully in these collaboration based organizations it is important to work with the same actors, otherwise every project becomes a kind of pilot project. The main priority is to focus on segments of the market with a longer value chain.

### *Consultants*

DB is regarded to be the best working organization for BIM at the moment, since the contractor can then set early requirements on how the designers should build the model. Using DBB there is typically a lack of time for the contractor to build a model if the designers only deliver 2D documents, which is usually the case.

### 4.1.3.3 Business model

#### *Contractors*

Finnish contractors have not noticed any increased prices from consultants in BIM projects. They agree that the consultants do produce a higher value but argue that the competition will decide the prices and therefore it will be difficult to make any large change in prices. Typically cost estimation is regarded to be a competition tool for consultants. Fixed price contracts are often too risky for both the consultant and the contractor if the project is more complicated and involves uncertainties.

#### *Consultants*

Today most consultants in Finland are contracted by the hour, making it difficult for them to increase their profit. In general model based cost estimations are more of a competition tool for Finnish consultants. One way to increase profits is to charge more for a BIM project. The client is expected to not only choose consultant based on the price but the one who can offer the highest value in both quality and price.

### 4.1.3.4 Roles of responsibility

#### *Contractors*

One contractor stated that Finnish law requires a main designer who is the contractors counterpart regarding the model. The main designer is responsible for the complete model but the specific designers are responsible for their part of the model. The other contractor however stated that there was no law regarding a main designer at the moment but that it could be a reality in the future. As of now they were doing model checking themselves to find errors between the integrated models. The errors found would then be sent back to the designers to correct them. 2D drawings are still the legal documents in Finland and to use information from the model in an “unofficial” way therefore requires skilled personnel that can evaluate the risk and reliability of the model.

#### *Consultants*

The consultant interviewed believed that whoever creates the model should be responsible for it. In Finland the 2D drawings are the legal documents and the model is only considered as additional information.

#### **4.1.4 The Netherlands**

*All of the Dutch interviews were performed on site at the local offices around the Netherlands. Of the participating persons one were a large contractor, two were consultants from different independent organizations and one was a design consultant.*

##### 4.1.4.1 Cost estimations

###### *Contractor*

In the Netherlands BIM is mostly used for visualization. One large contractor uses the visualization tools for all of their projects. Tools are e.g. clash control, visualization in team meetings on site and quantity takeoffs.

It is up to the contractor to set demands for BIM use in their projects, design consultants have to be convinced of the benefits to use it. Today it is the contractors who are driving the development in the question.

If the client would follow any form of national or international guidelines for BIM use, these must be coordinated with the contractors to achieve increased effectiveness in production. Such discussions and negotiations currently exist. Clients have been starting to demand BIM in some larger DBB projects.

One of the largest contractors in the Netherlands uses 3D models to optimize the work with risk management and site planning. Changing e.g. the tower cranes position on a construction site could appear to be profitable even if it means rework and design changes.

No use of true model based cost estimates exist within the building sector. Large pilot projects in the infrastructure sector have been tried. The main benefit of it is mainly the quantity takeoffs. For the cost estimation to function properly sector standards regarding models and objects must exist. Especially high-rise buildings are hard to estimate if the objects are not standardized because of the extent of objects.

One contractor states that if it would be possible to get model based cost estimations to work, the largest benefit would probably be to be able to evaluate design solutions in a more detailed way than today.

The same contractor also points out the importance of seeing BIM not only as a tool but as a complete package of processes and tools together. It will have a large impact on the traditional order of processes we are used to. BIM must be considered as the backbone of the project, everything should be connected through BIM during the project. That is why interoperability between software is vital. Different software could be used for creating one model that everyone should base the work on.

The designers in the Netherlands are today working hard with BIM implementation and the development is moving fast.

###### *Design consultants*

The Dutch design consultants had somewhat split opinions about the use of BIM and 3D modelling in the Netherlands. One consultant mentions that about 10-20 % of all projects conducted are in 3D or BIM. However clients in general do not require BIM in their projects. One of the largest design companies use 3D or BIM in all of their projects. Even if the model is not going to be used or delivered, they prefer to draft in

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3D and then extract sections and 2D drawings. This saves time and decreases the amount of re-work. The aspect of work environment is also important; the use of BIM has brought a more positive attitude and less frustration in the projects. One of their main issues is to convince other actors in the project teams to use BIM when collaborating.

The main benefiter of BIM would be the contractor. Today they can order drafted models very cheap but with high quality from external companies, often with their base in Asia.

The use of model based cost estimations is not comprehensive. In some smaller projects quantities from the model were paired up with unit prices. The cost matched the one from the manual estimation very well.

The interest for cost estimations is rising in the country, especially over the last couple of months (fall of 2010). One survey showed that cost estimations based on the model was one of the most rewarding benefits from BIM.

Some architects use early cost estimations based on the model to evaluate different design alternatives. The estimations are made on element level, e.g. walls, slabs and windows. Today when evaluating design solutions it might take up to 3-4 weeks to create new documents and calculate the cost. By then the client might be in a totally different mood and the work will have been wasted.

One of the larger design companies did one project where a number (10-15) of designs were presented to the client to choose from. Each model was used for a cost estimate and then compared with a manual one. The accuracy was rather good. To make it easier for the client to choose alternative a spreadsheet was created where the client could scale the importance of project aspects, e.g. cost, number of parking lots or total area. By adding values of each project aspect to the design alternatives the most beneficial alternative due to the client's scaling was presented in the spreadsheet. Just by sliding a control on the screen, the most suitable design alternative was presented. The client's choice in the end was not the one the designers would have guessed at all.

There is a general lack of trust in model based cost estimates today among cost estimators. Ways to secure the quality of the model are vital.

### 4.1.4.2 Organizations

#### *Contractors*

One of the largest contractors in the Netherlands mentions that the organizational form itself might not be the most decisive factor for how the collaboration in the project will work. The will to cooperate and the general attitude of the project participants may be more important. Even if a partnering project should function well, the negative attitude of one important individual might destroy the positive effects of collaboration. By using economical incentives it might be easier to motivate the persons involved and to activate passive members of the project teams.

In a large project a new approach of sharing information was tested. Every morning, all superintendents met in a meeting room with powerful visualization tools located on the construction site, scheduling and work reports were reviewed together so that a change in one area of the building immediately got response from all other teams that

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were affected. Since this project, the goal is to manage all projects like this for the contractor.

Even the design phase has been subject to some changes. In the past, documents and drawings were delivered when completely finished, in the end of the design phase, and then they were reviewed. Today, model builders make deliveries every two weeks. The contractor then integrates them and creates schedules and makes clash detections etc. This way time is saved since much work can run parallel. However the requirements for secure and careful documentation of what is drafted and what is missing is crucial.

### *Design consultants*

The most used project coalition is the DBB followed by the DB. All of the interviews mentions that the use of more collaborate organizations are growing. Partnering contracts are used with some difficulties. Company boundaries are hard to over-bridge and the clients are often interested in receiving more bids from a larger number of actors as in the DBB.

A specific issue with e.g. the DB organization is that when the contractor procures the designers, tools like clash detection is not always wanted. Instead the contractor performs the clash detection and charges the designers for the discovered mistakes.

A structural designer on one of the largest design companies points out that he has noticed that the number of change orders is significantly higher in a DBB organization than in the DB.

A benefit from using more collaborate approaches, e.g. when gathering the designers at one location for one project is that the time for making decisions dramatically decreases.

### 4.1.4.3 Business models

#### *Contractors*

The natural development of the designers' business models will probably be steered by the market forces. The general opinion is that working with BIM and 3D models should be seen as a way to get more projects, not as an extra feature.

#### *Design consultants*

One opinion was that whether designers like or not, the whole construction business is moving towards more BIM use. Today one assessment was that approximately 50 % of the consultants' projects are done with fixed price and the rest with an hour rate. In some cases a bonus has been added to the hour rate depending on the outcome of the project. In one company the guess was that 75-80 % of the projects were conducted with fixed prices. The consultant bases his price on key figures or percentage of the total project cost.

Today it is hard to make any large profits of cost estimations and quantity takeoffs. However, new services are being developed and are increasing in popularity. An example of this is model managers.

#### 4.1.4.4 Roles of responsibility

##### *Contractors*

One of largest Dutch contractors mentions that the roles of responsibility are a problem that needs to be resolved to get full effect from BIM. Today the drawings are the legal document and the information in the model can be hard to trust. The drawings are reviewed and if they derive from the model, the geometry of the model can be assumed to be accurate. If the geometry of the model is assumed to be correct, then scheduling can be done with good reliability. Quantities, since they are a product from the geometry can also be trusted. If another actor using different software has drafted parts of the model, danger exists in the problems with interoperability. Then quantity takeoffs might be impossible.

The contractor emphasizes the importance of creating structures and strategies for quality checking of the model. If the quantities are to be used, somehow the quality of the basic geometry must be controlled. To use the model in other ways it might be necessary with a different control approach. Today the contractor uses the model delivered from both in-house and external designers in the construction phase. It is also the in-house drafters who make corrections and the changes to the model during the construction phase. The main responsibility of the model lies with the original designer, but when the contractor uses the quantities he is responsible for them. Because of this the contractor needs to be very careful when writing the requirements needed from the designers.

A fact that is mentioned is that in the current situation projects worth billions of euros are conducted and dependent on systems and processes such as model based cost estimations that might not be as mature and safe as some might think.

##### *Design consultants*

The general opinion is that the roles of responsibility have not changed very much. The designer is always responsible for his model but a BIM manager often takes on the responsibility for merging the models. Using BIM and 3D models might even suit the existing legislation better than the traditional way of working. If everything is registered in a model it also becomes easier to identify who did what and when. Legal issues will then be easier to sort out.

There is however sometimes problems when the contractor needs to be involved early in the design phase since Dutch law states that it is illegal to change contractor when one contractor already have engaged the project. To solve this issue, guides and experience from the contractor's knowledge should exist.

#### **4.1.5 The United States of America**

*In the USA two interviews were performed, both with consultants in the building industry. The interviews were conducted through the use of an Internet conferencing tool.*

##### **4.1.5.1 Cost estimations**

The situation today in the US is rather unequivocally described as a market where the contractors are leading the development of BIM. The clients are starting to realize that they ought to set BIM requirements for their projects, however this is not very common. The features mostly used are BIM as a visualization tool with a 3D modelling and quantity takeoffs. Some larger US actors have started to investigate the impact of model based cost estimations on the initial project costs. One consultant mentions the importance of being able to estimate a buildings life cycle cost. However the focus today is almost entirely on the initial costs.

There is a large difference in the way contractor's work in the USA compared to Europe. In the USA the contractors do not have detailed cost information on the construction work since most of this work is performed by subcontractor.

In many cases the general contractor delivers 2D drawings to the sub contractor and then receives a price. The work with quantities is therefore relatively new to the general contractors. To be able to deliver accurate quantities would mean that the subcontractor would bid on the same preferences, which means a more even distribution of prices.

When creating early phase estimations there is a need for good cost information. The estimation is not actually based on the model but on previous conducted project with a similar nature. The price might be based on dollars per square meters or similar. This way of estimating the costs makes it hard to evaluate changes in design and to track where in the project the actual costs are.

One consultant points out that model based cost estimates might not be that effective since aspects of the project with large impact on cost is not represented in the model. E.g. outside circumstances like ground material, season of the year or weather conditions. It is the processes around the objects of the model that is important and in many cases not the object itself. Although this consultant means that quantity takeoffs is a valuable tool since it can significantly reduce errors. In a research conducted it was discovered that as many as 320 quantity takeoffs were made in a project. Then the human factor and the obvious risk for miscalculations could be very decisive.

A lot of effort has been put into value engineering in the US, but along the way the meaning of it has somewhat changed. It has gone from being a tool used continuously for evaluating design to a system where the project is made cheaper in the end of the design if the budget is exceeded.

The actors that use model based cost estimation usually creates a model in the conceptual phase with all the information that is known. Then as the project develops the model becomes more mature and detailed. To have a consistent way of developing a model like this it is very important to feel secure with the estimations. The American Institute of Architects (AIA) has created a document (E202) where the pre-defined levels of development of the model are described.

#### 4.1.5.2 Organizations

Today the DBB coalition is the most frequently used organization type. This is primarily because of regulations regarding public procurements. Using this type of organization means that boundaries are very distinctive and clear, which decreases the level of collaboration. Instead a DB contract works better with BIM since it allows for a more open project organization. Up to this point the contractors have been the driving part of the BIM development since they see the largest benefits of it. Since the contractor then is the actor who possesses the greatest knowledge of BIM it makes sense to allow him to be involved in as much of the project's value chain as possible. To really break the traditional structure with the segmented industry, IPD or partnering as a delivery method could be used. Then the chances of true collaboration exist but are still hard to accomplish since traditions are deeply rooted.

If such organizations are used, more time and effort should be spent in the design phase and procurement. This way change orders are decreased and also the risk of litigations destroying the project coalitions.

#### 4.1.5.3 Business models

All interviews reveal a difference in thinking regarding the business models of the designers. In Europe actors usually aim to maximize the profits in each project. In the US more focus is on being attractive on the market, getting more projects and growing the business. A way of achieving this is to present new technologies and organizational advantages.

BIM allows the designer to work in a more effective way and to get more time for other projects. At the same time it is claimed that the quantity takeoff and estimation process are not done faster than traditionally, at least if the project is not completely repetitive. However if more than one estimation is being made the following estimates will be made much faster if done from a building model.

One design company was being mentioned that fired all of their estimators and started to interview contractors and subcontractor to create huge cost databases. The designers could then create all estimations themselves and use this as a competition weapon. The company has reported that this has been a great success and that they have gained a large portion of the market due to these features. This company still charges by the hour but concentrates on winning more projects.

In general US designers are contracted with fixed prices. This allows the designers to optimize their own performance to increase profits. However this way of compensation also might create an incentive to search for change orders to get even more paid.

#### 4.1.5.4 Roles of responsibility

The model is still considered additional information and the 2D drawings are still the legal document. In a relatively near future this is likely to change. Today the designer is responsible for the model until delivered to the client. During that time the designer manages the model but he does not own it. Design companies are starting to see this a new service, to manage and maintain the model on the behalf of the client.

## 4.2 International Summary

### *Denmark*

- BIM is not used to any great extent in Denmark
- 3D models are used by architects for visualization
- Scheduling has been tried. Staff on construction site marked finished processes in the model to easier display the overall progress
- This made it harder for the contractor to control his cash flow
- Danish architects are often involved in project management
- No change has been made to business models for consultants
- The most important feature for consultants is to keep up with the development
- In Denmark they have a role similar to the PIO. That person coordinates and reviews the model
- He can also be responsible for the quantities. Even though these are always fully adjustable, meaning no extra charge is applicable for change orders

### *Norway*

- No project have been conducted with a direct connection between the model and a cost estimate
- The largest perceived benefit is improved visualization and quality in BIM projects
- Large clients have started to set requirements for BIM
- These requirements do not always comply with the guidelines from the contractor
- The development of BIM is depending on the client
- The client's main focus is not the economics when adopting BIM. It is more of a natural consequence of streamlined processes among actors.
- Main benefits are today more exact and even distributed tenders and increased quality due to less faults by the designer/contractor
- The model is not legally binding but merely used as additional information
- A risk with easier and cheaper tendering is that contractors that might lack the capacity still get involved in the tender process
- To avoid to exclude actors it is vital to use open standard file protocols such as IFC
- Most issues regarding BIM can be answered by asking how it is handled today and to do it the same way
- BIM is regarded to be more of an organizational then technological question
- The preferred organization for BIM is in general DB even though much focus will be on the costs. Clients mainly want the knowledge and not the actual contractor in an early stage
- DBB has also been used with good results
- Early involvement of the contractor is pointed out as important
- Early cost estimations are hard to perform since several actors wait to build their models until many decisions have been taken

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- More collaboration is regarded to be important for BIM
- One client believes that organizational questions have little to do with BIM, it was as important with good collaboration before BIM
- Early involvement of the contractor could have negative effects since competition could decrease. Employment of a construction engineer is discussed among clients
- The organization best suited for BIM depends on the project. DBB is better suited for complex architectural buildings.
- Lump sum contracts have been tried by consultants with good results
- New services such as scheduling and cost estimations could be performed by consultants
- The consultants are not making less money using CAD then they did drawing manually. The same goes for the BIM implementation
- The contractor has the main responsibility when using the model for production and estimations
- The responsibilities should not change by the use of BIM
- Quantities are often fully adjustable making the client pay for any inaccuracies
- Feedback from eventualities will be improved since traceability is higher making it easier to learn from previous mistakes and increase results in future projects

#### *Finland*

- BIM is used in especially residential and own developed projects
- Model based cost estimations were frequently used, often with a good outcome
- Typically models are used in early stages together with rough key numbers
- This process needs to be supervised by experienced personnel
- One of the contractors used the estimates to evaluate different designs with the focus not to exceed a “target project cost”
- One contractor mentioned that early model based cost estimations usually count for approximately 60% of the total information needed in the estimate
- It is more difficult to perform an accurate estimate after the detailed design is done since subcontractor models have to be coordinated as well
- The accuracy of quantities was regarded to be the largest benefit
- The main user of BIM is the contractor
- Large clients are making demands on BIM use
- This demands have to be coordinated with the demands from the other actors
- Finnish companies are in general smaller than e.g. Swedish companies, making it easier for them to adapt to BIM
- These smaller companies frequently sell services such as model coordinator and PIO to the larger firms
- Making guidelines for BIM is not a large cost and takes approximately a couple of days of consulting time, but is of great importance for a BIM project
- Model based cost estimations is not the same as automated cost estimates

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- There always have to be an estimator to add manual posts and verify the model
- The client/owner is regarded to have the largest benefits of BIM due to the increased quality, according to one consultant
- It has been difficult to present any numbers on increased return
- DB is best suited for BIM
- In DBB there is usually a lack of time for the contractor to build a model if only 2D documents are delivered from the designers
- Partnering and IPD are also mentioned to be good ways of working but is not used to any great extent
- To succeed in these kind of projects it is important to work with the same actors otherwise every project becomes a kind of pilot project
- The main priority for contractors is to focus on segments of the market with a longer value chain
- No increase in prices for consultants have been noticed in BIM projects
- Competition will decide the price
- Cost estimations are primarily regarded to be a competition tool for consultants
- Fixed price contracts are often too risky if the project is more complicated and involves uncertainties
- Most Finnish consultants charge by the hour
- An increase in prices could be possible due to the fact that the client is likely to choose consultant based on both quality and price
- One contractor states that Finnish law requires a main designer as the contractor's counterpart regarding the model. He is responsible for the coordinated model
- Another contractor states that there are no requirements of a main designer but that it might be mandatory in the future
- Model checking is usually done by the contractor
- 2D drawings are the legal documents
- To use the model in an "unofficial" way requires skilled personnel to evaluate the risk and reliability

#### *The Netherlands*

- BIM is mostly used for visualization by the contractor
- The contractor is the main driving actor in the BIM implementation
- Any form of national or international guidelines would have to be coordinated with the contractor to increase effectiveness in production
- One large contractor uses BIM for risk management and site planning
- Sector standards regarding the model and objects are desirable
- One consultant states that approximately 10-20% of all building projects are conducted with 3D or BIM
- Clients in general do not require BIM
- The use of BIM has brought a more positive attitude and less frustration in the projects

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- One consultant evaluated different designs together with the client by letting him scale project aspects and then present the most beneficial alternative
- In partnering projects the opinion is that the organization itself is not the decisive factor but the general attitude of participants
- Economic incentives could make it easier to motivate actors
- DBB is the most used coalition followed by DB
- Clash detection is not always wanted, instead the contractor performs this himself to receive more change orders
- One consultants states that there are significantly more change orders in DBB projects than in DB
- Approximately 50% of the consultants' work are done with a fixed price
- In some cases a bonus has been added to the hour rate depending on the project outcome
- The responsibility of the model lies with the original designer but if the contractor uses the quantities he is responsible
- BIM could potentially make it easier to solve legal matters since everything is registered in the model
- Dutch law states that it is illegal to change contractor when one have already engaged in the project

#### *The USA*

- There is a large difference between US and European contractors since US contractors do not have detailed cost information of the construction work. Most is being done by subcontractor
- Early phase estimations require data from previous similar projects. This is typically done by price per square meter making it hard to evaluate changes and track where the actual costs are
- One consultant states that model based estimates are not that effective since aspects with large influence on the cost are not represented, such as outside circumstances e.g. weather, ground material etc.
- However model based quantity takeoffs is regarded to be a valuable tool since it reduces the risk for miscalculations
- DBB is the most frequently used coalition in the USA
- Contractors are the driving actors in the BIM implementation
- In the US it is in general more important to be attractive on the market and win more projects than to have a large profit in every project
- Model based quantity takeoffs and cost estimations are typically not done faster than manually. At least if the project is not completely repetitive
- If more than one estimation is being made the following could be done much faster if done from a model
- Designers are usually contracted with a fixed price
- Fixed price contracts might be an incentive to search for change orders to increase profits
- 2D drawings are still the legal binding document, but this will most likely change in the future

## 5 Analysis of results

*The purpose of this section of the report is to make an analysis of the results and have a discussion around some particular topics that turned up to be of special importance. In the discussions the authors' will present their own thoughts and reflections on the discussed subjects.*

### 5.1 Current situation of BIM use

The use of BIM in the studied countries differs slightly. As expected, the approaches to this new way of working have been different between the countries. No exact mapping can be done from the results of this study since it is only qualitative with only some representatives from a selection of companies. Even so, a general difference that might have been expected did not. The countries with public clients requiring BIM did not show any signs of further development than the others. The largest difference that could be discovered in this study was that in some countries like the Netherlands and Finland, the features of BIM available was used to a greater extent. Of course there were issues, but instead of seeing them as obstacles they were handled by using traditional methods of work. In other countries there was more focus on uncertainties and the lack of fully functional tools. This might be one of the largest reasons why there is a difference of development even with countries with small geographical and cultural differences.

In common for all countries was the main use of BIM, which in general includes increased possibilities for visualization and to a less extent quantity takeoffs. Every actor agrees that BIM is currently a contractor's tool. This is both expected and not. Since the contractor in many cases is the one who owns the largest part of the value chain he is the one who will have the largest gain of optimizing his processes. At the same time, as mentioned in chapter 2, the largest benefiter due to a former research study is the architects and the structural engineers.

Also in common for all of the actors who have reached the furthest in the adoption of BIM was that one or more persons were pushing the development and trying to implement new features to the projects, sometimes without knowing the results in advance.

### 5.2 Cost estimations

Model based cost estimations are something that has been tried to different extents in all the studied countries. In no country this is commonly used. Several issues still exist, but as one interview revealed, why not use what can be used at the moment? Early phase estimations are hard since little information is known. As described in the Cost Management chapter the accuracy of the estimates at this point is rather low. They are based on key numbers from the known numbers of apartments, square meters etc. One consultant proclaimed that key numbers do not have to be unwanted. What if you shift the meaning of key numbers instead? From basing the estimation on rough key numbers with very large assumptions to information models with in comparison high level of detail where the key numbers are built into the materials

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displayed. An example is the tiling of a floor. How many tiles must be cut and fitted to irregularities of the walls? By modelling a complete and detailed model you could calculate the “extra” cost in each corner. Then in the next regular model, that extra cost can be added automatically to each corner. That way a relatively basic geometry can generate a fairly accurate cost.

In Finland similar ideas exist where “old” project information is stored and numerically calculated so that up-to-date key figures exist within a database for early estimations. To take model based cost estimations one step further and using it to improve the value engineering described earlier and to base the choice of design according to its economical impact on the cost is not done to any great extent in any country. There are glimpses of ground-breaking work such as the project in the Netherlands where an interactive chart was created and the client by altering his scaling of aspects like cost, total area, number of parking lots etc. could see the most appropriate design solution directly. This is one large step in the right direction. According to the theory of value engineering the estimation process during design should be continuously, how many cost estimations this means are however impossible to say since it must depend on the nature of the project. Today the time for creating a cost estimation has decreased in many cases, which would allow for increased numbers of estimations, however this is probably not the case at the moment. The estimator’s scope of work has to and will change in the near future to adapt to the value engineering thinking. His role in the design phase and during construction will be more prominent according to several interviews.

Today there is a general lack of understanding of BIM among experienced estimators in all countries researched. One of the interviewees stated that a company cut down on the number of senior estimators to move their work assignments to BIM-personal. This might be seen as if the estimator’s role is made more active, although what it actually means is that you derogate their profession.

There is a grave danger in this, since knowledge and experience is essential components to get accurate cost estimations, no regards if it is done in the traditional way or with modern tools. To benefit from model based cost estimations it is essential to integrate the design team with the estimate units.

One of the largest issues with model based cost estimations in general is the lack of cost information. That information is widely spread among the actors involved, e.g. the contractor, subcontractor or manufacturer. This causes a situation where the structure of the estimation is completed, the quantities are correct and accurate but for the estimation to be complete, cost information has to be collected from numerous places before assembly. If more accurate early phase cost estimations with fast updates shall be reality, several issues need to be addressed.

- Involvement of more actors at the same time in the project
- Faster loops of information between these actors
- Or databases of cost information based on previous conducted work

These are merely parts of a large series of processes needed to get accurate value engineering to work.

### **5.3 Driving actors of BIM development**

Somewhat different approaches to the BIM implementation have been noticed in the studied countries. In Norway, the USA and partially in Finland there are public clients who have been involved with the BIM implementation and have set the standards in many cases. Most actors interviewed see BIM as a contractor's tool and that he can reap most gains of it. It is also the contractor who is reported to have been the driving part of the development, except in Norway where Statsbygg, the public client is ascribed the positive development.

It is very hard if not impossible to draw any conclusions about the meaning of client requirements or if the development is based on separate actors. General guidelines from a strong client may very well be a push for actors to start an implementation work. It can also be counterproductive since the contractor who is involved in a large portion of the essential design/construction phase might be forced to change a process that works very well. If client demands are not coordinated with the other actors the advantages may be diminished. There are indications that this is the case in several situations. This is fully natural; each actor seeks to amplify the most suitable benefits for themselves, which might mean that the next actor have to abandon his primarily choice. Examples are such things as wanted level of detail of the model or amount of dimensioning displayed on the drawings in production.

The most reasonable fact seems to be that it does not matter who is driving the development or implementation as long as someone within a company dares to try a new approach and software without having previous numbers to rely on.

### **5.4 Business models for design consultants**

This is a sensitive question; designers need to follow the rest of the industry no matter what tool or process is implemented. While doing this, the processes within the organization must be streamlined. BIM, both according to the theoretical knowledge and the practical experience, is an effective tool to achieve this streamlining. The focus on immediate increased profit and the fear of loss of compensation may very well be one of the obstacles that restrain the development in many areas. In studies it shows that design consultants have the highest return of investment (ROI), even so the only business model that is discussed is theirs. Comparisons can even be made to the nineties where CAD was implemented. In only a couple of years, CAD knowledge was a criterion to even be able to leave tenders. The transition back then never required any change of business models, even if CAD improved the designers' work remarkably.

The industry in Europe seems to be moving towards an Americanised business situation. Highest possible profit in each project is less important when more resources can be overturned by being an attractive company with more commitments. Even the contractors are starting to change their business models with more aim to be a construction management organization where subcontractors perform most actual site work. Design companies search for new scopes of trade and start to follow the

contractors' lead and engage projects with a broader perspective than just design documents, e.g. project manager services. The big question does not seem to be about forms of compensation, if it is an hour-rate or a fixed price. It is rather a choice of which segment of the market you want to belong. Of course the form of compensation must suit the business process and should probably be managed by the risk management group. If it is possible due to risks and if the client approves then a fixed price would be suitable and large gains might be possible.

## 5.5 Organizational queries

Most of the interviewed actors believed that DB was the most successful organization for BIM projects at the moment. This was mainly due to the fact that the contractor got involved early and could set requirements on the model to suit the production of the building. However this is likely to be because there are general lacks of demands from the clients. In some cases where the client was more active in setting up guidelines for the designers, good results were achieved in e.g. DBB organizations as well.

Many actors also believe more collaboration based organizations to be the right approach for BIM projects. However, at the same time there seems to be a general disbelief in the openness required and these projects were not especially common in any of the studied countries. An important reason for this is likely to be that many business models are based on contracts that the actors do not want to share with each other. Partnering and collaboration based organizations have many benefits but are not suitable for all projects; it is furthermore not a requirement for a successful BIM project.

Most likely there is no right or wrong in this matter and different projects demands different organizations depending on the nature of the project. This will not change because of the use of BIM. BIM is mainly to be seen as a tool to reach the project goals in the most efficient and successful way.

What is important for a successful BIM project is to early on decide what the model should be used for and by whom. When that is done the structure of the model can be customized to suit those requirements. However to use BIM to its full extent it is important to minimize the barriers between actors and not make the organization a barrier in itself. To have an early collaboration between e.g. the estimator and the rest of the project team is vital to have successful value engineering. But as one of the interviewed clients stated it is not always important to get all the potential benefits of BIM in the same project, but rather to use what is most significant for that particular project. If the design is the highest priority e.g. when building a new opera house, it might not be suitable to use a DB organization since the client then wants absolute control over the design. In that case a DBB could be a better choice even though the benefits from early cost estimates with the contractors prices will not be possible. It will always be a question of balancing BIM benefits with the targets of the project.

## **5.6 Responsibilities, use of model in production and use by designers**

When discussing model based quantity takeoffs the responsibility for the extracted quantities was perhaps the most important issue. In Sweden as well as in the foreign countries the general opinion is that the actor building the model should also be responsible for it. However, as many models are coordinated into one, the responsibility is somewhat harder to clarify. A quantity takeoff made from a merged model will contain information from many different actors. If clear guidelines for the building of the model have not been created or if errors have been made, the accuracy of these quantities could be low. Depending on how the quantities have been used this can result in economical conflicts between actors.

Today the most common way of working is that the contractor is responsible for the quantities and performs the model checking to verify the model. This seems to be the case in most of the countries studied, probably since the contractor is regarded to be the main benefiter at the moment. However most actors interviewed believe that the best solution is to let the third-party estimator or a main designer verify the model and be responsible for the calculated quantities. This might be a good solution but some actors stated that it was in fact hard to direct any claims towards such actors and that his liability was often very limited. The actor paying for inaccurate quantities was therefore either the contractor or the client, depending on organization/contract type. Another approach that was used by a client in Norway was to use the quantities from the model but making them fully adjustable.

The other major question regarding responsibility was how the model could be used in production. This seemed to be an issue in most countries since the 2D drawings were still the legal document and the model was used only as additional information. To be able to use the model more efficiently it is probably necessary to change the legislations around the delivered documents. With a fully integrated and valid building model there should not be any need for 2D drawings and the contractor could extract all necessary measurements and sections from the model.

As stated above, there are some issues regarding responsibility that should be addressed to make BIM more efficient. However until these changes are made, using the same processes as today can solve most uncertainties. There are still many benefits from BIM and most legal questions seem to be based on fears for new technology and are not an actual obstacle for BIM use.

## **5.7 Practical implementations**

*Since this study has meant actual meetings and connections to persons with great interest and dedication to their work, several practical implements have been explained and discussed. To reveal them should hopefully be of assistance and inspire someone to start using these in the own organization.*

- Big room meetings, with a specified interval. For example the project group and the design team could meet not only for an hour or two as traditional but perhaps

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a complete day or two days every week. In these meetings decisions are made and drafting is done parallel. This has been noted to shorten the latency of the decisions and creates an opportunity to validate the consequences of different design alternatives since everything is drafted immediately.

- Similar ideas are used in several countries in Europe. In the Netherlands one contractor collects all superintendents every morning and goes through the daily planning. Effects of changes are evaluated immediately and all concerned staff is consulted. The information model is used as a visualization tool where everybody is able to see the extent of the others work to avoid clashes. This has been used with great results.
- Another actor in the Netherlands is reported to use the fourth dimension of BIM, scheduling, to present construction options to the client and the final customers. To sequence which areas are going to be blocked at which times during the construction may be a very valuable tool to convince or seek understanding with a client who is concerned over his production or work activities. This might also be an important competition weapon since the client feels secure with the building activities and a sense of less risk is perceived.
- A Dutch design consultant used different design solutions with scales connected to aspects like economics, space and design. By altering the scales in a document the client could see which alternative best suited his needs. Model based cost estimations were used in this case, even if they only were used to verify the manual estimations.
- A Swedish contractor used PDAs (Palmtop computers) with the model on the construction site. They saw this as a powerful tool for the foremen to display advanced geometries and assemblies to the craftsmen directly on site.

These are a few examples of innovative ways of improving the quality and effectiveness in the design and production phases. Sometimes it may pay off, sometimes maybe not. However the experience it brings may very well be what is driving the development of the construction industry forward.

## 6 Conclusion

*This final chapter will answer the problem formulations stated in the beginning of the report. The answer is based on the overall results from the performed interviews.*

- How is the use of quantity takeoffs for model based cost estimations affected depending on who is setting the requirements of BIM-use in the project?

The actor setting the general requirements for the model is in practise either the client or the contractor. The purpose of the quantity takeoffs seems to differ depending on if it is the client or the contractor who orders them. It might be hard for a client to benefit in an economical way from creating a high quality model during the design phase. However a model of high quality could potentially be a great tool in facility management and operation of the building.

The quantities are most often used for the tender phase, where the result is that contractors base their tenders on the same amounts. In many cases the quantities are fully reimbursable and adjustable which means that the client will have to pay for any additional work that differs from the quantities handed out. A high quality model paid by the client will therefore only result in higher efficiency for the contractor.

If the contractor on the other hand orders the model or draft one in-house the uncertainties will probably decrease and make the contractor more willing to lower his costs. Initially this will only lead to higher profits for the contractor. However as soon as the BIM-use with the contractors reaches a certain point the market forces and competition will put pressure on the prices and that “extra” profit will probably decrease. This way the client gains from the model even in an economical way.

The way the quantities are used is dependant on how the contract is written between the participating actors. As a key rule, the more actors that can reduce their uncertainties the more profits are possible.

The most beneficial for the project would probably be if the client could create such a model so that his needs are fulfilled with e.g. value engineering or presentations tools and that the contractor takes over the model and refines it or that he builds one himself. That way both actors may set their requirements on the model to suit their specific needs. On the other hand it may feel like it is rework to create a second model. If it was possible to coordinate what is needed by both client, designer and contractor and include those guidelines with the client’s general project demands, that would probably be the easiest and most economical solution.

To use model based cost estimations in the most efficient way the contractor should be the one who sets the requirements. This is due to the clients’ lack of cost information and experience from actual construction. It is also the contractor who has the connections and information about the subcontractors’ scope of work. Currently efforts are invested to build databases with cost information from completed projects to allow the client and designer to create accurate estimations themselves.

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- Have the scope of work for the estimator changed due to the use of model based cost estimations? If so, in what way?

Since more focus is put in the early phases of the project and on cost management with tools like value engineering, the estimator's role will probably become more prominent. His work will be to assist as a link between the design team and the client/contractor for evaluating the design alternatives and circumstances around the project. The estimator could be either the contractor or a third party consultant. In either way his role seems to become more integrated with the other project participants than it currently is.

- How do the estimator and designer manage the need for different levels of detail in the cost estimation due to project phase?

The opinion about which level of detail the model should have is widely spread. Some say it is enough with the basic geometry to extract the quantities and then use them for the estimation. Another opinion is that the model should contain as much details as possible as long as the model is still usable with regards to file size.

The most desirable process should mean that a model with a rather low level of detail is used for conceptualization in the early phases. This makes it easy to alter and to experiment with. This is typically based on the architect's model only and contains rough geometries for visualization and quantity takeoffs. By letting the estimator connect this model to a cost estimation, a collaborative cooperation between the design team and the architect could evolve. The model is then refined in certain steps during the design phase to be completely "as-planned" when the construction phase is initiated. The refinement of the model as the project develops is currently not used to a very great extent. To make it work the communication between the suppliers, e.g. contractor, subcontractor and manufacturer need to improve since their cost information is crucial to get the model accurate.

One important feature that is mentioned by several estimators is that the refinement of the model does not have to be to add more geometries or objects. By adding information to an object such as how many meters of cornice a wall contains, a very detailed quantity takeoff is possible. Although this is not very common and there might be practical implications with software.

- Which actor has the largest economical gain of model based cost estimations and how did that gain evolve?

The economical benefits of model based cost estimations are vaguely defined. For the client the increased profits from only the estimates are hard to quantify and measure since it is more a decreased uncertainty about the project cost that is achieved. Timesavings are not the primary gain; the time for making an estimation manually is the same as for a model based estimation. It is when the number of estimations increase that timesavings are won, since the model based estimation is easier to update and to refine.

The largest economical benefit of model based cost estimation is probably the ability to evaluate different design solutions economically. This requires that the estimation

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is fast and easy to connect to the model. This not only generates a lower cost but also means that the client can get a more optimized product according to his requirements. This is not yet fully achieved.

If the uncertainties in the project could be decreased by a safer cost control it might lead to lessened costs for insurances. This will however take time since the estimator and contractor must feel secure with the tools and processes to reduce their insurances. The interviews conducted during this study did not reveal any specific actor that had economical gains from model based cost estimations as of today.

- What do the business model look like for those actors providing estimation services today? Is there a difference between these business models and traditional models and types of compensation?

To see model based cost estimations as a new service or something that will induce money is probably not the right way. Today most cost estimations are done merely as something that needs to be done to keep the project budget under control. This is not likely to change. Maybe, and hopefully the use of cost estimation, not regarding to if they are based on the model or done in traditional ways will increase, both in numbers and in refinement. Model based cost estimating could be a service provided by third party consultants, but over time, these features will be integrated with each actor's organization itself.

In the current situation where the companies are almost overwhelmed with new technologies and processes, model based cost estimations will probably be a contractor's tool, perhaps with aid from consultants from software vendors or BIM-specialists. There will not be a certain business model for these services other than traditional compensation. It should rather be seen as a weapon of competition or a tool for increased cost control within the own organization.



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## **APPENDIX 1**

Questions prior to interviews, 2010

*Cost estimations (5D):*

- Automated cost estimates have only been used in pilot projects in Sweden, how extensive is the use of 5D in your country?
- Have you noticed any demand from the market? What is the owners, designers and contractors general opinion about 5D?
- Which actor do you believe has the largest benefit of automated cost estimates?
- What is the largest benefit? Is it timesavings or undefined cost savings due to higher quality cost control?
- When speaking to Swedish contractors we concluded that the mayor BIM-benefit for them at the moment was clash detections and visualization. Automated cost estimates were not regarded as a particularly powerful tool. Their opinion was that there were no financial benefits of it. Is that the general opinion from contractors in your country as well? Or has a more developed BIM implementation been used containing e.g. 4D and 5D?
- A Swedish consultant, described the implementation process as three phases:
  - Visualization, 3D-modelling, clash detection.
  - Integration, 4D, 5D, site-planning, cost control etc
  - Automatization, industrialized building, processes works as in the manufacturing industry.

Where in that process would you describe your country to be in?

- Is it realistic to increase the level of optimization of the building in the design phase using a higher number of iterations and comparing different solutions in an early stage? Has any reliable proof been presented that more optimization early in the project pays for the extra time the architect or the design consultant has to use?
- In what way does the use of cost estimates affect the cooperation between the calculator and the project manager? How does the shortened time for cost estimates affect the cost control in the projects different phases?

*Organizations:*

- In Sweden most contractors find it easier to reap the benefits of BIM in DB projects where they can be in control and “own their own process”. Are contractors in your country of the same opinion? What is your opinion in this? Pro-collaboration or should the contractor do as they please?
- In your opinion which organization is best suited for the use of BIM?
- How does the implementation of BIM work in classic delivery methods like DBB and DB?
- In DBB and DB projects where BIM is used, has the involvement of different actors changed in the design phase? If so, which actors roll has changed and in what way?

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- How common is collaboration between different actors in for example IPD and partnering projects?
- Do you have any experience from IPD projects? Positive/negative feedback?
- A part in the IPD collaboration is to share an incentive. Does everybody share the same incentive but with different proportion of it? Or does the owner write separate contracts/incentives with each actor?
- While interviewing Swedish actors we realized that when using partnering or types of partnering in projects some actors found it hard to trust each other, since there were no way of controlling the other actors finances. Has this been an issue in the Netherlands and in that case how has it been handled?

#### *Business models:*

- Design consultants in Sweden generally charge owners by the hour. A frequent question is how they should be able to get paid for the increased value they produce in a BIM in less time. How have design consultants in the Netherlands handled this issue?
- How do consultants in the Netherlands charge the owner for the work in a BIM project?
- Today, one way to change the business model for the consultants is to charge by a fixed price. That means you have to streamline your own process to increase your profit. Is there a danger in this for the clients or the contractor?

#### *Responsibility*

- Using quantity takeoff during the construction phase, from a model created by a designer, who should have the legal responsibility?
- Is it possible for a designer to charge extra for the quantity takeoff because of the new responsibility?
- The “as-planned” model consists of several models from different designers; do you believe there has to be a superior designer to take responsibility?
- During the project when the model is transforming into “as-built”, who do you believe should make the changes needed? Which qualifications should exist on the building site, “read-only” or “read & write”.
- In Sweden some contractors have had issues with the responsibility of the model. It is a frequent problem that for example the dimensions delivered by the designer are not sufficient for the contractor. If the contractor instead were to measure the required dimensions himself from the model, he would have to take on the full responsibility. How has this issue been handled in your country?
- If in an IPD-project, how would the answer to the previous question change?

#### *Further development:*

- What do you see as the next step in the building industry? General improvement or single cutting-edge developers amongst the larger actors?
- How long do you think it takes to take the next step in the ladder, visualization, integration, automatization?