LAPPEENRANTA UNIVERSITY OF TECHNOLOGY
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Information and Knowledge Management

POTENTIAL BENEFITS OF BUILDING INFORMATION MODELING FOR BUILDING MATERIAL SUPPLIER

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ABSTRACT

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This thesis investigated building information modeling (BIM) from a material supplier's point of view. The objective was to gain understanding about how a building material supplier could benefit from the growing use of BIM in the AEC (architectural, engineering and construction) industry.

Increasing amount of inquiries related to BIM from customers and other interest groups had awoken target company's interest towards BIM. This thesis acts as a pre-study for the target company related to potential of BIM. First of all BIM and its meaning from a material supplier's point of view was defined based on a literature review. To reveal the potential benefits of BIM for a material supplier a questionnaire survey and in total of 11 interviews were conducted.

Based on the literature review and analyzed results it came clear that BIM offers benefits also for material suppliers. Product libraries and material databases for BIM tools can act as an important marketing channel for material suppliers. Material suppliers could also utilize the information from the BIM models to schedule their deliveries more precisely and potentially even to schedule their own production. All this needs deeper cooperation between material suppliers, contractors and other stakeholders in the AEC industry. Based on the results also first steps for the target company to utilize the growing use of BIM were defined.

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Tämä diplomityö tutki rakennusten tietomallintamista (BIM) materiaali-toimittajan näkökulmasta. Tavoitteena oli selventää miten materiaalitoimittaja voisi hyötyä BIM:n käytön lisääntymisestä rakennusteollisuudessa.

Kohdeyrityksen mielenkiinto BIM:ä kohtaan oli herännyt, koska heille oli tullut yhä enemmän aiheeseen liittyviä kyselyitä asiakkailta ja muilta sidosryhmiltä. Tämä työ on esitutkimus BIM:n potentiaalista kohdeyritykselle. Aluksi työssä määritellään kirjallisuuskatsauksen pohjalta mitä BIM tarkoittaa yleisesti, sekä mitä se tarkoittaa materiaalitoimittajan näkökulmasta. BIM:n potentiaalisia hyötyjä materiaalitoimittajan näkökulmasta selvitettiin kyselytutkimuksen sekä yhteensä 11 haastattelun avulla.

Kirjallisuuskatsauksen ja analysoitujen tulosten pohjalta on selvää, että BIM tarjoaa hyötyjä myös materiaalitoimittajille. BIM työkalujen tuotekirjastot ja materiaalitietokannat voivat toimia merkittävinä markkinointikanavina. Lisäksi BIM malleista on saatavilla tietoa, jonka pohjalta materiaalitoimittajat voivat aikatauluttaa toimituksia tarkemmin ja potentiaalisesti jopa aikatauluttaa omaa tuotantoaan. Kaikki tämä vaatii kuitenkin syvempää yhteistyötä materiaali-toimittajien, urakoitsijoiden sekä muiden alan toimijoiden välillä. Tulosten pohjalta määriteltiin myös ensimmäiset toiminta-askeleet kohdeyritykselle BIM:n hyödyntämiseksi.

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Finally I would like to express my gratitude to my beloved wife Riikka who for the second time has given me her support during a master’s thesis process.

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ABBREVIATIONS

AEC	Architecture, Engineering and Construction
AEC/FM	Architecture, Engineering, Construction and Facilities Management
AGC	American General Contractors
BIM	Building Information Modeling
BOM	Bill Of Materials
bSDD	buildingSMART Data Dictionary
CIB	International Council for Research and Innovation in Building and Construction
COBie	Construction Operations Building Information Exchange
COBIM	Common BIM Requirements 2012
DTH	Dictionary of harmonized technical properties
ETO	Engineered to Order
FM	Facilities Management
gbXML	the Green Building XML
HVAC	Heating, Ventilation and Air Conditioning
IDDS	Integrated design and delivery solutions
IFC	Industry Foundation Classes
IFD	International Framework for Dictionaries
IPD	Integrated Project Delivery
MEP	Mechanical, Electrical and Plumbing
PDM	Product Data Management
PLIB	ISO 13584 Industrial automation systems and integration - Parts library
PLM	Product Lifecycle Management
ROI	Return On Investment
SCM	Supply Chain Management
SPie	Specifiers' Properties information exchange
STEP	Standard for the Exchange of Product Model Data (ISO 10303)
TPS	Toyota Production System
VDC	Virtual Design and Construction
VDI	The Association of German Engineers (Verein Deutscher Ingenieure)
XML	eXtensible Markup Language

1 INTRODUCTION

Product information modeling has its roots in the traditional mass customization but nowadays it is used in various business sectors. The benefits of product information modeling have been recognized also in the architecture, engineering and construction (AEC) industry. In the AEC industry product information modeling is called building information modeling (BIM). But BIM is also much more than just the modeling it is closer to product lifecycle management (PLM). BIM is said to be one of the most promising development trends in the AEC industry (Eastman et al. 2008, p. 1).

As BIM tools are gradually evolving from basic 3D design tools to product information management and PLM tools, also other stakeholders in AEC industry than designers and contractors are starting to show interest towards them. Nowadays BIM could already offer benefits for example in facilities management or for material suppliers (Eastman et al. 2008, 243-245; Grilo & Jardim-Goncalves 2010). So it is clear that interest towards BIM is growing outside the main actors in AEC industry.

Typically BIM is studied either from the designer’s or contractor’s point of view. In this study BIM is studied from a material supplier’s point of view which is seldom discussed. Possibilities of BIM for a material supplier are defined based on comprehensive literature research, questionnaire results and interviews made with different stakeholders in AEC and process industry.

1.1 Background of the study

Interest toward BIM has awoken at Paroc as more and more enquiries related to it have started to come from the customers and other interest groups. BIM has been earlier discussed in separate contexts. For example PAROC® sandwich panels, one of the business sectors of Paroc, has done separate development work related to BIM. On Paroc Group level it hasn’t been earlier discussed what the increasing use of BIM means from insulation supplier’s point of view. For this reasons Paroc had set defining what BIM means from their point of view as a one of the goals in their development strategy.

This study is part of that definition work and it is planned to act as a pre-study to the subject. Therefore the research is done on more generic level instead of being a case study only from Paroc’s point of view. First there was a clear need to define what BIM means in general and from a material supplier’s point of view. Secondly it was pondered if BIM could provide potential benefits for a material supplier and how these benefits could be realized. It was also considered if same kind of possibilities exists in other industry sectors. To answer these questions research questions presented in chapter 1.2 were defined.

1.2 Objectives and limitations of the study

The main objective of the study is *to gain understanding about how building material supplier could benefit from the growing use of BIM in the AEC industry*. As Paroc provides same or same kind of insulation products and solutions also to process industry, the similarities of modeling in AEC and process industry are also studied. Based on the research problem following main and sub research questions were defined.

Main research question:

- ***How building material supplier/manufacturer can benefit from building information modeling?***

Sub research questions:

1. *What is the utilization rate of building information modeling at the moment and how fast is the development?*
2. *Which software are being used and how compatible are they?*
3. *Can a material supplier provide useful information for building information modeling and at the same time promote its own products?*
4. *Does building information modeling produce information which a building material supplier can exploit in its own production or logistics?*

5. *What kinds of risks are associated with building information modeling from a material supplier's point of view?*
6. *Are there similarities between BIM and product modeling in process industry which could be utilized?*

To answer these questions first a wide literature review on generic level to the subject is conducted. The focus is on defining what BIM means, how and how much it is used, and what it means from a material supplier's point of view. Therefore the theoretical part is not limited to handle the subject from a certain point of view or theoretical approach. It covers the background of BIM in generic level with a wide scope.

To gain insight to the subject from insulation supplier's point of view, more practical approach was selected for the empirical part. The empirical part consists of qualitative interviews and quantitative questionnaires. The focus of the empirical part is on major stakeholders in AEC and process industry. The study is limited to cover mainly building and HVAC insulations. Modeling of insulations in process industry applications are studied for comparison. Insulations for ship structures are limited out as it is clearly a separate application area. PAROC® sandwich panels are also limited out of the study because as a separate business sector they already have their own approach to BIM.

The interviews are limited to Finland for practical reasons. In the AEC industry the interviews are limited to three sectors, structural engineering, HVAC engineering and contactors. So the architects are limited out of the study. This is because insulations are defined by structural and HVAC engineers. A semi structured interview method is used so that the focus of interviews can be adjusted according to the interviewee's background.

The questionnaire part of the study is limited to Finland and Sweden as they are the main market sectors for Paroc and have the most potential regarding BIM usage. To gain better overall picture the questionnaire related to BIM has a wider scope. In addition to engineering companies and contractors also precast concrete and prefabricated house manufacturers are contacted. To reach the most interesting and important companies from Paroc's point of view the contacts are limited to known major stakeholders and contacts in Paroc's CRM system. As the main objective of the process industry study is to find out how similar the product modeling is in process industry and AEC industry from an insulation supplier's point of view, the process industry questionnaire is limited to major stakeholders in this business sector and to smaller engineering companies whose contact information is in Paroc's CRM system. This way it is known that all the contacted companies have at least some connection to insulations and modeling of insulations.

1.3 Structure of the study

This thesis consists of six main chapters which can be divided into five categories. Categories are introduction, literature review, empirical research methods, results of the empirical research and conclusions. The inputs and outputs of different chapters divided into the five categories are summarized in table I. The introduction part of the thesis starts with a short description of the background and motives of the thesis. Based on Paroc's motives and needs the objectives of the study are presented in the form of main and sub research questions. Also the limitations on the study are defined. After presenting the structure of the study, the background of Paroc, and thus the main point of view of the thesis, is presented. Finally short introduction to product information management is given.

Chapters two and three form the theoretical part of this thesis. Chapter two, building information modeling, is the main part of the theoretical study. First the definition of BIM for this thesis is derived from prior researches. After that different opportunities and challenges related to BIM in general are described. Also product libraries and BIM standards are described in this chapter. Finally the opportunities and challenges of BIM are discussed from a material supplier's point of view. Based on earlier research the meaning and different possibilities of BIM for a material supplier are described. Chapter three gives insight to how BIM works in practice based on literature. First the building information modeling process is shortly described. After that the commonly used BIM software are presented. The final subchapter gives insight to current utilization level of BIM in the Nordic countries based on previous studies.

Fourth chapter first defines the methodology of the study. Data collection methods are defined and the data collection process is described. The source and selection of data, practical implementation of data collection and the structure of questionnaires and interviews are presented. Also methods to analyze the data and its reliability are presented.

Chapter five present the main results of the empirical part of this thesis. The results are also analyzed and discussed in this chapter. First the respondents' background information is presented followed by the main results of the questionnaires related to BIM. Also the findings from the interviews related to BIM are connected to the questionnaire results. After the main findings are presented they are analyzed and discussed to reveal the possibilities of BIM for a material supplier like Paroc. In the final subchapter of chapter five the main questionnaire results and findings from the interviews related to 3D modeling in process industry are depict and analyzed. In the final chapter, chapter six, conclusions based on the analyzed results are presented to answer the research questions. Based on the conclusions suggestions for Paroc's first steps to leverage the crowing use of BIM are made. Also the quality of the results is evaluated.

Table I Structure of the thesis

Input	Chapter	Output
Introduction		
Background information about the study Motives for the study Description of the target company Introduction to product information management	Chapter 1 Introduction	Research questions and objectives Delimitations Overview to the target company and product information management
Literature review		
Theoretical frameworks of BIM Theory about; opportunities and challenges of BIM, product libraries and what BIM means from a material supplier's point of view Information about BIM standards	Chapter 2 Building information modeling	Definition of BIM Understanding the opportunities and challenges of BIM Understanding different possibilities which BIM offers for a material supplier
Theory about the BIM process Information about BIM software Previous studies about the use of BIM in Nordic countries	Chapter 3 Utilization of building information modeling	An overview to current utilization BIM
Empirical research methods		
Information about research methods Sources of data Information about ways to analyze and evaluate the data	Chapter 4 Research process and data collection	Understanding how the study is conducted and evaluated
Results of the empirical research		
Data from questionnaires and interview The literature review	Chapter 5 Results and analysis of the BIM study	Main results of questionnaires and interviews Analysis of the results
Conclusions		
Main findings of the thesis	Chapter 6 Conclusions	Conclusions Suggestions for Paroc Evaluation of the study

1.4 Description of the target company

Paroc Group is one of the leading stone wool insulation manufacturers in Europe and the leading insulation supplier in Finland, Sweden and the Baltics. Paroc's product range includes building insulation, technical insulation, marine insulation, structural stone wool sandwich panels and acoustics products. Paroc operates in 13 European countries including production facilities in Finland, Sweden, Lithuania and Poland. The history of Paroc reaches back to 1930s when the production of stone wool began in Sweden. In Finland the production started in 1952. In the 1980s the Paroc name was registered for the first time and production of stone wool in Finland and Sweden merged under the same brand. After being part of Partek, Paroc Group became an independent company in 1999. In the 1990s also the expansion of the company continued with several new sales companies and new production plants in Lithuania and Poland. After 2000 Paroc's business has grown steadily, slowed down only by the slump in the construction market after the financial crisis of 2008. (Paroc Group 2012; Paroc Group 2013).

Paroc Group is divided into four business sectors; Building Insulation, Technical Insulation, PAROC® sandwich panels and Base Production. Product range of building insulations is wide and it offers solutions for all types of buildings and various customer groups. Application areas of building insulations are mainly thermal, fire and sound insulation and they can be used for exterior walls, roofs, floors, basements, intermediate floors and partitions. Building insulations also include acoustic products like sound absorbing ceilings and wall panels as well as industrial noise control products. Technical insulations can be divided into insulations for heating, ventilation and air conditioning (HVAC), process industry, marine & offshore and industrial equipment manufacturing (OEM). Technical insulations are used for thermal, fire, sound and condensation insulation. Sandwich panels are lightweight steel-faced stone wool core panels used for facades, partitions and ceilings in public, commercial and industrial buildings. Base production serves the needs of other business sectors as it is responsible for all line production, factory activities, and technology related to stone wool. It is also responsible for the development of building insulation products. (Paroc 2013).

Net sales of Paroc Group in 2012 was 430 million EUR and the average number of employees was 2019 people. Main market areas for Paroc are Finland and Sweden representing 50% of the net sales. The other 50% of the net sales is divided between rest of the EU (32%), other Europe (17%) and other countries (1%). With 87.5% share a total of 34 Banks are main owners of Paroc Group. Remaining 12.5% is owned by Paroc employees. (Paroc Group 2012; Paroc Group 2013).

Paroc's products are sold either directly to end customers, like major contractors, or through wholesalers. The division is not clear because part of the wholesalers' sales is delivered directly to the customer by Paroc and vice versa. Roughly about 60% of building insulations are delivered directly to end customers by Paroc and the rest are delivered through wholesalers. About 80% of the Paroc's own deliveries of building insulations are based on annual contracts. (Fagerlund 2013.)

HVAC products represent about 50% of technical insulations sales and about 25% comes from insulations for process industry applications. Majority of HVAC insulations (about 90%) are delivered through wholesalers. The rest is delivered mainly directly to major construction projects. About 60% of insulations for process industry applications are delivered through wholesalers and the rest is delivered directly to customers by Paroc. (Suurkuukka 2013.)

1.5 Introduction to product information management

Modeling of products has its roots in mass customization. In its simplest form different product configurations in mass customization are created by modeling and combining different modules of a product. The created model contains the information about which modules are to be assembled and the modules contain the information about components to be used. Product information modeling is becoming more and more important as the complexity of products is increasing and the modeling tools are developing. There is also a trend of adding more details to the model. However as modeling is now also used more and more for engineered to order products (ETO), the emphasis should be more on attributes than detailed components and modules. This can help to postpone the decisions about the accurate product structure which can be very helpful when the order handling is performed over a long period and many changes are expected. (Jørgensen 2006, p. 63-66, 82-83.)

One of the main reasons for modeling is the ability to manipulate and test the model before the actual product is build. This way it can be tested that the design works properly. Also the effects of different decisions can be tested beforehand by modifying the model. This is especially beneficial in a situation where a totally new product is designed because in such a case the design is based purely on ideas, thoughts and imaginations. (Jørgensen 2006, p. 67.) This is typically the situation when producing ETO products as customer's needs are taken into account already in the design phase. These types of products are typically produced for example by companies designing and manufacturing industrial machinery, building companies, clothing factories and many handicraft shops. (Forza & Salvador 2007, p. 11.)

On important fact is that modeling can have different meanings to designers. (Jørgensen 2006, p. 66.) For example to Forza and Salvador (2007) divide product modeling into two main perspectives, commercial product modeling and technical product modeling. Commercial product modeling produces the generic product model based on customer's needs and technical product modeling produce's the accurate technical description of a product in form of bill of materials (BOM). The technical model and commercial model can be the same model or separate ones connected through linkages. The model or models can also include a lot of other information than just the technical information and customer requirements. For example graphical model is nowadays typically created and cost estimation models are used. (Forza & Salvador 2007, p. 67-121.) An important thing is also that designers and engineers should be able to create the models concerning their own domain without the help of computer science experts (Hvam 1999). So the usability of modeling tools is an important factor.

As the product complexity is increasing and more and more information is added to the model, product data management (PDM) becomes more important. Also the fact that product information might be stored in different formats within a variety of systems increases the requirements for PDM. PDM is used to manage all the information needed to design, manufacture or build products and then to maintain them. So PDM is not just about handling the technical information related to a product it is also used to integrate and manage processes, applications and information that define a product. In addition to design phase PDM can be used to manage product conception, detailed design, prototyping and testing, manufacturing or fabrication, operation and maintenance. This means that all the information needed throughout a product’s lifecycle is managed by a PDM system. This way correct data is always available to all people and systems that have need for it. Thus PDM not only helps the engineering design phase but also induces benefits like cost savings in manufacturing, reduced time to market and increased product quality. (Philpotts 1996.)

When PDM is used during the whole lifecycle of a product it can be referred as product lifecycle management. PLM includes the management and control of all product related information throughout the whole lifecycle of a product from the first idea to the disposal of the product (Sääksvuori & Immonen 2008, p. 3; Stark 2011, p. 1). This means that PLM covers all phases in both the product process and product delivery process illustrated in figure 1 (Sääksvuori & Immonen 2008, p. 3).

As the lifecycle of products and components is getting shorter and at the same time there is a need to deliver new products to market more quickly than before, the importance of PLM has increased. PLM is very important for companies in the manufacturing, high technology and service industries, especially in situation where they are trying to move from a bulk provider role to a solutions provider role. (Sääksvuori & Immonen 2008, p. V-VI; Stark 2011, p. 3.)

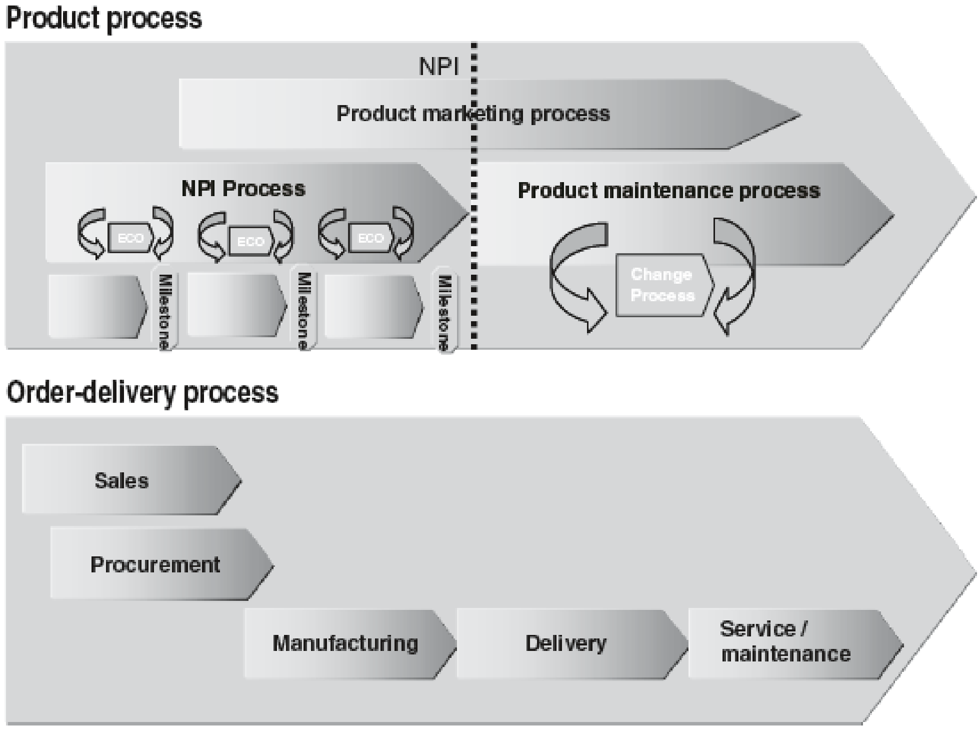

Figure 1. The product process and product delivery (customer) process related to PLM. NPI refers to New Product Introduction. (Sääksvuori & Immonen 2008, p. 4.)

Typically in different phases of the product's lifecycle different departments are responsible for it. This brings challenges to managing the information in coherent way. The situation becomes even more challenging as companies form networks and the responsibility for the product is divided between multiple companies and their different departments. PLM is used not only to share and control the product information but also to manage the product creation and lifecycle processes in these networks of companies. (Sääksvuori & Immonen 2008, p. V-VI; Stark 2011, p. 3.)

So despite of challenges, product information management and modeling can offer many benefits. As mentioned product information management has its roots in mass customization and mass production but it is used more and more even for ETO products. ETO product deliveries are typically project based deliveries. Products are designed and delivered specially for a certain project like buildings in construction industry. This means that product information management and modeling can be utilized also in construction industry like it is already utilized for example in companies manufacturing industrial machinery.

2 BUILDING INFORMATION MODELING

In AEC industry product information modeling is called building information modeling. BIM is said to be one of the most promising development trends in AEC industry (Eastman et al. 2008, p. 1). In general BIM refers to new technologies and processes which are used in AEC industry to create and utilize a virtual model of the building (Taylor & Bernstein 2009). But the idea behind BIM is not something new. According to Howard and Björk (2008) the development of building information modeling has started at least 30 years ago. The focus has been on standards and the development has been lead by researchers, software developers and standard committees (Howard & Björk 2008). In recent years the focus has shifted more and more to the implementation of BIM as large property owners have started to show interest towards BIM (Howard & Björk 2008). The quality and management issues experienced in AEC industry calls for actions like Aranda-Mena et al. (2009) notes. BIM is one potential solution for these types of problems and studies show that the use BIM is expected to grow (Aranda-Mena et al. 2009; Azhar 2011).

AEC industry differs from other areas of industry based on some special characteristics arising from traditional ways of working (Harty 2005). Construction work is based on projects done in close inter-organizational collaboration which leads to high importance of communication and dispersed distribution of power (Harty 2005). Construction projects are typically also very complex (Bresnen et al. 2005) and the traditional way of working depends on paper based information sharing (Eastman et al. 2008, 2). Hence it’s not a surprise that better integration, cooperation and coordination of construction project teams is a widely recognized problem in the industry (Cicmil & Marshall 2005). It is obvious that solutions are needed to reduce the amount of paper based information sharing and to develop better integration, cooperation and coordination of construction project teams. Inter-organizational information systems, like BIM, are one way to achieve this (Maunula 2008, 1). So BIM is not just a modeling tool it can also be a PLM solution for AEC industry. Unfortunately the use of BIM is still mainly passed on old operating models which are based on the paper based information sharing and independent work of different design disciplines (Mäki et al. 2012).

It is widely acknowledged that the use of BIM offers productivity and economical benefits to AEC industry (Azhar et al. 2008). The use of BIM can also enhance the information management in building projects or even totally change the information management during construction projects and building lifecycle (Palos 2012). Despite of the benefits the adaptation of BIM has been slow so far (Azhar et al. 2008). There are both technical and managerial reasons for the slow adaptation of BIM (Azhar et al. 2008). Sometimes also high initial costs are mentioned as a reason for not adopting BIM (Aranda-Mena et al. 2009). Technical reasons are mainly related to interoperability and computability of the design data (Bernstein and Pittman 2005). In the other hand it has been said that the technology for BIM implementation is already available and maturing fast (Azhar 2011; Howard & Björk 2008).

The managerial issues slowing down the adaptation of BIM are more problematic. Azhar (2011) point out that, "there is no clear consensus on how to implement or use BIM". So standardized processes and well defined guidelines for the implementation and use of BIM are needed (Azhar 2011). Howard and Björk (2008) point out that it's not just a question how to implement and integrate different systems and software but how to integrate all the people involved in the process and how to organize their information. This interoperability of business practices in AEC industry's project networks has been largely ignored as the focus has been on technological perspective (Taylor & Bernstein 2009). Also issues related to development and operation of the building information models are problematic. There is no clear consensus about who is responsible for the development and operation of the models and how the cost related to development and operation should be divided (Azhar 2011). Also processes and policies to govern issues related to ownership and risk management have to be developed (Azhar 2011).

Regardless of the issues slowing down the adaptation of BIM, many studies suggest that the use of BIM will increase (Aranda-Mena et al. 2009; Azhar 2011;

Howard & Björk 2008). In fact in recent years the interest towards building information modeling has been growing. Especially large property owners and the public sector have shown interest towards the use of BIM (Howard & Björk 2008). Interest from the public sector may push forward the adoption of BIM and related standards. For example major government clients in Finland (Senate Properties), Norway (Statsbygg) and the US (GSA) are encouraging the use of standardized BIM tools (Howard & Björk 2008).

2.1 Definition of BIM

Problem with the term building information modeling is that it can mean different things to different people (Aranda-Mena et al. 2009). There are many different definitions for BIM and it can be seen at three different levels (Aranda-Mena et al. 2009):

1. “for some, BIM is a software application;
2. for others, it is a process for designing and documenting building information; and
3. for others, it is a whole new approach to practice and advancing the profession which requires the implementation of new policies, contracts, and relationships amongst project stakeholders.”

In addition to many definitions, there are many terms which are related to or regarded as synonyms to BIM. Related terms are for example, object-oriented modeling, project modeling, virtual design and construction, virtual prototyping and integrated project databases (Aranda-Mena et al. 2009). An example of a synonym to BIM is nModeling (Aranda-Mena et al. 2009).

Penttilä (2006) gives one definition for BIM:

“Building product modeling, product data modeling or building information modeling (BIM) is a methodology to manage the essential building design and project data in digital format throughout the building’s life-cycle.”

Aranda-Mena et al. (2009) highlight two different definitions to BIM; the definitions by buildingSMART initiative and the American General Contractors (AGC). AGC (2006; in Aranda-Mena et al. 2009) defines BIM in their publication The Contractors' Guide to BIM as follows:

"Building Information Modeling is the development and use of a computer software model to simulate the construction and operation of a facility. The resulting model, a Building Information Model, is a data-rich, object-oriented, intelligent and parametric digital representation of the facility, from which views and data appropriate to various users' needs can be extracted and analyzed to generate information that can be used to make decisions and improve the process of delivering the facility. The process of using BIM models to improve the planning, design and construction process is increasingly being referred to as Virtual Design and Construction (VDC)."

BuildingSMARTS definition for BIM has changed since Aranda-Mena et al. (2009) cited it. The latest definition for BIM by buildingSMART (2013) is:

"BIM is an acronym which represents three separate but linked functions:

Building Information **Modeling**: Is A BUSINESS PROCESS for generating and leveraging building data to design, construct and operate the building during its lifecycle. BIM allows all stakeholders to have access to the same information at the same time through interoperability between technology platforms.

Building Information **Model**: Is The DIGITAL REPRESENTATION of physical and functional characteristics of a facility. As such it serves as a shared knowledge resource for information about a facility, forming a reliable basis for decisions during its lifecycle from inception onwards.

Building Information **Management**: Is the ORGANIZATION & CONTROL of the business process by utilizing the information in the digital prototype to effect the sharing of information over the entire lifecycle of an asset. The benefits include centralized and visual communication, early exploration of options, sustainability, efficient design, integration of disciplines, site control, as built documentation, etc. -effectively developing an asset lifecycle process and model from conception to final retirement."

In overall it seems that all definitions agree on that BIM includes the digital representation of the building like Aranda-Mena et al. (2009) also notes. But the digital representation of the building is not the same thing as the building information model. In building information model all the relevant information is merged in to the digital representation of the building. It is also clear that BIM is much more than just the model it is also the process behind the modeling. In this thesis the definition of BIM is mainly based to the buildingSMART's (2013) definition which is slightly modified based on AGC (2006; in Aranda-Mena et al. 2009) definition and Maunula's (2008, 6) work. So BIM includes the process, the model itself and the management aspect (figure 2).

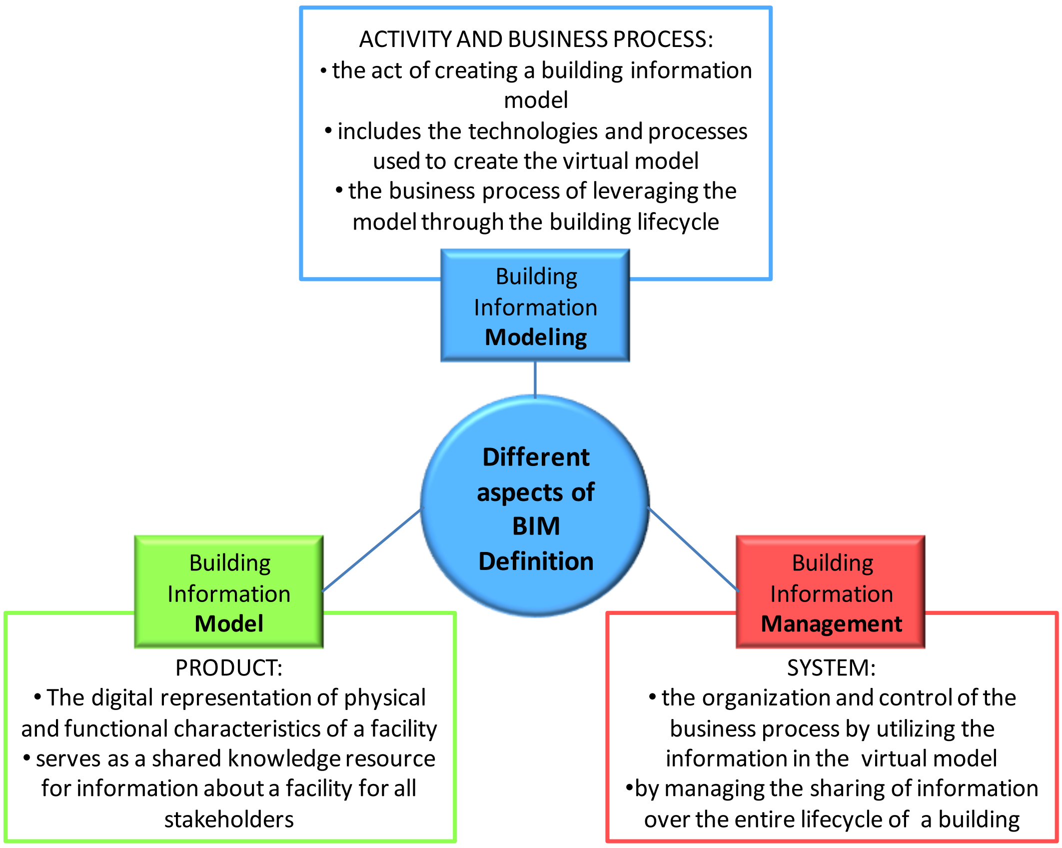

Figure 2. Definition of building information modeling (BIM). Adapted from BuildingSMART's (2013), Aranda-Mena's et al. (2009, ref. AGC 2006) and Maunula's (2008, 6) definition.

2.2 BIM standards

Standards play an important role in communication between different specialists especially if this communication takes place internationally and over long periods (Howard & Björk 2008). Sometimes standards might be seen rigid but standards are the way to ensure interoperability of different ICT tools. According to Howard and Björk (2008) the main benefit from the use of standards compliant tools is the interoperability because not having interoperability will increase costs. The use of standards and the resulting interoperability has many benefits for AEC industry. Palos (2012) referring to Jardim-Goncalves and Grilo (2010) lists five benefits: reduced complexity in semantics, time savings and cost cuts, possibility to reuse data created in one place in another place, possibility to create a common operating scheme and encouragement of innovation. Standards and interoperability are especially important for product libraries in AEC industry because many applications are used in design, engineering and construction and the end product is assembled of components acquired from multiple vendors (Palos 2012).

According to the Howard and Björks (2008) study, which was based on qualitative questionnaire to BIM experts internationally, many standards for BIM already exist. The problem is that they are incomplete, poorly known and there is no proper framework into which they could fit. According to most experts Industry Foundation Classes (IFC) are the ones which should be promoted and ISO standardization could help in this. Work is needed especially in the field of classification and data definition. At the moment object libraries are being developed based on ISO 12006-3 and they will be proposed as an international standard to ISO TC59/SC13. It was also pointed out that data dictionaries should be developed because common terminology is important particularly internationally. (Howard & Björk 2008.)

There are many standards related to BIM. In table II nine major standards or data exchange tools mentioned by Palos (2012) and one major data exchange format mentioned by Eastman et al. (2008, 67-69) are listed. The IFC has been referred as the most ambitious standardization project related to BIM (Howard & Björk

2008). Other major standards related to BIM are different ISO standards like STEP (ISO 10303), PLIB (ISO 13584) and ISO 13567 for standardizing CAD drawings (Howard & Björk 2008; Palos 2012). Autodesk® Seek is not a standard it is software supporting three international classification systems; CSI MasterFormat 2004, CSI OmniClass 1.0 and CSI UniFormat II (Palos 2012). Autodesk® is an example of software vendor’s product which has become at least close to an industry standard. The Association of German Engineers (VDI) maintains the VDI guidelines. VDI guidelines are technical regulations for broad field of technology (VDI 2013a). Next some of the standards are described more closely.

Table II Different standards and their objectives related to BIM. From Palos (2012) and Eastman et al. (2008, 69).

Standard	**Objective**
Autodesk® Seek	Web service for BIM and product specifications exchange.
COBie (Construction Operations Building Information Exchange)	Data exchange guide for construction operations. Developed by several North American public agencies.
DTH (Dictionary of harmonized technical properties)	French system that defines a common language based on harmonized properties, which are suitable for electronic data transfer and BIM purposes.
IFC (The Industry Foundation Classes)	A neutral data format used for describing the exchange and sharing of information in AEC industry.
IFD/bSDD (International Framework for Dictionaries/buildingSMART Data Dictionary)	An open reference library intended to support improved interoperability and enrich the IFC.
PLIB (ISO 13584 Industrial automation systems and integration - Parts library)	Standard for electronic data arrangement.
SPie (Specifiers' Properties information exchange)	A pool for construction industry professionals for open information exchange. Offers a very comprehensive list of properties from over 400 specification sections. Common applications, sustainability requirements, basic materials, and attributes needed for specifying products in construction projects.
STEP (ISO 10303, Automation systems and integration - Product data representation and exchange)	Standard for the Exchange of Product Model Data
The VDI Guideline 3805 (Product data exchange in the Building Services)	A manual for product data exchange. The guideline VDI 3805 Part 1 describes fundamental rules for the exchange of product data in the computer-aided process of planning technical building services.
XML formats (AecXML, Obix, AEX, bcXML, AGCxml)	Different XML schemas have been developed for the exchange of building data. They vary according to the information exchanged and the workflows supported.

2.2.1 Industry Foundation Classes

The development of IFC started at mid 1990s and the first version was issued in 1997 (Howard & Björk 2008). The IFC is developed by International Alliance for Interoperability (IAI) which has been re-branded as buildingSMART (Azhar 2011; Howard & Björk 2008). The IFC is an open standard which describes the exchange and sharing of information in AEC industry. More precisely the IFC is an object oriented data model which describes the structure for sharing data between different applications and is based on class definitions. These class definitions can represent for example elements, processes and shapes that are used by different software applications. As IFC is an open standard it's not restricted to any certain software or controlled by software vendors. (Palos 2012.) This is both a strength and weakness. On one hand open standard gives the possibility to use it for any vendor's software, but on the other hand it typically gives only a limited interoperability between different software (Owen et al. 2010).

At the moment it seems that the development in standardization has been what the BIM experts wished for. IFC is registered as ISO/PAS 16739 and it's becoming an official International Standard ISO/IS 16739 (buildingSMART 2013a; Palos 2012). BuildingSMART (2013b) has also developed a data dictionary which is based on concept in ISO 12006-3: 2007 (Building construction: Organization of information about construction works, Part 3: Framework for object-oriented information). This International Framework for Dictionaries (IFD) is an open, shared and international terminology library that provides open complementary product data definitions, identification and distribution methods (Palos 2012). It is the "vocabulary" for structuring object oriented information exchange (buildingSMART 2013b; Palos 2012). So the IFD library provides terminology, definitions and relationships for generic objects in a model. It also defines a Global Unique Identifier (GUID) for all defined terms in the system (Palos 2012). Through the use of the IFD library product specific data can also be linked to a model (Mehus & Grant 2012). In practice the IFD library is a dictionary for IFC based building information models, a product library for generic products and basis for commercial product library.

Standard for the BIM processes has also been developed by the buildingSMART. This Information Delivery Manual, or IDM, defines when and by whom certain types of information has to be provided during the process. IDM also groups together information that is needed in other activities related to process like cost estimating, volume of materials or job scheduling. IDM has been standardized as ISO 29481-1:2010 Building information modelling - Information delivery manual - Part 1: Methodology and format. Related to IDM a Model View Definitions (MVD) has been created. MVD defines how the information exchange (required data element and constraints) in practice happens by using IFC. So MVD is definition for the software implementation. (buildingSMART 2013c.)

To summarize, the open BIM standard development by buildingSMART can be divided into three separate but interacting parts (figure 3). IFC is the actual data model standard, IFD is the standard about dictionary terms and IDM is the process definition standard. (buildingSMART-tech 2013.) All these are needed to fully implement BIM.

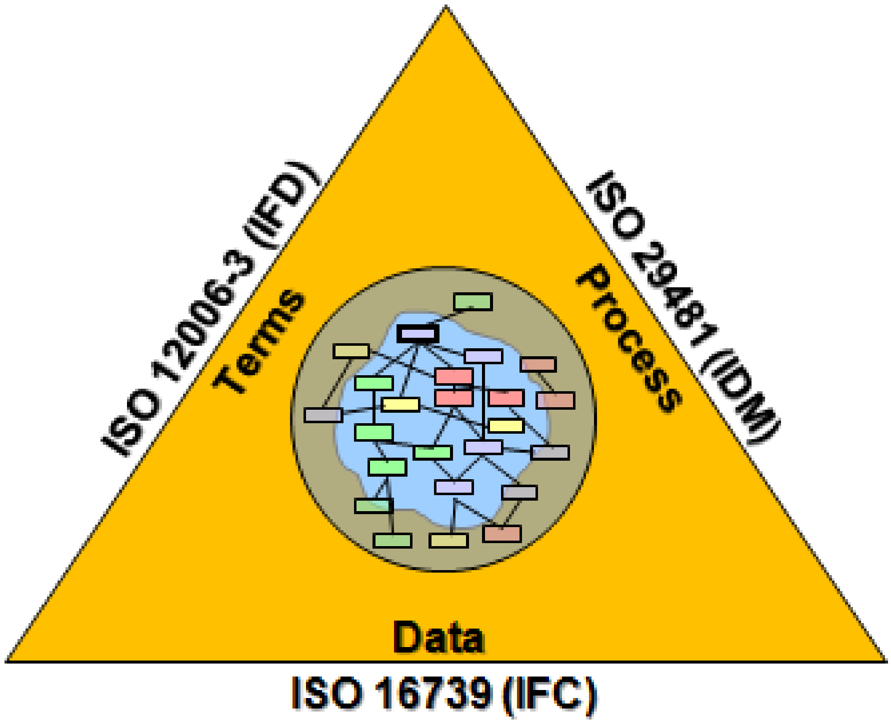

Figure 3. The open BIM standards by buildingSMART (buildingSMART-tech 2013).

2.2.2 ISO standards related to BIM

Other ISO standards related to BIM are for example ISO STEP and ISO 13567. ISO STEP standardization project started at 1985 and its goal is to solve the data exchange needs of different manufacturing industries (Howard & Björk 2008). STEP defines how the values of a material and other engineering properties of products are presented (Palos 2012). It also defines how the composition of products is defined (Palos 2012). So STEP is a standardization project for many different industries but there have been some applications especially for building industry. Applications for building industry include the general AEC reference model (Gielingh 1988) and the building systems model (Turner 1990). General AEC reference model is the STEP product definition model for AEC industry and building system model defines the composition, connectivity and semantical classification of building systems and components (Gielingh 1988).

ISO 13584 Industrial automation systems and integration - Parts library (PLIB) is a standard for electronic catalog for technical components. PLIB defines information, mechanisms and definitions which are needed to exchange, use, archive and update product part library data. It includes both a model and an exchange format for the libraries and it covers the whole lifecycle of a product from product design and manufacturing to use, maintenance and disposal. PLIB has three major objectives: to enhance productivity, quality and data storage/exchange efficiency. Productivity increase is obtained as the components are not modeled several times. The PLIB data models are guaranteed by the supplier of the library which should lead to better quality. Better product data storage/exchange efficiency is achieved as product data of a component is represented only as a reference. (Palos 2012.)

ISO 13567 is a standard for standardizing CAD drawings more precisely for organization and naming of layers for CAD (Howard & Björk 2008). ISO 13567 based CAD layer standards have been implemented especially in northern European countries but they are not that widely used (Howard & Björk 2008).

2.2.3 Other standards related to BIM

The Association of German Engineers (VDI) is a large German, financially independent, politically unaffiliated and non-profit organization (VDI 2013b). VDI is maintaining a database of standards which includes more than 2000 VDI Guidelines for broad range of technologies (VDI 2013a). The VDI Guideline 3805 is basically a set of standards for product data exchange in building services including guidelines mainly for HVAC products. VDI 3805 part 1, Product data exchange in the Building Services – Fundamentals, describes the basic rules for data exchange in the computer-aided process of planning technical building services (VDI 2011). VDI 3805 part 1 specifies the general product data model, the associated data record structure and the description of geometry data, technical data and if applicable any media data (VDI 2011). VDI 3805 is same kind of standard as ISO 13584 but it’s focused on HVAC products.

Autodesk® Seek is not an official standard. It is a web service for exchanging product specifications, BIM models and detailed drawings between users of Autodesk’s software. It gives the product manufacturers an opportunity to upload information about their products into the service and by this way share their product information with designers and consumers. This means that architects and building engineers are able to search, review and download product information from the web service and utilize it directly in their design projects. (Palos 2012.)

eXtensible Markup Language (XML) is an extension to HTML. With XML the structure and meaning of some data of interest can be defined. The structure is called a schema and these schemas can be used to exchange many types of data between different systems. XML is used especially for exchanging information between different Web applications to support ecommerce or collect data. Different XML schemes can support work among different stakeholders working in collaboration but the problem is that these different schemes are not compatible. (Eastman et al. 2008, 68, 84-86.) One of the most interesting XML schemas for AEC industry is the Green Building XML (gbXML). gbXML has been developed to transfer building information between different design tools and engineering analysis systems (gbXML 2012). gbXML is also supported by major CAD vendors like Autodesk and Bentley (gbXML 2012). Also buildingSMART has developed its own XML scheme (ifcXML) which is derived from the actual IFC model (buildingSMART-tech 2013b).

COBie (Construction Operations Building Information Exchange) can be seen as an extension or the next level from the IFC and other standards related. It was developed by several North American public agencies and the goal was to improve the handover process of building owner-operators (Palos 2012). COBie reduces the need of transferring paper documents especially between the contractor and facility operators (East 2007). Also the need for post-hoc as-built data capture is eliminated and operational costs can be reduced (East 2007). The main idea behind COBie is to enter the data as it is created during design, construction and commissioning (East 2007).

The idea in COBie is that designers provide the geometrical layouts of the building and contractors provide the as-build data (Palos 2012). COBie doesn’t include the 3D BIM model as it is a digital representation of the building information model in a spreadsheet data format (East 2007; Palos 2012). This is a major difference to object oriented IFC data format. The COBie spreadsheets contain all the building information in digital form and thus it is exchangeable between modeling software (Palos 2012). The use of spreadsheet data format might seem as a step backwards for object oriented modeling. COBie is a compromise between the 3D object oriented way of representing data and the natural way that practitioners use the data (East 2007). So COBie is a simpler way of representing all the building information and thus the information is also easier to transfer between modeling software. COBie doesn’t anyhow restrict the use of object oriented IFC models. It is an extension to IFC designed especially to improve the data transfer process between contractors and building owner-operators (East 2007; Palos 2012).

2.3 Opportunities and challenges of building information modeling

Use of BIM can bring up many different types of opportunities and challenges compared to traditional ways of working in AEC industry. Many times these opportunities and challenges are directly related to each other. In this chapter, major opportunities and challenges related to BIM are described. Also ways to overcome the different challenges are shortly discussed.

Many studies have been made to reveal the opportunities and challenges related to the use of BIM. Typical benefits mentioned in the studies are better building quality, time savings and economical benefits (Aranda-Mena et al. 2009; Azhar 2011; Fischer & Kam 2002). These benefits arise mainly from better flow of information between different stakeholder and increased collaboration (Aranda-Mena et al. 2009; Azhar 2011; Fischer & Kam 2002; Wong et al. 2010). BIM tools make the design information explicit and available to all stakeholders (Wong et al. 2010) and BIM supports decision making in construction projects through better management, sharing, and use of information (Fischer & Kam 2002). As project data can be freely accessed via various software and media, the sharing and control of project information becomes more efficient (Palos 2012).

According to Azhar (2011) the use of BIM will increase collaboration within project teams. Better collaboration improves profitability, reduces costs, improves time management and leads to better customer-client relationship (Azhar 2011). Case studies conducted by Aranda-Mena et al. (2009) showed that BIM; improves information management and flow, improves coordination, leads to improved design, improves efficiency and reduces the need for rework. In addition to quality improvements and better time management through better information flow, use of BIM can decrease costs by minimizing the cost of reusing project information among project stakeholders and by lowering lifecycle costs of the facility (Fischer & Kam 2002). Lower lifecycle costs can be a major benefit as lifecycle costs have been estimated to be five times as much as the initial capital costs (Evans et al. 1998). Also risks may be lower when utilizing BIM. This is due to better reliability in budget control and the possibility to do more lifecycle analysis and compare different alternatives (Fischer & Kam 2002). Table III shows a summary by Fischer and Kam (2002, 20) of the common benefits related to use of BIM.

Table III The common benefits and respective examples resulting from the use of BIM (Fischer & Kam 2002, 20).

	BIM benefits	**Project Examples**
Quality	(1) Accuracy-improved design quality (2) Improved long-term performance (3) Better decision support	(1) Eliminated both the needs and risks associated with 2D drafting, manual quantity take-offs, and balancing of building systems (2) Life-cycle cost and environmental studies on building system alternatives (3) Qualitative and quantitative analyses of different design alternatives provided informative decision support to the owner and end-users early during the schematic design phase
Costs	(1) Minimized cost for reusing pertinent project information among project stakeholders (2) Lowered facility life-cycle costs	(1) The sharing of the architectural product model benefited the project team to conduct thermal simulations, quantity takeoff, life-cycle analyses, etc. (2) Life-cycle analysis tools projected energy and operation cost through facility's service life span
Risks	(1) Provided higher reliability in budget control	(1) Early generation of budget based on product model and resource data from past projects
Time	(1) Efficiency-reduced design time to allow the project team to conduct more life-cycle analyses and evaluate multiple project alternatives (2) Early inputs from clients and end-users	(1) 3 design and 2 life-cycle alternatives within a tight and fast-track design schedule (2) Aisle location and slope concerns made in VR-EVE (Virtual Reality-Experimental Virtual Environmen)

2.3.1 Pre construction and design benefits

One of the first benefits BIM brings up is the required early involvement of design and construction stakeholders (Hannon 2007). This will lead to increase in upfront costs but it has been shown that overall lifecycle costs of the construction phase are lower due to savings in delays, change orders, claims, etc. (Hanno 2007). Also the possibility to influence is increased in the beginning of the construction project (Hanno 2007) as input from constructors, fabricators, installers, suppliers and designers is available and possible to integrate (The American Institute of

Architects 2007, 22). This concept where the design decisions are made earlier in the project has also been called the Integrated Project Delivery (IPD) approach. The idea in IPD is to integrate knowledge, systems, business structures and practices of different stakeholders into a collaborative process. The "MacLeamy Curve" (figure 4) can be used to illustrate this situation where the design decisions are made earlier in the project as opportunity to influence positive outcomes is maximized and the cost of changes minimized. (The American Institute of Architects 2007.)

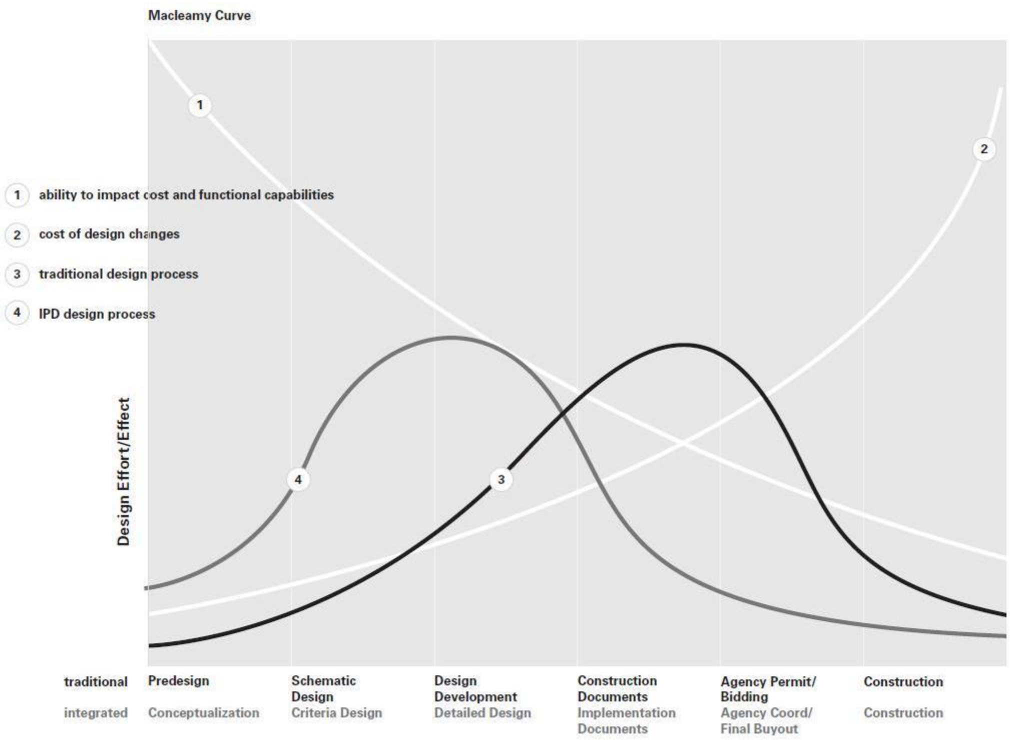

Figure 4. "The MacLeamy Curve" illustrates the concept of making design decisions earlier in the project when opportunity to influence positive outcomes is maximized and the cost of changes minimized, especially as regards the designer and design consultant roles. (The American Institute of Architects 2007, 21.)

In addition to earlier decision the use of BIM enables the design to be brought to a much higher level of completion early on (The American Institute of Architects 2007, 22). This will help especially building owners to evaluate and compare different possibilities and to find out if the planned building can be build in given timeframe and budget. Major benefits can be achieved if BIM based quantity take-offs are used and the model is linked to a cost database including at least historical cost information. Estimations can be even more precise if productivity and other estimating information are available for different components in the BIM model. BIM can also enable for example energy analyses already in the early design phases, which is not possible by using traditional methods. This can lead to major improvements in the building's energy performance which lowers the lifecycle costs of the building. By linking different kinds of analyses, like structural, air flow or building function analysis, to BIM model building quality can be improved. (Eastman et al. 2008, 16-18, 99-100, 167-171.)

Use of BIM also enables more accurate 3D visualization of the model (Eastman et al. 2008, 17). The possibility to visualize the designs early on is a major help in the evaluation and comparison of different possibilities. Visualization is seen as an efficient way to communicate the designs to different stakeholders in the project network (Taylor & Bernstein 2009; Maunula 2008, 47-48). Especially if the stakeholders are not construction specialist, like building owners or end users, visualization can be a very efficient way of communicating different design options to them. For example in Maunula's (2008, 48) case study it was noted that 3D visualization helped the end users to evaluate the architect's designs and to give feedback. BIM and the 3D visualization also make it easier to check early on if the design corresponds to the requirements given to it (Eastman et al. 2008, 18).

The use of BIM also improves the quality of design. As accurate and consistent 2D drawings can be extracted when needed, the need for design change management is reduced and the coordination of the simultaneous work of multiple design disciplines becomes easier (Eastman et al. 2008, 17). Better coordination and the ability to exchange information between different BIM and non-BIM software and systems automatically without loss of data significantly reduces design errors and omissions (Eastman et al. 2008, 17; Wong et al. 2010). Also design problems will be detected earlier and thus the design can be continuously improved. This will lead also to economical benefits as many design problems can be addressed early on before major design decisions are done. (Eastman et al. 2008, 17-18.)

2.3.2 Benefits during the construction phase

The utilization of BIM can be beneficial also during the construction phase. First of all the visual nature of BIM can help in planning and controlling of the construction work. The building and its structures can be viewed and studied from the model beforehand and thus task orders and work coordination can be planned in advance. In addition to planning the construction work, BIM can be used to follow up the actual construction status by regularly updating the actual installation dates of structures and systems to the model. (Karppinen et al. 2012; Mäki et al. 2012.)

Eastman et al. (2008, 18-20) call the use of BIM for scheduling and following the construction work as 4D BIM. It means that construction plan is linked to 3D objects in the model which enables the simulation of the construction process and precise scheduling. This will help to detect possible problems related to for example available crew and equipments, safety issues or delivery schedules. As fourth dimension, time, is added to the model BIM can help in implementing lean construction techniques. (Eastman et al. 2008, 18-20.)

Lean construction means the adaption of lean working methods and process used in other industries to construction. Lean originally arises from working methods and process developed in Toyota called the Toyota Production System (TPS). The main idea in TPS and lean construction is to reduce waste, increase value to the customer and continuously improve. (Sacks et al. 2010.) Use of BIM can help the adaptation of lean especially by better coordination of the supply chain in construction industry. The 4D BIM model can provide accurate information about which resources and when are needed in the construction site. This information can be used by sub-contractors and material suppliers to plan and schedule their work and deliveries. This will help to ensure just in time arrival of people, equipment and materials. This will lead to better collaboration, reduced need for onsite material inventories and reduced costs. (Eastman et al. 2008, 20.)

As mentioned earlier the utilization of BIM improves the quality of design as errors and conflicts are detected earlier. This will help also during the construction process as most of the problems are detected before they have an effect at the construction site. Also problems detected on site and other design changes can be addressed more quickly by using BIM as there is no need for time consuming paper transactions. Also the changes will be automatically updated to all stakeholders and the consequences of a design change to the rest of the model can be checked easier or even automatically. All of this will make the construction process faster, reduces cost, minimizes the risk of legal disputes and makes the process smoother altogether. (Eastman et al. 2008, 19.)

BIM based quantity take-offs are also a major benefit during construction. If the model is done right, BIM provides more accurate quantity take-offs. Also the BIM based automatic quantity take-off calculation is much faster than traditional manual calculation and it reduces the amount of duplicate work. In the future it could also be possible to include material supplier's BIM based design/planning to the model. In addition BIM can be used to model the construction site area and for example different safety issues can be planned in advance. (Karppinen et al. 2012; Mäki et al. 2012.)

2.3.3 Post construction benefits

The possibility to store and share all project related data through BIM doesn't only enhance the actual design and construction process. The BIM model includes information about all systems used in a building and it enables the use of the information for other purposes than design and construction (Eastman et al. 2008, 20-21). For example if manufacturers' information is embedded into the components or objects in BIM it can be retrieved and used for facilities management (FM) and as-built model (Grilo & Jardim-Goncalves 2010). Based on Mäki's et al. (2012) study BIM is not yet utilized in FM and stakeholders in FM don't see clear needs for BIM based information in FM.

But there is potential for the use of BIM models and BIM based information in FM. For example different analyzes made based on the model can be used to check that the building and its systems work properly (Eastman et al. 2008, 20). For example Järvinen (2013) mentioned in his presentation that energy analyzes and simulations can be used to check if the building is working properly by comparing the energy consumption estimates gained from analyzes and simulations to the actual energy consumption of the building. As-build model can also be used as a starting point for managing and operating a building as it includes accurate information about the spaces and systems of the building. The model supports monitoring of real time control systems and it could be used as an interface for sensors and remote operating systems. (Eastman et al. 2008, 20-21). One concrete example is the use of simulation results as a first guess when balancing the air conditioning system (Järvinen 2013).

This type of approach could have a major impact to information management of construction projects and building lifecycle but it requires that BIM is truly used to store all the information related to the building project and that there is interoperability between different software (Grilo & Jardim-Goncalves 2010; Palos 2012; Tulke et al. 2008). To embed manufacturers' information to BIM objects it is also required that there is a commonly agreed method for determining product data in BIM (Palos 2012).

2.3.4 Opportunities of BIM for supply chain management

Common agreement on methods for determining product data would also enable comprehensive use e-commerce and product libraries containing comprehensive product data definitions. Product libraries are described more precisely in chapter 2.4. The possibility to use e-commerce and product libraries would enable automatic identification of products corresponding to the generic products in the building information model. This would lead to savings in resources, possibility to automatically update as-built model as acquisitions are done and more accurate building lifecycle assessments. Also the tendering and procurement processes in over all would be more efficient as less manual work is needed and risk of information losses is reduced. This could benefit and enhance the whole supply chain in construction industry. (Palos 2012.)

Supply chain management (SCM) is more problematic in construction industry than in manufacturing industry. In the construction industry supply chains are more fragmented and less stable than in manufacturing industry. This is due to large number of different product types, national codes, classification systems and the need to support multiple languages. So major benefit from utilizing BIM and BIM based product data management would be more efficient SCM. (Palos 2012.)

2.3.5 Economical benefits related to BIM

The use of BIM and more efficient flow of information will lead also to economical benefits. Economical benefits are mainly indirect because they are due to other benefits related to utilization of BIM like better efficiency of whole construction project and quality of design (Azhar 2011; Palos 2012). These economical benefits have been studied but there is no clear consensus of how the benefits should be calculated. For example the case studies in Azhar's (2011) article showed average BIM ROI of 634%. The study was limited to 10 cases which varied both in scale and scope. Also there was no standard way of calculating the BIM ROI in the studied case projects. As Azhar (2011) also points out, for these reasons the actual BIM ROI can be something else but he estimates that it could be even greater. In overall Azhar's study shows that BIM has a great potential for economic benefits.

Calculating the economical benefits of BIM is difficult because the initial cost might vary a lot, like Azhar's (2011) study shows, and benefits are mainly indirect or do to time savings. The typical economical benefits of BIM come from the other benefits it offers. As the information flow is better and more accurate, less rework is needed because of collisions in different designs (Azhar 2011). It can only be estimated how many of the collisions would have been detected also with traditional methods and how early one. Also less time is needed for scheduling and calculating cost estimates (Aranda-Mena et al. 2009; Azhar 2011). Faster and more precise schedules and cost estimates not only save time but also increase predictability and enable more informed decisions (Aranda-Mena et al. 2009; Azhar 2011). Especially the ability to do more informed decisions earlier might save a lot of money in a building project.

2.3.6 Challenges related to adaptation and use of BIM

Adaptation of BIM doesn't differ from the adaptation of any other major new technology. Acquiring new software and training of users is not enough. Changes to the company's business process are needed, there has to be a clear plan for implementation and support from top level management is needed. (Eastman et al. 2008, 10, 21-22.) To gain the full potential out of BIM all impacted processes have to be examined and potentially re-engineered. Also the role of different practitioners in different processes has to be reassessed. (Owen et al. 2010.) This once more shows that BIM is not just a new technology; it is a whole new way of working in AEC industry. To support the integrated and coordinated merger of people, BIM and other new technologies and processes in AEC industry the International Council for Research and Innovation in Building and Construction (CIB) has launched the integrated design and delivery solutions (IDDS) priority theme (Owen et al. 2010).

After the adaptation of BIM it might be challenging to manage the cooperation and information sharing in a project team. This is because all project stakeholders might not use BIM tools. In such a case the non-BIM drawings and information has to be added to the model by some other party which adds costs and the possibility of errors. Also the project team members not using BIM might need information from the model in 3D CAD, 2D or even paper based format and therefore conversions are needed. (Eastman et al. 2008, 10, 21-22.) In addition to managing the project team it might be difficult to find capable people. The amount of people who truly understand the advanced BIM systems and their capabilities is limited. Also new skills are needed especially related to integration of work processes, information technology systems and prior knowledge. (Owen et al. 2010.)

Even if everyone in a project is using BIM many challenges must be over come to realize the benefits related to free and automatic sharing of information between project stakeholders and their software. First challenge to tackle is the interoperability of different software. As there can be many different companies involved in a construction project, many different software and software infrastructures might also be used (Tulke et al. 2008). Interoperability between different software is not guaranteed as many major BIM vendors address interoperability only among their own products (Palos 2012). In such a situation tools for moving the models between different systems or combining these models are needed. This can lead to increased complexity in the project and risk of errors is increased. (Eastman et al. 2008, 21.) Thus protectionism by major BIM vendors is definitely a challenge for BIM adaptation. To resolve this problem the development and use of open BIM standards should be encouraged (Wong et al. 2010) instead of different BIM vendors developing their own systems.

Just the development of these open standards is not enough. There has to be a common agreement in the AEC industry about the ways to implement and use BIM software and standard compatible solutions has to be demanded from software vendors (Azhar 2011; Palos 2012). The common agreement about the ways to implement and use BIM is the second challenge to tackle. It’s not just a question about the technical implementation of BIM but also about work processes and how different peoples’ work and information is integrated and managed (Howard & Björk 2008). So in addition to standards development there is a need to develop new work processes and management methods for building projects.

Maunula (2008, 64) summarizes in his work three different managerial issues to tackle when utilizing BIM. First is the amount of information needed for decision making especially in the early stages of a project. Lot of information can be available through BIM but the building owner needs to decide which information is needed to support decision making. Second thing is that as there is tighter integration between designers and cost estimators more accurate construction and lifecycle cost estimations can be done. But for this to be efficient it requires that changes in bidding practices of the business processes are made. Third challenge rises from the tighter integration. It brings up challenges in coordination and training and there is a need for a person responsible for overseeing and coordinating the design and construction companies as a whole. (Maunula 2008, 64.)

Interoperability issues are not only dealt between AEC industry stakeholders and software vendors. Many different national and regional initiatives have been launched to solve these problems (Wong et al. 2010; Palos 2012). Even though this may lead to new challenges in a global level in form of different BIM policies, in national level it is helpful if government demands the use of BIM in public sector projects and specifies policies for using BIM (Wong et al. 2010). A clear BIM policy should lead to BIM standards and guidelines which can be created in cooperation with public and private sector (Wong et al. 2010). In this way the different companies in AEC industry will use same policies when adopting BIM and interoperability issues can be resolved.

2.3.7 Risks related to BIM

There are also many risks related to BIM. Azhar (2011) divides these risks to two main categories, legal or contractual risks and technical risks. Ownership of the BIM data is typically the first risk mentioned in studies (Aranda-Mena et al. 2009; Eastman et al. 2008, 22; Thompson & Miner 2007). Typically the building owner is paying for the design and therefore it would seem appropriate that the building owner is entitled to own the BIM design. Problems can arise if project team members have provided proprietary information to be used in the design. In such a case this proprietary information has to be protected somehow. Because of these types of situations questions related to the ownership of the data has to be solved separately in every project. (Thompson & Miner 2007.) For example in the Finnish Common BIM Requirements 2012 (COBIM) it is defined that all models and electronic documents will be handed over to the customer according to the contract (buildingSMART Finland 2013). So the customer doesn’t automatically gain the rights to the model as the ownership of the model is defined in a contract.

Also project team members other than the owner or architect/engineer can provide data to the building information model. In such a case licensing issues can arise. Typically equipment and material suppliers can offer designs related of their own products to help the designers work and at the same time to promote their own products. (Thompson & Miner 2007.)

One risk is related to the entry of data into the model or a product library. It should be clear who is responsible for entering the data to the model and responsible for ensuring the accuracy of the data (Eastman et al. 2008, 22; Thompson & Miner 2007; Palos 2012). Taking this responsibility is a high risk because of the liability issues (Thompson & Miner 2007). Inputting and reviewing the data also causes new costs and it should be defined who is responsible for these costs (Thompson & Miner 2007). In fact the question of dividing costs related to the use of BIM in overall is a major contractual risk to be resolved (Eastman et al. 2008, 22).

The challenge of integrating different BIM software can also be a direct technical risk. As it is important to ensure the proper technological interface between various programs used in a project, it should also be clear who is responsible for this integration. If a proper integration between different programs cannot be achieved then it comes back to the issue of responsibility of the entry of data into the model. (Thompson & Miner 2007.)

Azhar (2011) also brings up the risk of losing a check and balance mechanism related to AEC industry. This check and balance mechanism means that as different participants in the project see each other as rivals they are more keen to critically review each other work and this way find possible mistakes. Azhar (2011) claims that as the use of BIM brings harmony among the participants in a construction project, and they start to see themselves as a team instead of rivals, they might stop to look for mistakes in each other’s work. On the other hand it is clear that BIM improves information sharing and for example Aranda-Mena et al. (2009) emphasize the reduced risk of information related errors as one main benefit of BIM.

2.4 Product libraries

BIM based product libraries enable virtual data management and information exchange (Palos 2012). This enables different stakeholders in a construction project to add their own discipline specific knowledge to design process (Palos 2012). Product libraries also play an important role when utilizing BIM and building information models for supply chain management. Even though it’s not yet common to utilize BIM and building information models for supply chain management (Taylor & Bernstein 2009) it is clear that major benefits could be achieved. Traditionally the designs are based on generic building elements and products. Typically based on their best knowledge designers add some products in to documents as examples of requirements (Palos 2012). During the procurement process these suggested products might be changed without updating the designs and therefore important product data can be lost (Palos 2012). The use of BIM and product libraries could enable a process where commercial products corresponding to the properties of designed generic products would be identified automatically (Palos 2012). Also after procurement the as-built model could be updated automatically.

In addition to ensuring the data integrity in models the use of product libraries can enhance the entire tendering and procurement process. Traditionally construction material information has been obtained from printed catalogues of suppliers (Palos 2012). Based on this information contractor firm’s estimating teams select the best suited products and suppliers based on their experience (Palos 2012). After the selection a lot of manual labor is needed for sending enquiries and handling quotations. Nowadays the use of electronic marketplaces has increased also in construction industry (Jardim-Goncalves & Grilo 2010) which reduces the need for manual labor. But the use of electronic marketplaces solely doesn’t remove the manual process of selecting products and suppliers based on estimator’s experience. For that BIM based product libraries are needed. By using BIM based product libraries suitable building materials and products can be automatically found based on designed models. This will also allow computer aided comparison of product parameters (Palos 2012). In addition to automating the process of searching suitable products the estimator programs based on product libraries could identify building materials or parts in conflict (Palos 2012). In overall the use of BIM based product libraries would reduce the time required for tendering and procurement process which would directly lead to cost savings for all stakeholders in the project and reduced lead time of the construction project (Palos 2012).

To enable these types of automatic processes there has to be common agreements in the AEC industry about the data structure or about a clear methodology of how to move from generic design objects to specific and detailed product data (Kiviniemi et al. 2011). This way reliable and compatible product libraries can be developed. According to Palos (2012) major software developers, in collaboration with user groups, are developing interoperable models and services which would be suitable to all applications. Essential information content for these types of product libraries includes at least identification-, classification-, composition- and performance-information (Palos 2012). In practice the identification and classification data enable general product searches and composition and performance data are the actual technical product data. Typically product data includes the technical specifications, specifications for manufacturing and processing and what resources will be required to produce the good (Palos 2012).

The use of open and interoperable product libraries could open new opportunities for business development and partnering (Palos 2012). This would also make it possible to use suppliers know how and detailed designs to improve constructability. As the use of product libraries reduces the need for manual labor in data exchange it will also reduce errors. This is because many times errors in data exchange occur due to the human intervention (Jardim-Goncalves et al. 2006).

2.5 Building information modeling from a material supplier’s point of view

As BIM enhances the information flow over the whole supply chain, it can offer benefits to all stakeholders in AEC industry. Typically BIM has been studied from designer’s or contractor’s point of view. Only few studies have been made from a material supplier’s point of view even though some major benefits could be gained by utilizing BIM and BIM data efficiently throughout the whole supply chain. Next the opportunities and challenges of BIM from a material supplier’s point of view are described.

As construction process and the actual buildings have become more and more complex, there is a need for multi-disciplinary design and fabrication skills. So many systems and products related to buildings are developed and manufactured or pre-assembled of site. Therefore information flow from designers and contractors to suppliers and back is more and more important. BIM can be utilized to enhance and control this information flow. Therefore BIM can bring direct benefits also to material suppliers. (Eastman et al. 2008, 243-245.)

The problem in AEC industry is that vertically integrated supply chains are very rare and if some kind of integration happens during a project it will last only for the time of that project. Especially from the material supplier's point of view this means that there is now real possibility for comprehensive information and knowledge sharing, learning and improving common working methods through cooperation. Therefore the fragmented supply and value chains in AEC industry are the main obstacle limiting the possible benefits of BIM tools and related processes. (Eastman et al. 2008, 10; Owen et al. 2010.)

As there are many types of components in building industry there are also many types of material suppliers. Eastman et al. (2008, 246) divides material suppliers into three categories according to what kind of components they are producing. First there are the made to stock components which include different standard components like plumbing fixtures, drywall panels, pipe sections etc. Second type is the made to order components which are standard products manufactured after ordering like windows and doors selected from catalogs. The third croup is the engineered to order (ETO) components. These products are designed and customized according to specific needs. Typical ETO components include for example; the members of structural steel frames, structural pre cast concrete pieces, facade panels or custom kitchens. (Eastman et al. 2008, 246.)

According to Eastman et al. (2008, 282) economically ETO component manufacturers could benefit from BIM more than any other stakeholder. They could benefit from BIM same way as for example fabricators in automotive industry have benefitted from the application of computer aided modeling for manufacturing. (Eastman et al. 2008, 282). Owen et al. (2010) also point out that AEC industry could benefit by adopting new work processes developed in other sectors. The better flow of accurate information between suppliers and their customers or customer's designers is beneficial especially to ETO component manufacturers. Efficiency is increased as less effort is needed for producing and updating different documents when using BIM. For example as information is ones entered into BIM system it can be reviewed and used by all stakeholders and there is no need to enter it separately to every stakeholders system or design tool. Also the amount of inaccuracies and inconsistencies is lower when utilizing BIM systems as with traditional methods and documents. Like when designing a building, the actual designing of an ETO component is faster when utilizing 3D BIM tools instead of traditional methods. It is also easier to communicate the design to the customer and for the customer to give feedback. (Eastman et al. 2008, 248-250, 282.)

The benefits of BIM tools and related processes are not limited just to design purposes. When BIM is utilized in the level of new way of working it will enable also the integration of other IT systems than design tools. In addition to information sharing BIM will also lead to knowledge sharing throughout the supply chain. This will lead to possibility for every stakeholder in supply chain to learn from each other and enhance their own work processes. BIM could also enable suppliers to use the designers' design information and the contractors' construction schedules to planning of its own production and deliveries. This would be beneficial to all stakeholders in AEC industry as the supply chain would be more efficient and agile. (Owen et al. 2010)

On more concrete level BIM and related 3D modeling tools can also help marketing and tendering processes of material suppliers and subcontractors. New technologies help the engineers to develop multiple alternatives, detail the solutions more accurately and measure quantities. Sophisticated tools not only enable 3D visualization of products for marketing purposes it can be for example possible to change designs parametrically and thus utilize the embedded engineering knowledge more efficiently. This way design development is faster and the needs of a customer can be satisfied better. As quantities can be measured automatically and more accurately from BIM model or material suppliers own design, more precise offers can be given faster. Shorter response times to tenders can help suppliers to address the client's decision making process and win deliveries. (Eastman et al. 2008, 250-252.)

The use of BIM can bring also many other benefits to material suppliers. Eastman et al. (2008, 251-263, 282) mention for example things like reduced production cycle times, reduced design coordination errors and lower engineering and detailing costs. These are similar benefits that BIM brings to AEC industry in overall and they are mainly due to faster and more precise flow of information and design. From material suppliers' point of view one interesting possibility is the integration of BIM with ERP systems which could lead to various improvements in quality control and supply chain management. One of the possibilities is to adopt pull flow control in manufacturing. This means that work is only performed when there is demand for it from the client (Eastman et al. 2008, 259-263, 282).

BIM related risks especially from a material supplier's point of view are not mentioned in the literature. But the risks related BIM data ownership, protection and validity mentioned by Thompson and Miner (2007) are risk also from material supplier's point of view. The ownership, protection and responsibility of the validity of data provided by a material or equipment supplier are things which should be carefully discussed and agreed on at the beginning of a building project (Thompson & Miner 2007). Especially for ETO product manufacturer the possibility of information leaks through the BIM model can be a major risk. Also because of the liability issues (Thompson & Miner 2007), adding data to BIM model can be a risk for a material supplier. It should be clearly agreed on who is responsible for assuring that the data about products and materials, which is added to a model, is correct and up to date.

3 UTILIZATION OF BUILDING INFORMATION MODELING

In this chapter an overview to the utilization of BIM in practical level is given. First the building information modeling process is described based on the buildingSMART Finland's Common BIM Requirements 2012 (COBIM). After that the commonly used BIM software according to literature are presented. Also findings from previous studies about the use of BIM in Nordic Countries are presented.

3.1 Building information modeling process

Local legislation, standards and operation models affect the BIM process in every country. Therefore the BIM process has to be defined separately in every country. As buildingSMART is an international organization its sub organizations in different countries have same basis for their BIM process descriptions. Therefore the building information modeling process is described next according to the buildingSMART Finland's Common BIM Requirements 2012. COBIM is based on the BIM Requirements published earlier by Senate Properties, user experiences gained from them and also to the thorough experience of the writers of the COBIM (Henttinen 2012). In COBIM seven different stages for BIM process is defined; defining needs and objectives, design of alternatives, early design, detailed design, contract tendering stage, construction and commissioning (Henttinen 2012). In addition to defining what should be done in each stage and how the model can be used in them, COBIM defines in its 13 different parts lot of technical and contractual issues related to BIM. In this chapter only the main idea behind BIM process is presented.

Like in any project, first stage of a BIM passed project is the definition of needs and objectives of the owners and end users. In this phase geometrical model is not necessarily needed but at least the principal space requirements should be recorded in electronic form. This will help the management and checking of requirements during the construction process. Also automatic generation of space objects to the model can be possible. This first stage is very important as many important decisions are already maid and the initial data for the design process is generated. At least the project’s budget, schedule objectives and overall objective for scope are decided. The scope includes gross area, volume and the total areas of different activities. These decisions are made based on so called Requirement BIM. In its minimum Requirement BIM is a room program in a table format and it can be used to compare the program and the design solutions. (Henttinen 2012.)

In the second phase different preliminary alternatives are designed based on decisions made in the first phase. In this phase first rough spatial models are created by every discipline but the architect’s model is the most precise one. Based on these spatial models costs, energy consumptions and lifecycle costs of different possible solutions are compared. This is also the first stage where visualization can be used to compare and check the models. One important thing is to update the requirements as the selection of a certain design solution typically affects them. (Henttinen 2012.)

In the next two phases, early design and detailed design, the selected basic design solutions are developed further based on the architect’s design. All the different models (architect, structural, HVAC etc.) are developed and use of BIM enables fast, illustrative and interactive visualization and analyses. More precise cost estimates and analyses can be done. Also in the early design phase the different models are merged and the joint assessment of different models is started. In the detailed design phase the accuracy of the generated information is raised and the models are brought to level that is required for calls for tenders. After the detailed design stage the models should be on such level that bills of quantities for cost estimates and tenders can be taken from them. (Henttinen 2012.)

After the detailed design stage the models and other documents generated from them are handed over to the contractors. Based on them the contractors can start preparing tenders and plan the construction work. During the contract tendering phase and construction the contractors can use the models for example to better familiarize themselves with the plans, plan installation procedures and coordinate the work. (Henttinen 2012.)

From the modeling perspective commissioning is the last stage. During the construction and commissioning the as-built models and the maintenance manual should be created. These enable the use of the models in maintenance. The maintenance manuals are currently in development stage and they are not typically required. According to the COBIM as-build models should be created during the construction stage. All modifications made during the construction stage should be updated to the models so that the models correspond with the actual end result. (Henttinen 2012.)

3.2 BIM software

Many different software vendors are offering wide range of solutions for utilization of BIM. There are different software solutions for different disciplines like architects, structural engineers, MEP (mechanical, electrical and plumbing) engineers or facilities management. Then there are also software solutions for other purposes than design like cost estimation or viewing and checking the model. Based on literature clear market leaders are hard to define but in table IV is a summary of different software mentioned in literature. In addition to software mentioned in table IV there are software for construction management (e.g. ArchiCAD Constructor and Estimator or DDS-CAD Building), for different project management purposes (e.g. Tocoman Quantity Management Solution or Granlund integration tools) and for viewing and checking the model (e.g. Solibri model checker or NavisWorks) (Kiviniemi et al. 2008, 18).

Table IV Different BIM software solutions mentioned in various publications. (Aranda-Mena et al. 2009; Howard & Björk 2008; Kiviniemi et al. 2008, 17-19; Millichap 2012.)

Discipline			
Architecture	**Structural**	**MEP**	**Facility Management**
ArchiCAD	Tekla Structures	MagiCAD	Bentley Facilities
AutoCAD Architecture	Bentley Structural	AutoCAD MEP	ArchiFM
Autodesk Revit	Allplan (Nemetschek)	Bentley Building Electrical Systems	FMDesktop
Bentley Architecture	StruCAD	Bentley Mechanical Systems	Rambyg
Vectorworks Architect	ScaleCAD	DDS CAD Electrical	Vizelia
	ProSteel 3D	DDS HVAC	
	Autodesk Revit	Autodesk Revit	

Questionnaire in Kiviniemi’s et al. (2008, 121-126) study included questions about the use of different BIM software. Respondents were mainly from Denmark, Finland, Norway and Sweden. There were also 4 respondents from the Nederland. The amount of respondents per country for these questions was so low that no conclusions on the level of different countries can be made. In overall the study showed that for architectural design ArchiCAD is the most used software trailed by AutoCAD Architecture and Revit. Tekla seems to be the most used structural engineering software and MagiCAD the most used HVAC engineering software. Of the programs for viewing and checking the model both NavisWorks and Solibri are used. (Kiviniemi et al. 2008, 121-126.)

3.3 Building information modeling in Nordic countries

The use of building information modeling is growing worldwide. In this study the focus is in Nordic Countries. Nordic Countries, and especially Finland and Sweden, are in main focus because they are main interest areas for Paroc Group related to BIM usage. According to Wong et al. (2010) Nordic Countries are also one of the earliest adopters of BIM outside of North America.

According to WSP Group, one of the world’s leading engineering and design consultancies, Finland is maybe the most advanced country in BIM usage. Sweden is trailing a bit of Finland in overall but is leading in the use of BIM in large and complex infrastructure projects. Norway has a quite small AEC industry but in BIM usage it is at the same level with Finland. (WSP Group 2011, 66-70.)

According to Wong et al. (2010) the involvement of both private and public sector stakeholders to the promotion of BIM usage is the key for effective implementation of BIM in a country. As it can be seen from table V, many stakeholders from private and public sector are involved in promoting and developing BIM in the Nordic Countries. For this reason it’s not a surprise that Nordic Countries are leaders in BIM adaptation. Kiviniemi et al. (2008) have conducted a comprehensive study about the use of BIM in Nordic Countries. It shows that in 2007 CAD was still the dominant design technique but the use of BIM was increasing (Kiviniemi et al. 2008, 88, 90). The study also illustrates that architects in Nordic Countries are the main users of BIM, with about 30% of design work done with BIM tools, trailed by engineers with about 20% and contractors with little over 10% (Kiviniemi et al. 2008, 88). Next the use of BIM in Finland, Sweden and other Nordic Countries is reviewed.

Table V Public and private sector stakeholders involved in promoting BIM adaptation in Nordic Countries, edited from Wong et al (2010).

Country	**Sector**	**Organization**	**BIM Role**
Finland	Public	Senate Properties	Regulator and guidelines developer
	Private	Skanska Oy	Application and research
		Tekes	Application and promotion
		Association of Finnish Contractors	Application and promotion
		Helsinki University of Technology	Education and research
		Tampere University of Technology	Education and research
		VTT	Research and application
Norway	Public	Statsbygg	Application and promotion
		Norwegian Homebuilders Association	Application and promotion
	Private	Selvaag-Bluethink	Application development
		SINTEF	Research and development
		Norwegian University of Science and Technology (NTNU)	Research and education
		Norwegian IAI Forum	Application development
Denmark	Public	The Palaces and Properties Agency	Regulator
		The Danish University and Property Agency Regulator	Regulator
		Defence Construction Service	Regulator
		Gentofte Municipality	Regulator
		KLP Ejendomme	Regulator
		Danish Enterprise and Construction Authority	Guidelines development
	Private	Bips Guidelines	Guidelines development
		Rambøll	Research and development
		Aalborg University	Research and development
		Aarhus School of Architecture	Research and development
		Technical University of Denmark	Research and development

3.3.1 BIM in Finland

In the Finnish public sector Senate Properties has been strongly pushing forward the usage of BIM (Wong et al. 2010; Kiviniemi et al. 2008, 16, 39; WSP Group 2010, 66). Senate Properties has carried out a number of pilot projects and it has required the use of models meeting the IFC standard in its project since 2007 (Senate Properties 2013). This was a real catalyst for development of BIM in Finland (WSP Group 2010, 66). Senate Properties also published detailed modeling guidelines 2007 which have been updated in to Common BIM

Requirements 2012 in 2011-2012 in the COBIM project (buildingSMART Finland 2013). Finland differs from most other countries in the way BIM is used. Typically BIM offers greatest benefits on large projects but in Finland it is utilized efficiently also in smaller straightforward projects (WSP Group 2010, 66).

In private sector, Skanska Oy has been strongly involved in utilizing BIM (Wong et al. 2010; Kiviniemi et al. 2008, 17). Tekes has promoted and funded the BIM development in Finland whereas VTT and the Universities have performed R&D related to BIM (Wong et al. 2010; Kiviniemi et al. 2008, 15). Universities are also offering courses related to BIM (Kiviniemi et al. 2008, 42-43).

According to Kiviniemi's et al. (2008, 19) study in 2007 approximately 33% of design work in Finland was done by using BIM. Kiviniemi's own prior study showed that nearly 70% of all designers had used BIM in some parts of their work but it has to be noted that the sample in the study was small and it was directed to companies with higher interest in R&D (Kiviniemi 2007). Paroc has also conducted a questionnaire in Finland and Sweden about the use of modeling tools in 2010. It was targeted for architects and structural engineers and it showed quite different results about the level of use of BIM. Only about 37% of the 217 respondents reported that they were using modeling tools (Paroc Group 2010). 49% of the respondents in Kiviniemi's et al. (2008, 93) study reported that the use of BIM had increased in past two years. The actual percentage can in fact be much higher because 36% of respondents had no opinion to this question (Kiviniemi et al. 2008, 93). This shows that the use of BIM in Finland is truly increasing.

3.3.2 BIM in Sweden

In Sweden the public sector hasn't been as active in promoting BIM as in other Nordic Countries. The major drivers promoting the use of BIM have been the major contractors like NCC. The major stakeholders have also created organization called OpenBIM which is a national version of buildingSMART international organization. The main focus in BIM usage has been on big infrastructure projects. Regarding the education related to BIM technologies at least the Luleå University of Technology has been active in Sweden. (Kiviniemi et al. 2008, 17, 42-43, 49; WSP Group 2010, 68.)

According to Kiviniemi's et al. study the use of BIM for design work in Sweden seems to be at same level as in Finland, about 33%, but the use of IFC compliant BIM is negligible. Kiviniemi et al. point out that the results concerning the use of BIM in Sweden might be bit too high because over 50% of the respondents were architects. Also in Sweden major part of respondents (51%) reported that the use of BIM had increased in last two years. (Kiviniemi et al. 2008, 87-89, 94.) According to the Paroc's questionnaire only about 35% of the 239 respondents were using modeling tools in Sweden (Paroc Group 2010). This is quite similar result as in Finland.

3.3.3 BIM in other Nordic Countries

The guidelines for BIM usage in public sector projects have been created by Statsbygg in Norway and government in Denmark. In the Norwegian public sector Statsbygg and the Norwegian Homebuilders Association have promoted the use of BIM and in private sector many contractors have invested in BIM. In Denmark also Ramboll, the Danish Enterprise and Construction Authority and an organization called Bips have strongly promoted the use of BIM. Also Universities in Denmark have been active in development and education related to BIM. (Wong et al. 2010; Kiviniemi et al. 2008, 16, 43.)

In overall about 22% of architecture, engineering, construction and facilities management (AEC/FM) companies in Norway have used BIM (Wong et al. 2010). In Denmark approximately 50% of the architects and 40% of the engineers have used BIM in their projects according to the surveys conducted by B3D-kosortiet (2006a,b; in Kiviniemi et al. 2008, 22-23). Kiviniemi et al. (2008, 20) study showed that the volume of design work done with BIM is in Norway little under 15% and in Denmark little over 20%.

4 RESEARCH PROCESS AND DATA COLLECTION

In this chapter the research process and data collection methods of the present study are described. This study consists of both quantitative and qualitative part. A quantitative survey was selected to clarify the current situation in the industry and qualitative semi structured interview was selected to find out the future prospects. This type of combined research method can be called mixed method research (Creswell 2009, p. 4). To truly be a mixed method research the two different methods have to be combined so that they truly complete each other (Creswell 2009, pp. 4, 14-15).

4.1 Research methods

Quantitative approach was used to collect information about the current situation of BIM usage in the industry. More precisely a survey questionnaire was conducted. Survey provides quantitative information about trends, attributes or opinions of a population (Creswell 2009, p. 145). Therefore it is well suited for collecting data about the current situation in the industry.

A qualitative semi structured interview was selected as a method to complement the survey. The goal of the interviews was to gain more precise information about the actual use of BIM and future trends in the industry. According to Hirsjärvi and Hurme (2001, p 35) interview is a good selection if the research area is quite new. Interview is also a good way to get more deep information about the studied subject (Hirsjärvi & Hurme 2001, p.35). For these reasons interviews were selected to complement the survey part of the research. As the point of view of the study was new and the background of the interviewees varied, a more open interview method than structured interview was needed. Semi structured method called theme interview was selected. In theme interview the themes of discussion are selected in advance but the questions can vary according to the interviewee (Hirsjärvi & Hurme 2001, pp.37-48). Thus theme interview gives more freedoms related to direction and depth of the interview than a structured interview.

4.2 Data collection

Data collection was started from the interviews. First the most interesting companies were selected from the lists of biggest engineering and construction companies in Finland. It was assumed that all of these companies were using BIM in some level. The companies were contacted based on contact information in their web pages or by contacting an already known contact. The actual interviewees were selected according to the recommendations of the first contact. At least one interview per contacted company was conducted. From one company three separate interviews were conducted and from two companies two persons participated in the same interview. In total 11 face to face interviews with 13 interviewees and on e-mail interview were conducted. All the face to face interviews were recorded. The interviewees represented 10 different companies from four different business sectors; structural engineering, HVAC engineering, building contractor and process industry. The backgrounds of the interviewees varied from designers to head of engineering department and BIM experts. Backgrounds of the interviewees are described in appendix I and themes for interviews are presented in appendix II.

The electronic questionnaire part of research was prepared during the interviews. This way information from the first interviews could be used to select the most appropriate questions and response alternatives for the questionnaire. Two separate questionnaires were prepared. First one was related directly to the use BIM. It was targeted mainly to structural engineers, HVAC engineers and building contractors but also some pre-cut house manufacturers and concrete panel manufacturers were contacted. The second questionnaire was related to the use of 3D modeling in process industry. It was targeted to largest technology and equipment suppliers and engineering offices in process industry sector. The second questionnaire was also sent to some smaller engineering offices. Both questionnaires were conducted in Finland and Sweden and they were translated to corresponding native language. The basic structure of the BIM questionnaire and the questionnaire for process industry stakeholders was the same. The questionnaire for process industry stakeholders was rephrased from the BIM questionnaire and some specific questions related to utilization of BIM were excluded. Structure of the BIM questionnaire is depicted as an example in appendixes III. The questionnaire has been translated into English.

The questionnaires were sent to companies via e-mail which included a link to the questionnaire. The e-mail contacts were mainly selected from list in Paroc's customer relationship management system. Some contacts were obtained from companies' web sites and from direct contacts to companies. Regarding the interviewed companies, the questionnaire was sent to the interviewed person or to person whom the interviewee suggested. In Finland the BIM questionnaire was send to 336 companies. 10 companies e-mail addresses were inactive so 326 companies were reached. In Sweden 200 companies were contacted from which eight were inactive, resulting in 192 active contacts. The questionnaire for process industry companies was send to 27 companies in Finland which all were active contacts. 13 companies in Sweden were contacted from which one was inactive. So there were 12 active contacts for Sweden. After sending the questionnaire two reminders about it were sent.

4.3 Methods for analyzing the data and its reliability

In this chapter data analysis methods in general and for this study are presented. First the analysis of quantitative questionnaire results is discussed followed by the analysis methods for interview results and open answers from the questionnaire. Finally the evaluation of reliability of the study is discussed.

According to Bernard (2013, p. 393) both qualitative and quantitative data can be analyzed in qualitative and quantitative ways. Different possibilities are defined in table VI. Data analysis consists of searching for patterns in data and finding out explanations for those patterns (Bernard 2013, p. 394). Thus essentially all analysis is qualitative (Bernard 2013, p. 394).

Table VI Qualitative and quantitative analysis of qualitative and quantitative data (Bernard 2013, p. 393).

Analysis	**Data**	
	Qualitative	Quantitative
Qualitative	Iterpretive text studies. Hermeneutics, Grounded Theory	Search for and presentation of meaning in results of quantitative processing
Quantitative	Turning words into numbers. Classic Content Analysis, Word Counts, Free Lists, Pile Sorts, etc.	Statistical and mathematical analysis of numeric data

4.3.1 Methods for analyzing the questionnaire results

Literature offers a wide range of quantitative analysis methods for different kind of quantitative data. As this is a pre-study and exploratory in nature, questionnaire questions were simple multiple choice questions. Also the main goal of the questionnaire was to find out simple statistical fact about the use of BIM. Therefore no special statistical or mathematical methods are used to analyze the questionnaire results in this study.

Percentages of respondents who selected certain response alternative are calculated. As the main goal is to gain basic understanding of the use of BIM in Finland and Sweden, visual inspection of bar and pie graphs is the main method for finding patterns in the results. So the data analysis of questionnaire results in this study is mainly qualitative.

4.3.2 Methods for analyzing the interview results

According to Hirsjärvi and Hurme (2001, p 136) analysis of interviews can starts already during the interviews if the researcher does the interviews by himself. After the interviews the analysis process can be divided into three phases. The phases are transcription, reading the material and the actual analysis. There are many quantitative and qualitative methods for analyzing data from interviews. For theme interviews at least quantitative thematizing is an oblivious choice. In thematizing the interview data is classified according to the themes used in the interview. This way factors which are common for several interviewees can be found. (Hirsjärvi & Hurme 2001, pp. 138-142, 173).

The actual analysis phase can further be divided into four phases; description of the data, classification of the data, combination of the data and interpretation of the data. Description of the data is the basis for the actual analysis. Its goal is to answer the questions who, where, when, how much and how often. To limit the length of the report it should however be carefully considered what needs to be described and how accurately. Classification is the basis for interpretation. During classification the researched phenomenon are structured by comparing different parts of the data with each other. Selecting the classes for classification can be problematic. Criteria for forming the classes are connected to the research scheme, quality of the data and also to researcher's own theoretical knowledge and capabilities to use this knowledge. The classes can be defined for example based on following factors. (Hirsjärvi & Hurme 2001, pp. 143-152).

- The research question and sub research questions
- Research tool or method
- Concepts and classifications used in prior studies in the same field
- Theories and theoretical models
- Data itself
- Imagination and intuition of researcher

Purpose in combining the data is to find out regularities and similarities within and between the classes. This is the basis for interpretation of the data. Especially interviews can be interpreted in many ways and from many different points of views. This means that typically there is no single right interpretation of the data and all interpretations are based on researcher's personal knowledge and opinions. (Hirsjärvi & Hurme 2001, pp. 149-152.)

In this study the analysis of interviews was started already during the interviews. Knowledge and experience gained from first interviews was used to focus the following interviews more precisely and in the preparation of the questionnaire. The recorded interviews were transcribed, read through and classified into classes according to the interview themes used. These themes were further divided according to the research questions. At this point also the open answers from the questionnaires were added to the analysis. Factors which occurred most frequently in the data were raised up in the analysis. But as the background of the interviewees varied and they weren't evenly divided between business sectors accurate quantitative analysis were not done for the data. Also some factors which are interesting from a material supplier's point of view were raised up even though they were mentioned only by one of the interviewees. So even though quantitative analysis method thematizing is used, the final analysis of the data is mainly based on the researchers own interpretations after comparing the findings with previous literature.

4.3.3 Methods for evaluating the reliability of the study

Reliability of data means that you get the same answer when asking the same thing from same person more than ones (Bernard 2013, p. 46; Hirsjärvi & Hurme 2001, p. 186; Plumb & Spyridakis 1992). In questionnaires this can be measured for example by asking few things in different way twice (Plumb & Spyridakis 1992). Problem is that this makes the questionnaire longer and that can lower the response rate (Plumb & Spyridakis 1992). So it has to be considered which is more important evaluating the reliability or the response rate. Other part of reliability is validity. Validity can be divided into internal and external validity (Hirsjärvi & Hurme 2001, p. 188; Plumb & Spyridakis 1992). Internal validity is the degree to which the survey actually measures what it is supposed to measure, and external validity means the extent to which the results can be generalized to the tested population (Plumb & Spyridakis 1992).

For qualitative interview data determining the reliability is more difficult because at least time and context can affect the interviewee's responses. Therefore the evaluation of reliability and validity of interview data can be questioned. The reliability of interview data depends mainly on the quality of the data and that all data is acknowledged. Validity in qualitative research is mainly defined by the researcher's ability define how he or she has reached the presented classifications and interpretations. (Hirsjärvi & Hurme 2001, p. 184-190.)

5 RESULTS AND ANALYSIS OF THE BIM STUDY

In this chapter the main empirical results of this study are described and discussed. First the response rates and some basic background information about the respondents and companies which they represent are shown. In the second subchapter the main questionnaire and interview results related to BIM are presented. After the main results related to BIM are presented, they are discussed in sub chapter 5.3. Also some more findings from the interviews are presented. Finally the main findings from the questionnaires and interviews related to 3D modeling in process industry are presented and discussed.

In the following chapters only those questionnaire results which are relevant for this study are presented. Some original results, combination graphs and filtered results are also shown in appendix IV. All questionnaire results cannot be presented due to space requirements.

5.1 Response rates and background information

To the BIM questionnaire for AEC industry stakeholders 74 responses were obtained from the 326 active contacts in Finland and from Sweden 35 responses were obtained from the 192 active contacts. So the response rate for Finland was 23% and for Sweden 18% resulting in total response rate of 21%. The response rate for process industry questionnaire in Finland was 48% as there were 13 responses from the 27 contacts. From Sweden only two responses from the 12 contacts were obtained so the response rate was 17%. The total response rate for process industry questionnaire was 38%.

The respondents were first asked if they were the first ones from their company to answer the questionnaire. The idea was that as the respondents were given the opportunity to forward the questionnaire to other people in their organization this question would have been used to filter one answer per company where necessary. Unfortunately only three respondents in total informed that they were not the first respondents from their company and quite many chose the alternative “I don’t know” (figure 5). As the amount of “I don’t know” answers was quite high responses from these respondents are not filtered out from most of the results. This of course lowers the reliability of some results as more than one answer from the same company might be in the results. But in overall this was seen as a smaller problem than the lower amount of responses if responses from the respondents who didn't know if they were the first respondents from their company would have been filtered out.

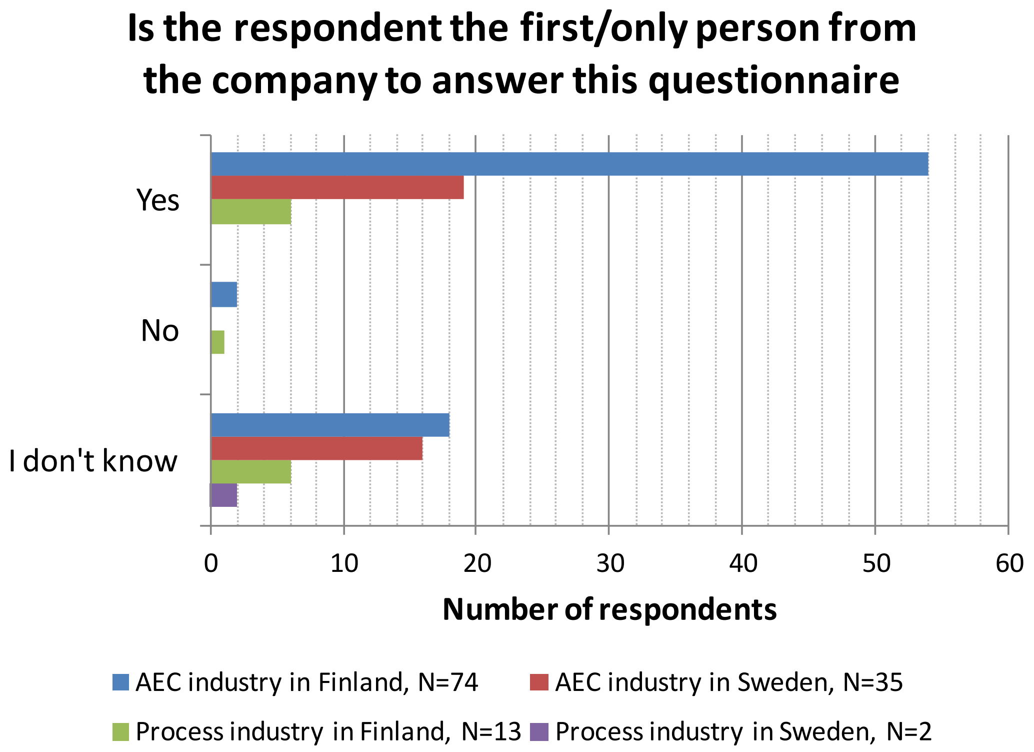

Figure 5. How many of the respondents are the first or only respondents from their company to the AEC and process industry questionnaires in Finland and Sweden.

Age and gender distributions of the respondents are shown in figures 6 and 7. Respondents from Sweden were quite evenly distributed to different age groups but in Finland the mature age groups were bit emphasized. Most of the respondents were men what was expected based on the general gender distribution in the studied business sectors.

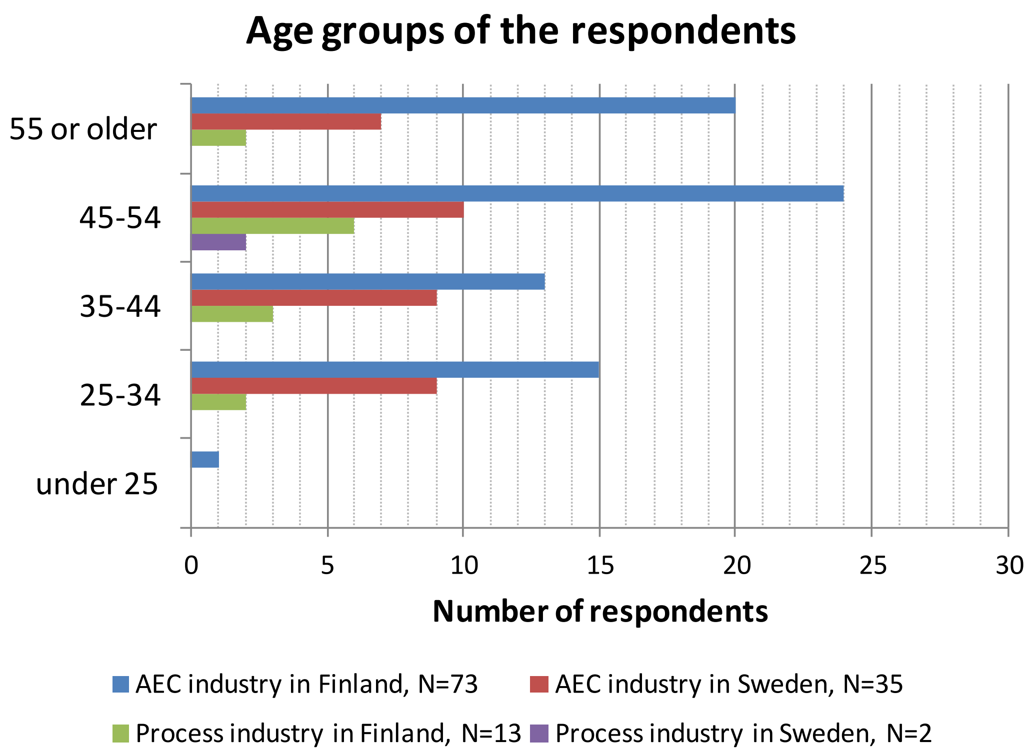

Figure 6. Age distribution of the respondents for AEC and process industry questionnaires in Finland and Sweden.

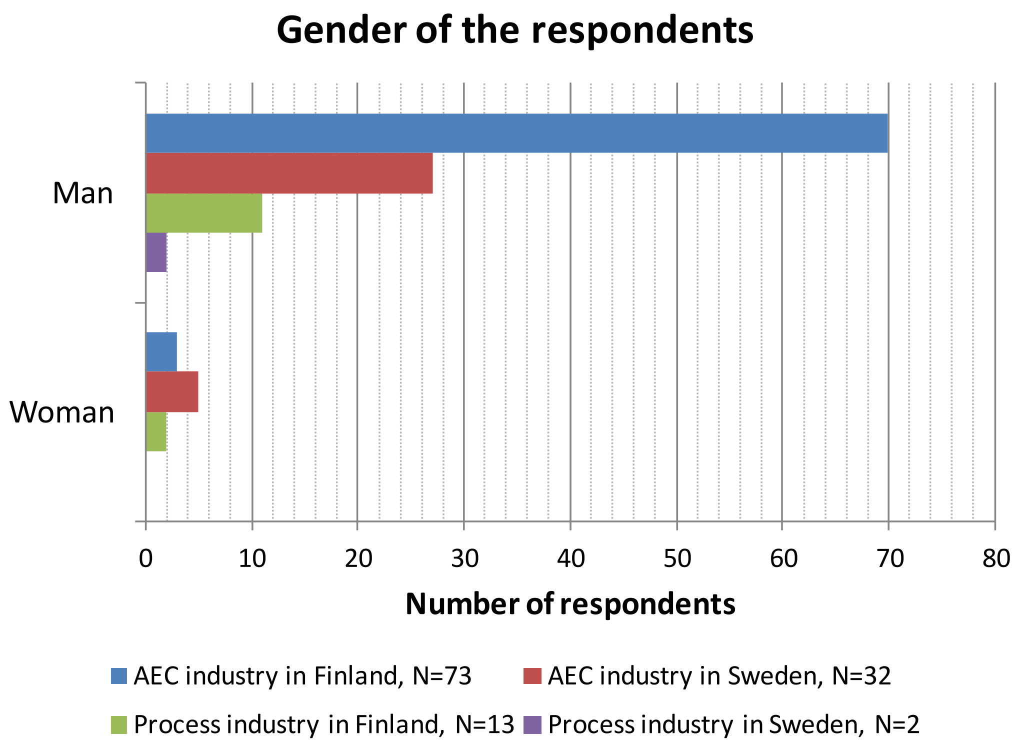

Figure 7. Gender distribution of the respondents for AEC and process industry questionnaires in Finland and Sweden.

In figures 9-12 results about the size, fields of operations and areas of activity of the companies which the respondents represent are illustrated. Figure 8 depicts the size distribution of the AEC industry companies which the respondents represent. 42% of the respondents to the BIM questionnaire for AEC industry stakeholders represented companies with less than 10 employees and 68% on the respondents represented companies with less than 50 employees. So most of the respondents were from smaller companies but there were also quite many responses from larger companies. The size distribution of construction industry companies in Finland in 2011 (Tilastokeskus 2013) is shown as a reference in the figure 8. Compared to this the amount of large companies was emphasized in the results. But as the main target groups of the study were the larger companies and Paroc's customers, this is an expected result.

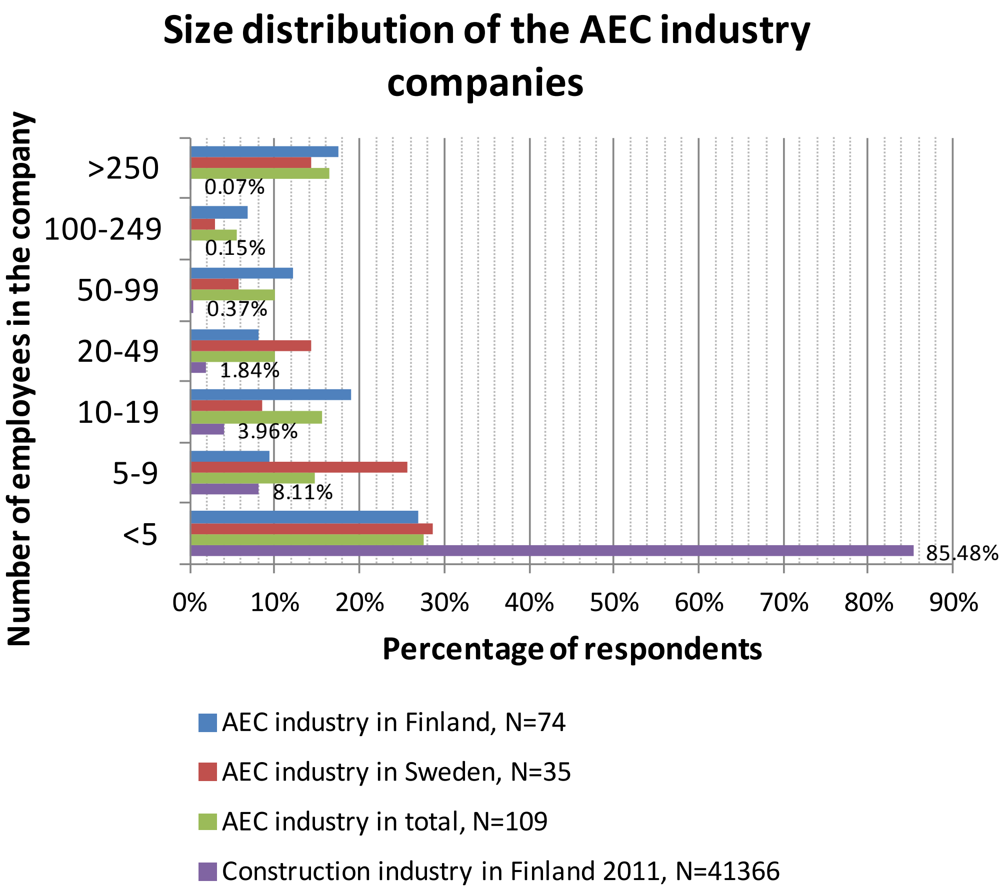

Figure 8. Percentage of employees in the AEC industry companies which the respondents represent. Results from Finland, Sweden and combined. Size distribution of construction industry companies in Finland in 2011 as a reference (Tilastokeskus 2013).

Figure 9 shows the fields of operations of the AEC industry companies that the respondents represented. It’s important to take into account that respondents could select more than one answer for this question. This shows especially in the amount of representatives of companies responsible for architectural design. No architectural companies were knowingly contacted but 21 out of the 109 respondents informed that their company is responsible also for architectural design. This is because many of the structural engineering companies are also working in the field of architectural design. 18 out of the 21 respondents who had selected architectural design for their company’s field of operation had also selected structural engineering.

In overall most of the respondents were from companies responsible for structural and/or HVAC engineering. This is not surprising as most of the contacts were from those sectors. Responses from other sectors of AEC industry were also gained. In total 30 respondents represented contractors, precast concrete manufacturers or prefabricated house manufacturers.

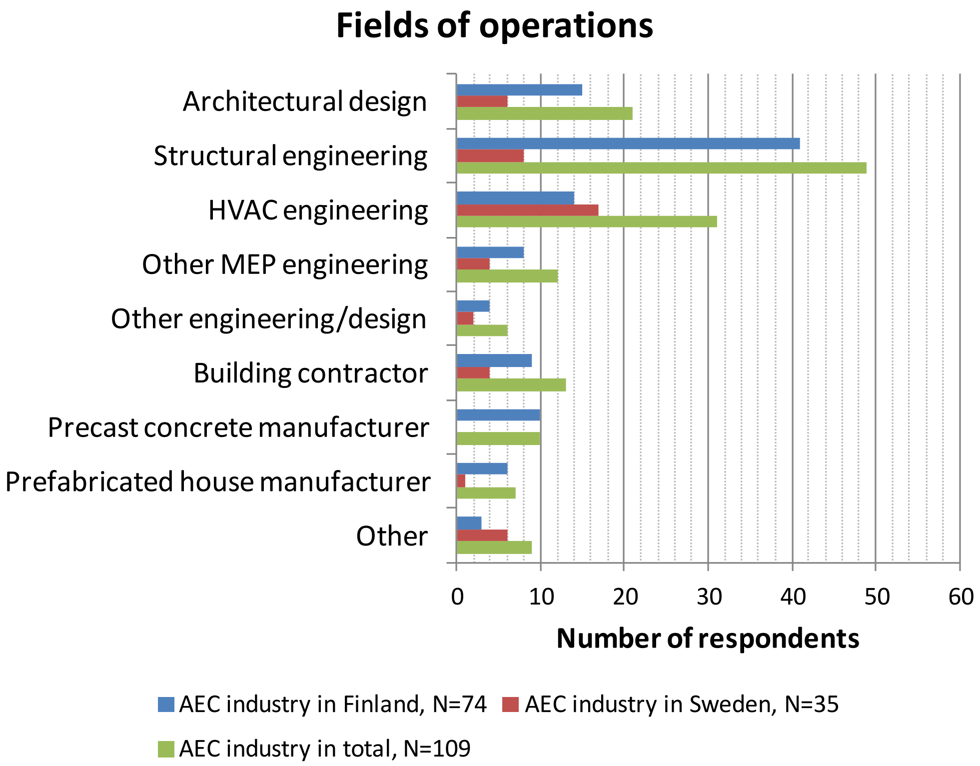

Figure 9. Fields of operations of the AEC industry companies that the respondents represent. Results from Finland, Sweden and combined.

Based on figure 10, nearly all of the AEC industry companies in Finland and Sweden act only locally. Some have activities in neighboring countries and only few have activities in larger geographical area. As the results were analyzed more carefully it was found that only four companies, that had fewer than 100 employees, had operations outside the Nordic countries, Baltic or Russia.

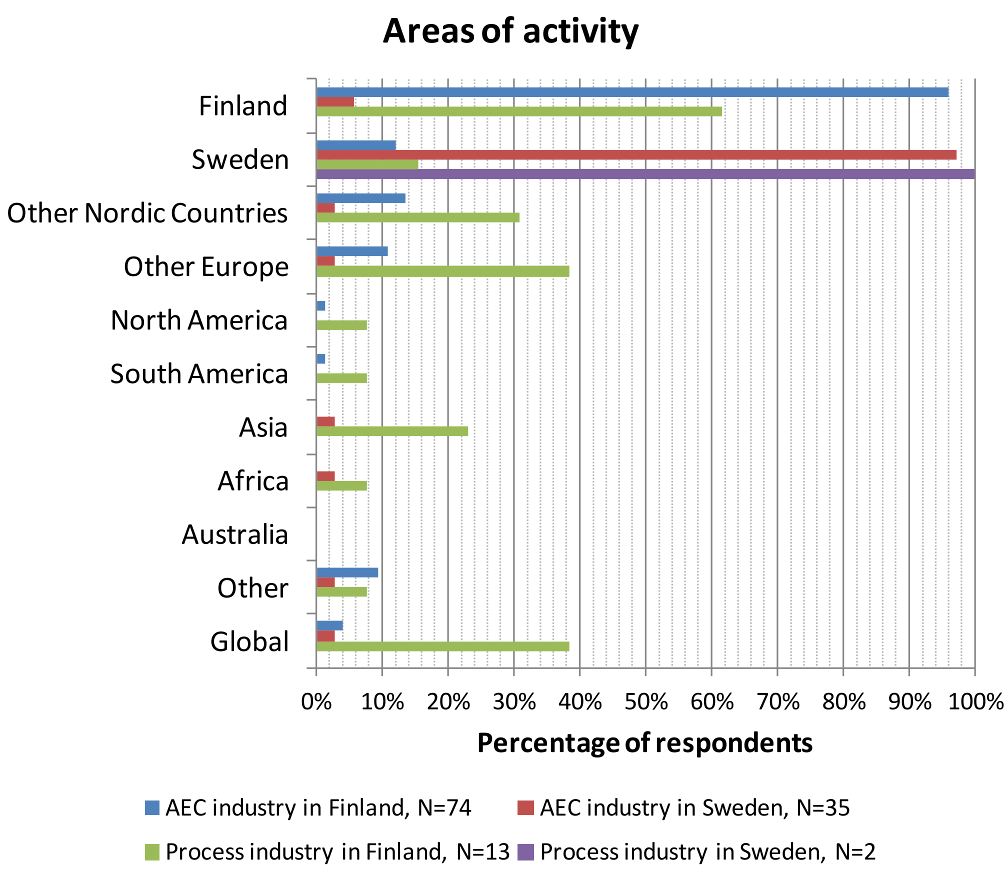

Figure 10. Areas of activity of the companies that the respondents represent. Results from AEC and process industry questionnaires in Finland and Sweden.

Figure 10 indicates that process industry companies, which the respondents represent, have more international activities than the AEC industry companies. As the amount of respondents for the process industry questionnaire is low rest of the results are presented as numbers of respondents. In total six out of the 15 respondents represented a company with more than 250 employees (figure 11). This is an expected result as mainly larger companies were contacted. Most of the respondents represented engineering companies but quite many responses were also from different plant or equipment manufacturers (figure 12).

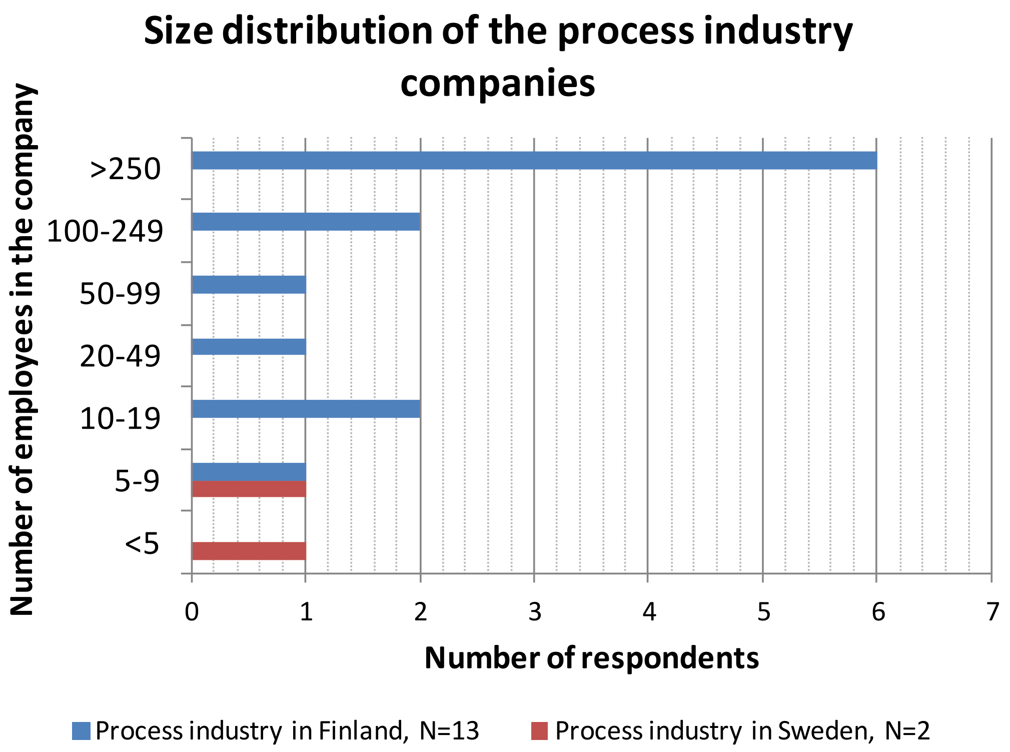

Figure 11. Number of employees in the process industry companies which the respondents represent. Results from Finland and Sweden.

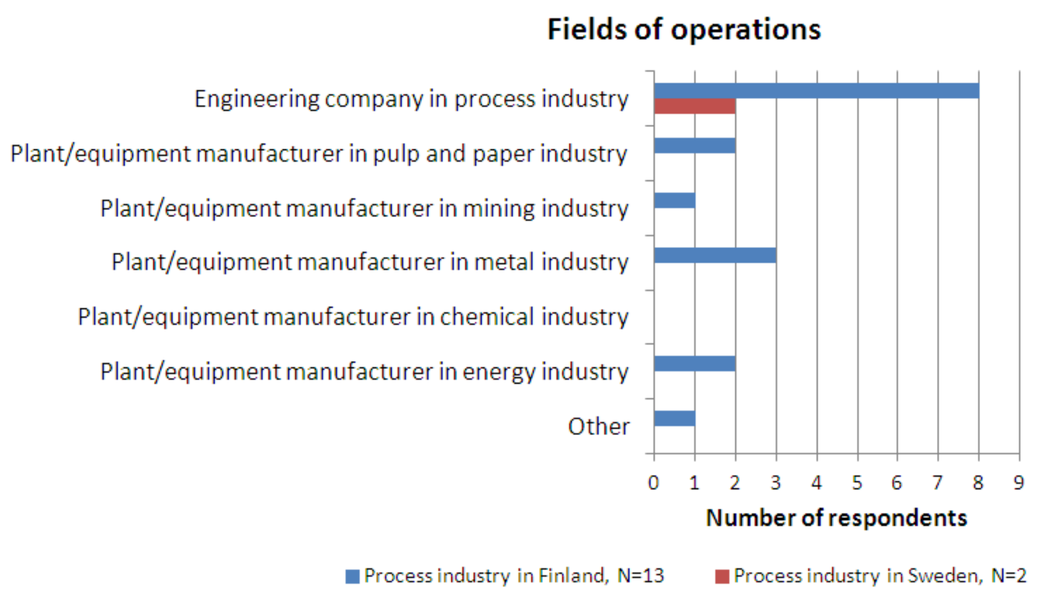

Figure 12. Fields of operations of the process industry companies which the respondents represent. Results from Finland and Sweden.

5.2 Main results of the questionnaires and interviews related to BIM

In this subchapter main results of the questionnaires and interviews related to BIM are presented. First the questionnaire results about the use of BIM in Finland and Sweden and the related findings from the interviews are presented. After that the questionnaire results and findings from the interviews related to the use of different BIM tools are presented. Then the results describing what information is needed from a material supplier for modeling, how much product libraries are used and what information from BIM a material supplier could utilize are depict. Finally results related to benefits and the future prospects of BIM are presented followed by emerged risks related to BIM.

5.2.1 Utilization of BIM in Finland and Sweden

Figures 13 and 15 show the same utilization rate of BIM in overall for Finland and Sweden (57%). In figure 13 the two respondents from Finland informing that they are not the first ones from their company to respond this questionnaire are left out and in figure 15 results for all respondents from Sweden are presented. Results from the respondents informing that they are the first respondents from their company to this questionnaire are shown in figures 14 and 16. In this case the overall utilization rate of BIM for Sweden changed only 1% but for Finland it dropped 5%. Taking into account the uncertainties in the results, it can be said that the overall level of BIM usage in Finland and Sweden is at the same level.

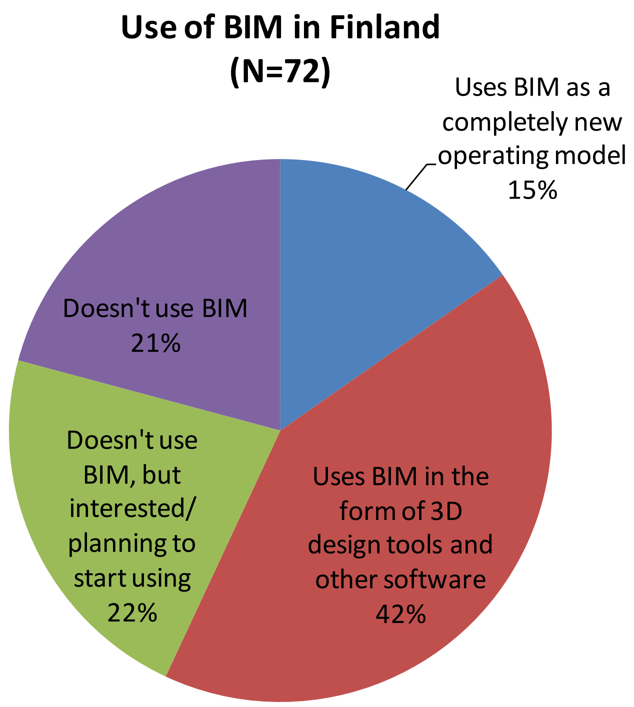

Figure 13. The utilization rate of BIM in Finnish companies. The two respondents informing that they are not the first ones from their company to respond this questionnaire are excluded from the results.

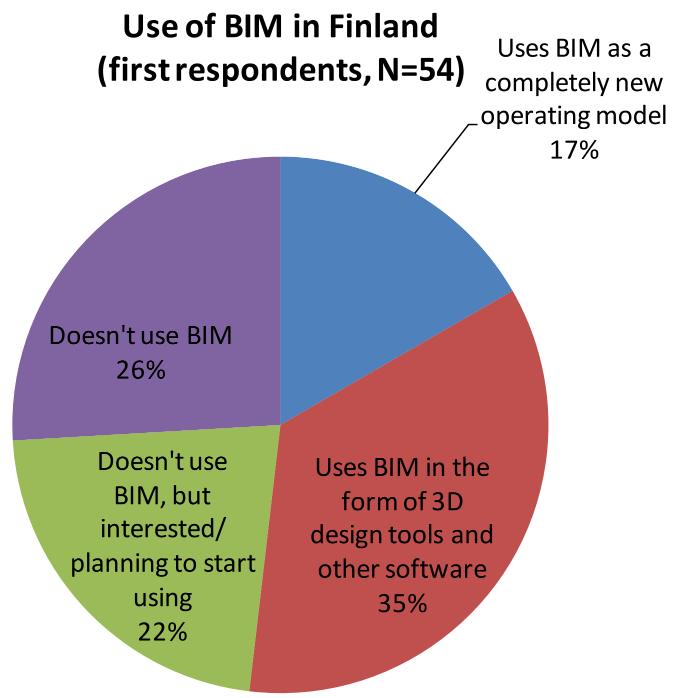

Figure 14. The utilization rate of BIM in Finnish companies. Results from the respondents informing that they are the first respondents from their company to answer the questionnaire.

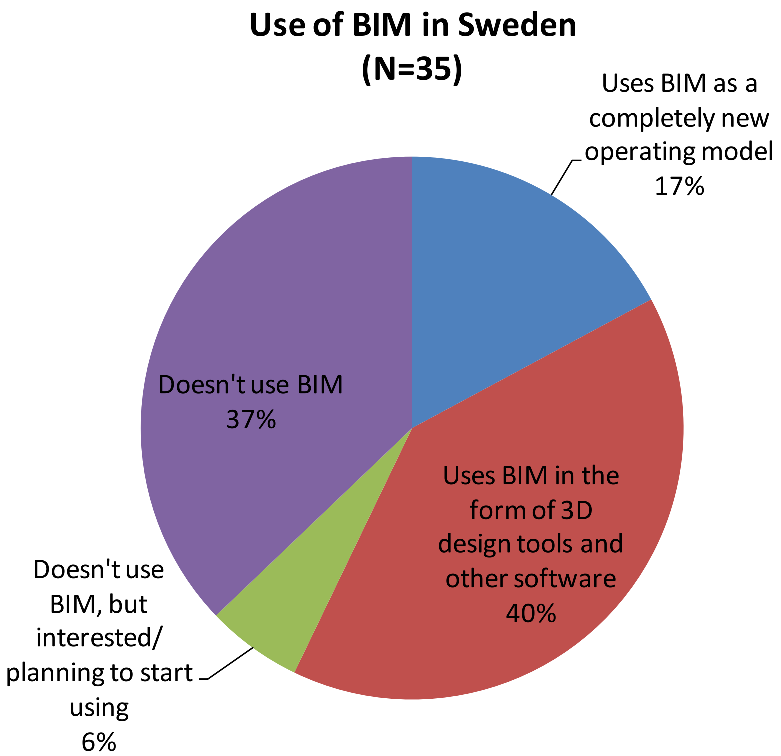

Figure 15. The utilization rate of BIM in Swedish companies. Includes all respondents from Sweden.

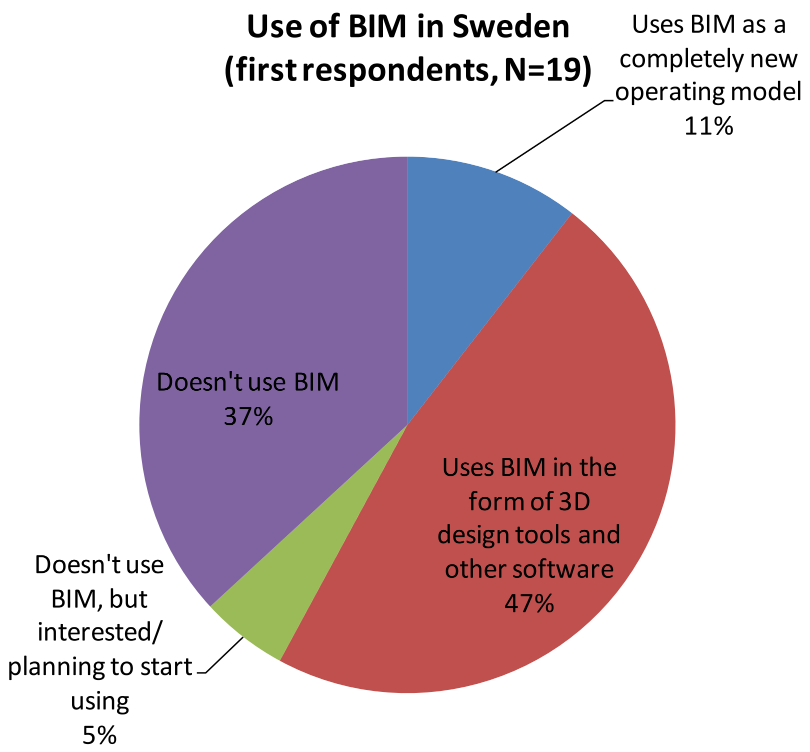

Figure 16. The utilization rate of BIM in Swedish companies. Results from the respondents informing that they are the first respondents from their company to answer the questionnaire.

There is a major difference in the interest towards BIM between those respondents from Finland and Sweden who are not using BIM. In Finland about half of those respondents who aren't using BIM were interested in it or planning to start using it whereas in Sweden this percentage was under 15%. So the overall level of interest towards BIM in Finland was much higher than in Sweden. To gain more insight to this the situation in small companies was reviewed. Figure 17 shows that quite many Finnish small businesses, which are not using BIM, were very interested about it but the Swedish weren't. In fact Swedish small businesses are already using BIM more than Finnish ones. So there seems to be difference in the interest towards BIM in general between Finnish and Swedish companies which are not using BIM. There also aren't differences in the requirements for sub-contractors to use BIM tools (see appendix IV, graphs 1 & 2).

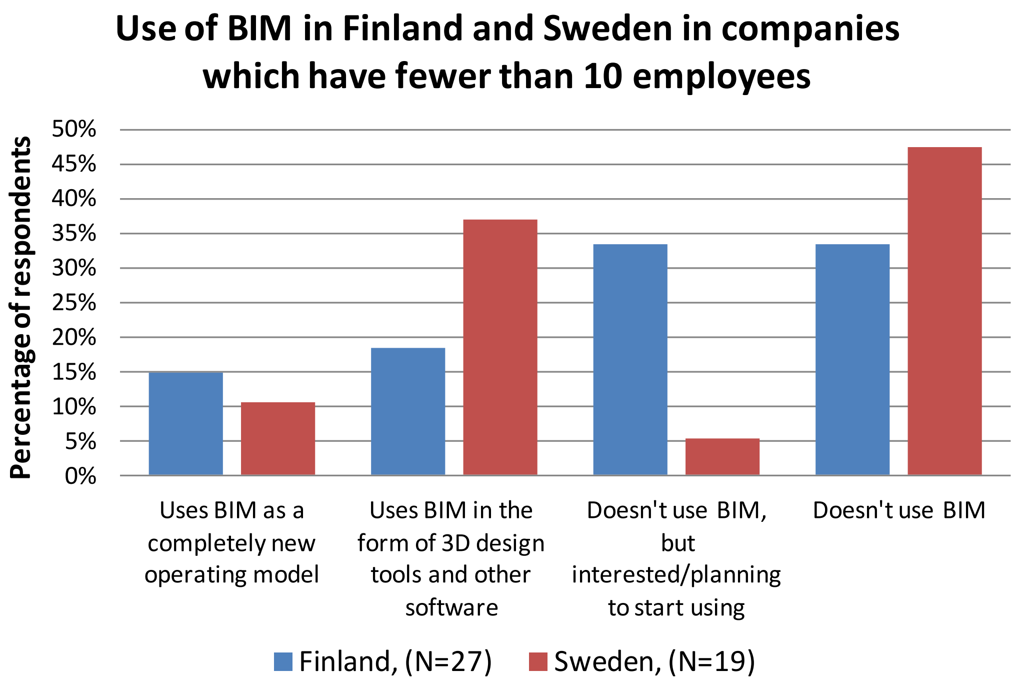

Figure 17. The utilization rate of BIM in Finnish and Swedish small companies. All respondents from this group included.

Figure 18 illustrate the utilization rate of BIM on project level. 51% of the respondents in Finland and 40% in Sweden informed that BIM was used only in under 30% of the projects. So it seems that according to this questionnaire Swedish companies, which are using BIM, were utilizing it more in their projects. It has to be noted that the sample size from Sweden was significantly smaller than from Finland. Based on the interviews major stakeholders in Finnish AEC industry are using BIM quite a lot. All interviewees mentioned that in more than half of their projects BIM is used. Contractors said that they are using BIM in all of their own production if there are resources for it. Some of the design and engineering companies have decided that modeling will be used in all projects where it is reasonable. Typically it was mentioned that BIM is used for designing new buildings but not for renovations because it would take too much time to create the model from an old building. Major factors limiting the use of BIM were lack of capable recourses and money.

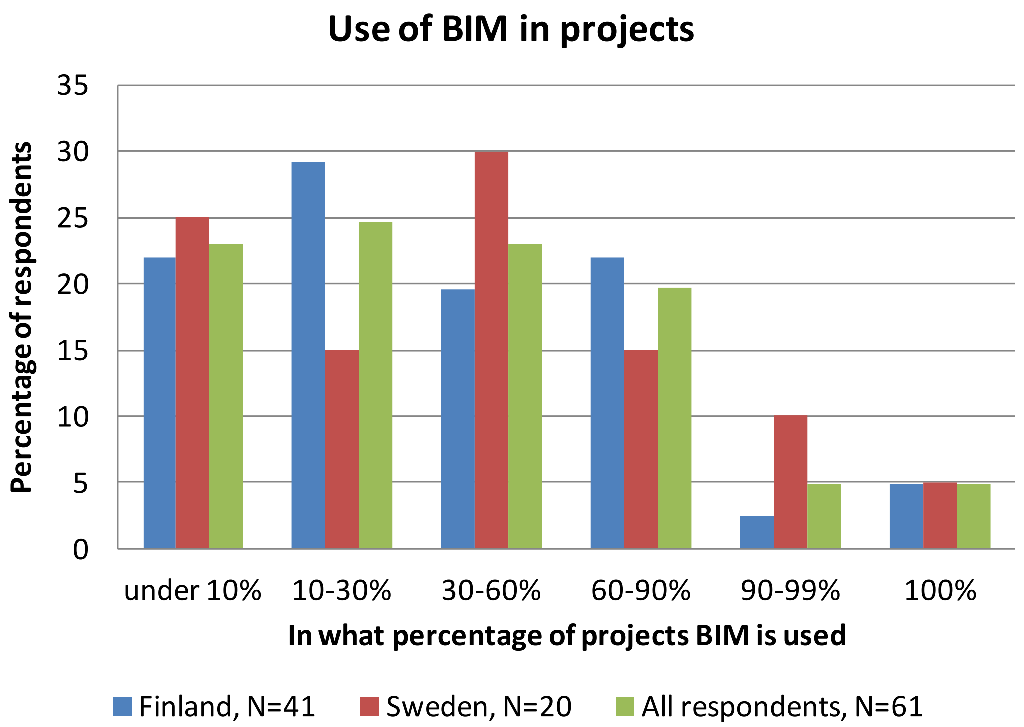

Figure 18. The utilization rate of BIM on project level in Finland, Sweden and combined.

In appendix IV (graphs 3-5) are shown the results about the use of BIM for other purposes than design or engineering and results about the level which insulations are modeled. Excluding design and engineering purposes, BIM and information gained from it was mostly used for quantity take-offs. In Finland BIM was used for clash detections nearly as much as for quantity take-offs. Other major areas of use were cost estimation and energy analyzes. In Sweden after quantity take-offs

BIM was used most for cost estimation and different analyzes trailed by clash detection. It seems that in over all BIM is not used that much for scheduling purposes, tendering or procurements. This is partly explained by the fact that those are typically responsibilities of a contractor and the amount of contractors answering the questionnaire was quite low. Graph 4 in appendix IV illustrates that contractors are actually using BIM and information gained from it for scheduling purposes and procurements. Regarding this graph it has to be reminded that respondents could select more than one response alternative when selecting their field of operation. So some answers are in both structural and HVAC engineering. None of the contractors selected any design/engineering alternatives as their field of operation.

Findings from the interviews correspond well with the questionnaire results. Quantity take-offs and clash detections were typically mentioned as the most important uses for BIM data. Also cost estimations and different analyzes were mentioned in the interviews. Interviewed representatives of contractors also emphasized the role of BIM in construction site for many different purposes. In addition to scheduling the project, BIM models are used for example to pre plan installations and schedule material orders.

Graph 5 in appendix IV depicts in what level or how the insulations are modeled. It is clear that in most cases insulations are modeled in some level. Most used way to model the insulations is to just reserve the spacing for insulation but in over all the answers were surprisingly evenly distributed. Based on interviews it was expected that insulations are only in special cases modeled fully but for example about 30% of the respondents informed that insulations are fully modeled in outer walls. It was mentioned in the interviews that the level of the modeling varies and there is no clear consensus about when something is fully modeled. It was mentioned many times that the quantity information is the most important information related to insulations. The quantities can be calculated based on the dimensions of the insulated are and the thickness of insulation needed to achieve the desired level of insulation. Therefore insulations are typically modeled only as a space reservation. It is enough for calculating the quantities and other technical information can be linked to the model otherwise.

5.2.2 BIM tools in Finland and Sweden

Based on interviews it was expected that at least in Finland Tekla structures would be dominant BIM software in structural engineering and MagiCAD in HVAC engineering. AutoCAD was included in the list of design software to see how much it is still used for design purposes in companies which are already utilizing BIM. The overall results in appendix IV (graphs 6 & 7) show that MagiCAD is clearly the most used BIM software in HVAC engineering both in Finland and Sweden. Tekla structures is also dominant BIM software in structural engineering in Finland but in Sweden it’s basically tied with Autodesk Revit.

As the overall results can included multiple answers from one company in figures 19 and 20 results from the respondents who informed that they are the first respondents from their company are presented. They show the same trends but also more clearly point out that Autodesk Revit is coming to markets. This was also mentioned by many of the interviewees. It was mentioned that Autodesk has been marketing Revit aggressively and Revit has also some benefits compare to the traditional software. Revit has solutions for architectural, structural and HVAC design. It was also said to be more of a modeling than design software compared to traditional solutions. This could lead to better usability which was seen as a major problem for the traditional solutions by the interviewees. But it was also mentioned that as a design software for structural and HVAC engineering Revit is lagging behind. Also it is clearly indicated that AutoCAD is still much used on the side as a design program. By the Finnish structural engineering companies software called Vertex was also mentioned couple of times. The low amount of CADS users in HVAC sector was bit surprising. In the interviews it was mentioned that CADS is used by the smaller companies quite a lot. But it was also noted that CADS is used more for electrical planning than HVAC engineering.

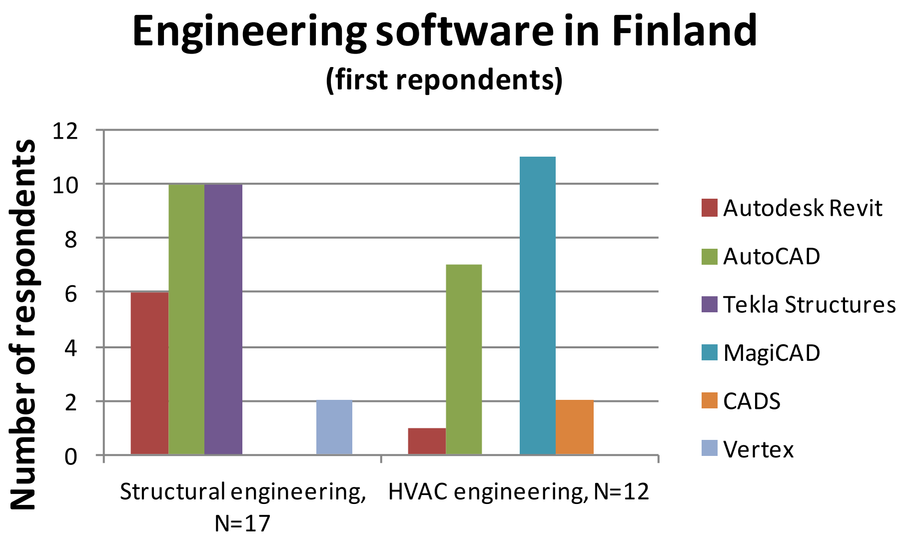

Figure 19. Engineering software used by Finnish structural and HVAC engineering companies.

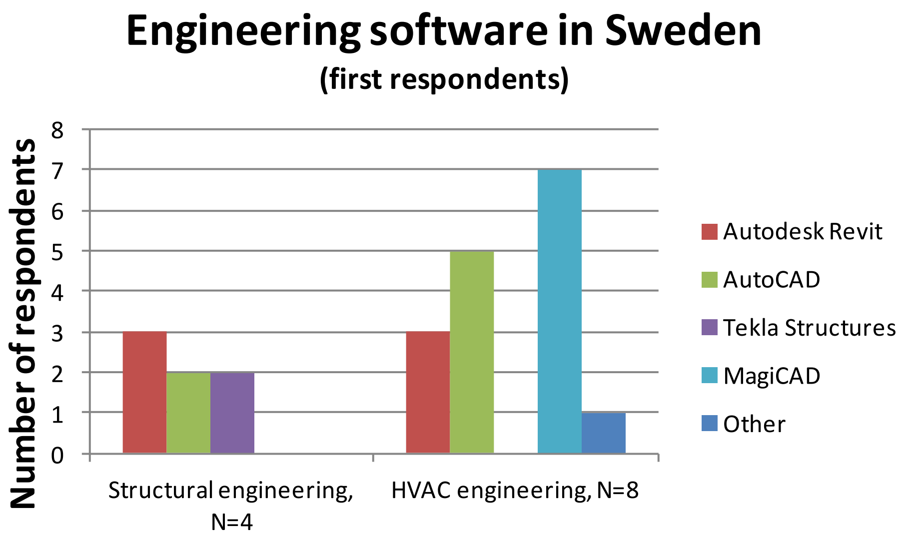

Figure 20. Engineering software used by Swedish structural and HVAC engineering companies.

It was also inquires from the respondents which BIM software they use for other purposes than design or engineering. Solibri and Navisworks were the most used ones. In the open answers for the questionnaire and in the interviews it was mentioned that Solibri is mainly used for clash detections and quantity take-offs. It can also be used to view the models. Navisworks in the other hand is used for viewing and managing the models. By Finnish respondents Tekla BIM sight was also mentioned. It is used to view the models and also for clash detections. It was also inquired if the companies were committed to using their current software. Most of the companies were and only few of the ones who weren't were willing or able to tell which other software they are considering.

Regarding the compatibility of the software used it was mentioned in the interviews that IFC standard based data transfer is working quite well and it is the main method used in Finland if models are transferred between different software. Most of the software nowadays are IFC compatible as can be seen also from the questionnaire results (appendix IV, graphs 8 & 9). Also the interviewees mentioned that all the major software are IFC compatible. Based on the interviews it can be said that the frequent updates of different software causes more compatibility problems nowadays than the actual IFC data transfer. Couple of interviewees with IT background mentioned that IFC can't ever be a perfect solution as it is a compromise solution for transferring data between different vendors software.

5.2.3 Information which a material supplier can provide to BIM and vice versa

In the interviews and questionnaires it was asked from an insulation supplier's point of view what kind of information the supplier could provide about its products to be used in BIM. The emphasis was on technical information both in the interviews and open answers in the questionnaire. It was several times mentioned that for bulk products, like basic insulations, there is no special need to model them accurately. So it's enough that they are modeled as a generic object or space reservation and the accurate technical specification is linked to the object. Sometimes some vendor's product or solution is used as an example in the technical specification in the design phase but the actual product used in the building is added to the model by the designer only in special cases. One example mentioned was the ventilation units. They have to be selected already in the design phase because the size of the unit and positions of outlets and inlets in them can have major impacts to the structures around them. So for more technical products and material solutions readymade objects could be useful according to the interviewees.

It was also an interesting point that even though contractors have annual contracts with material suppliers and the technical information about the materials is available they don’t ask the designers and engineers to add the accurate technical information about the materials to the model in design phase. At the same time it was emphasized that the accurate technical information would increase the accuracy and quality of models. Therefore the availability of technical information directly in the BIM software was seen as a good thing.

Also based on interviews the actual products and materials used are seldom updated to the model after the construction phase. This is because the models are not typically used after the construction phase so there is no need for as-build models jet. Though it was mentioned in the interviews that as lifecycle projects become more common in AEC industry then the accurate product data will be needed. This means that typically BIM model is not in any point finalized as an accurate technical model of the building. The BIM model is actually something between generic commercial product model and accurate technical product model.

So the interviewees nor the respondents couldn’t actually pin point what kind of information and in what form is at the moment needed from a material supplier. But it was clearly stated that technical information in some form should be available preferably directly from the BIM software’s product library or material database. One way of providing this information would be through product libraries. It was asked in questionnaires if product libraries were used. There weren’t any significant differences between Finland and Sweden and as can be seen from figure 21 most of the respondents are using at least some kind of product libraries. Also surprisingly many are using product libraries containing manufacturer specific products.

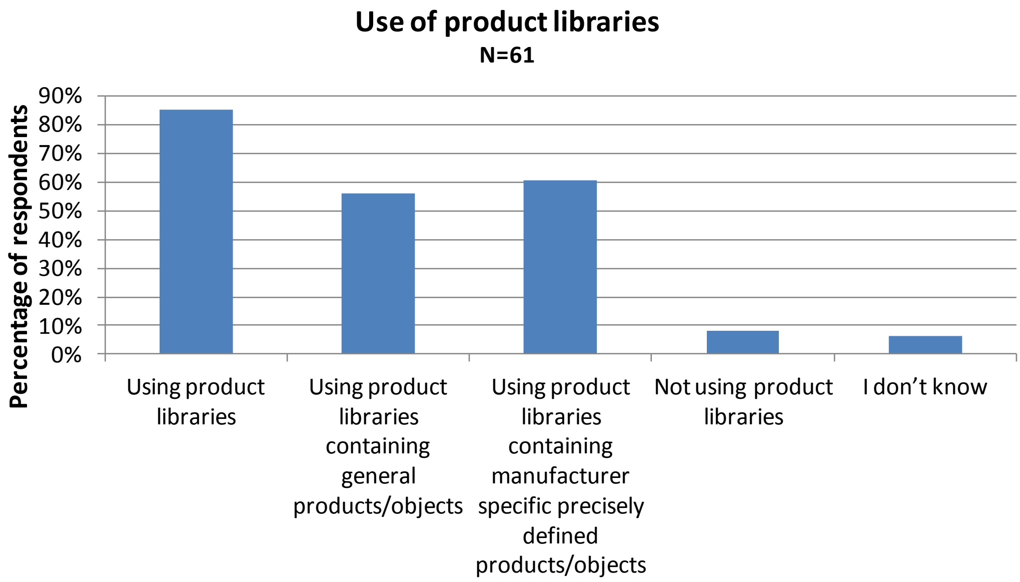

Figure 21. Use of product libraries. Results from Finland and Sweden combined.

The open answers revealed that most are using the software's own product library and material database or some vendors own product library. Only one of the mentioned libraries was found to be independent from a specific BIM software provider or material supplier. Based on interviews in Finland product libraries and material databases in BIM software are most used ones. Also readymade objects provided by different product manufacturers are used.

It was also asked from the respondents if there were insulation products in the product libraries. Figure 22 shows that more than 60% of the respondents informed that there are some kind of insulation products in the product libraries. Mainly there are general insulation products or objects but some informed that there are also manufacturer specific products or objects available. None of the interviewees had run into manufacturer specific insulation objects.

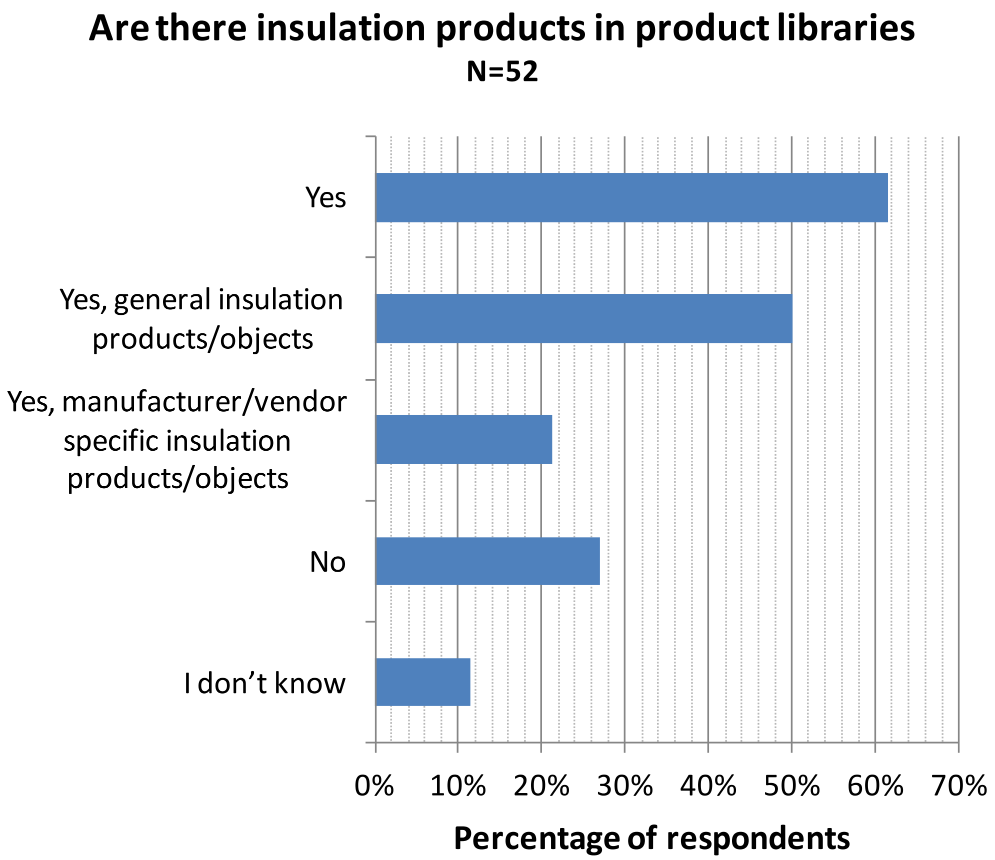

Figure 22. Insulation products in product libraries for BIM. Results from Finland and Sweden combined.

In the interviews it was also discussed if some information from BIM could be utilized by a material supplier. It was raised up by the contractors that the BIM based construction schedules are already used to schedule material deliveries. For example it was mentioned in an interview that the delivery and installation of precast concrete elements is already scheduled based on the BIM. It was also mentioned that it could be highly beneficial to schedule the deliveries of insulation products based on the installation sequences in the BIM model. This is because insulation products take a lot of space in the construction site. Also some very specific cases were raised up. Like that some engineering works use BIM design information directly in their production to manufacture for example custom sized metal products.

5.2.4 Benefits, future prospects and risks related to use of BIM

Also the realized or expected benefits and the future prospects of BIM usage were inquired from the respondents. Results about the realized benefits according to BIM users and expected benefits according to those who are not using BIM are presented in appendix IV (graphs 10 & 11). There are no major differences in the realized benefits between Finland and Sweden. Also the respondents who are not using BIM are expecting similar benefits from BIM which are realized according to BIM users. Results from Sweden about the expected benefits of BIM also show similar trends with the other results but they are more scattered. This is because eight out of 15 respondents replied that despite the benefits they are not considering to start using BIM. So there were actually only seven respondents for this question from Sweden.

In overall the earlier detection of errors and problems in the models is the most important benefit realized and expected. This was also mentioned many times in the interviews and it is directly related to the second most realized benefit which is better quality of design work. This is also a major expected benefit by those who are not using BIM. Also better communication between designers or with the client and the possibility to compare different design alternatives more easily are seen as major benefits. Possibility to use product libraries and better building quality are also seen as major realized benefits by quite many respondents. The interviewees typically mentioned the automatic quantity take-offs as a major benefit of BIM. In the questionnaire quantity take-offs were not listed as a benefit but as mentioned earlier it was the main application are of BIM outside design and engineering purposes. Also in these results it has to remind that the background of the respondent of course affects the results. Graph 12 in appendix IV illustrates the results of contractors using BIM. It reveals that same things are seen as the most important benefits by contractors as in over all but better building quality and especially more accurate cost estimation and budgeting are also important benefits for contractors.

Interesting thing is that faster design and especially cost savings are not seen as major realized benefits. Also only few contractors see the faster progress of building contract as a major benefit. This was quite surprising as according to literature time and cost savings are major benefits gained from the use of BIM. Also interviews support the questionnaire findings. It was many times mentioned that modeling takes more time than traditional 2D CAD design and therefore it costs more. It was noted in the interviews that as most of the errors and problems are detected earlier by comparing the models and through clash detections less time for fixing the problems in construction site is needed. Contractors also pointed out that BIM is already used quite a lot in construction sites. But in fact no one mentioned that the overall time need for a construction project would be shorter when using BIM.

As mentioned in the literature the cost savings from the use of BIM are indirect and therefore they are hard to calculate and verify. This is most likely the reason why cost savings are not seen as a major benefit by most of the respondents. Also the fact that at the moment BIM based design costs more than traditional design diminishes the cost savings. From designers point of view modeling takes more time than producing the traditional 2D CAD drawings. This is at least partly due to poor usability of BIM software and lack of experienced BIM designers. The possible other time savings for designers and engineers are not seen as the actual design work is more complicated. Contractors pointed out some clear benefits which save time but they are not yet seen as a major benefit. One explaining factor could be that the time savings are still minor compared to the total duration of a building project.

In figure 23 the results from questionnaires in Finland and Sweden about the future development of the usage of BIM are combined. It is clear that the use of BIM will continue to grow. No one believes that the use of BIM will decrease. This was expected based on earlier studies. The results also indicate that the use of BIM in general is expected to grow bit more than in one’s own company.

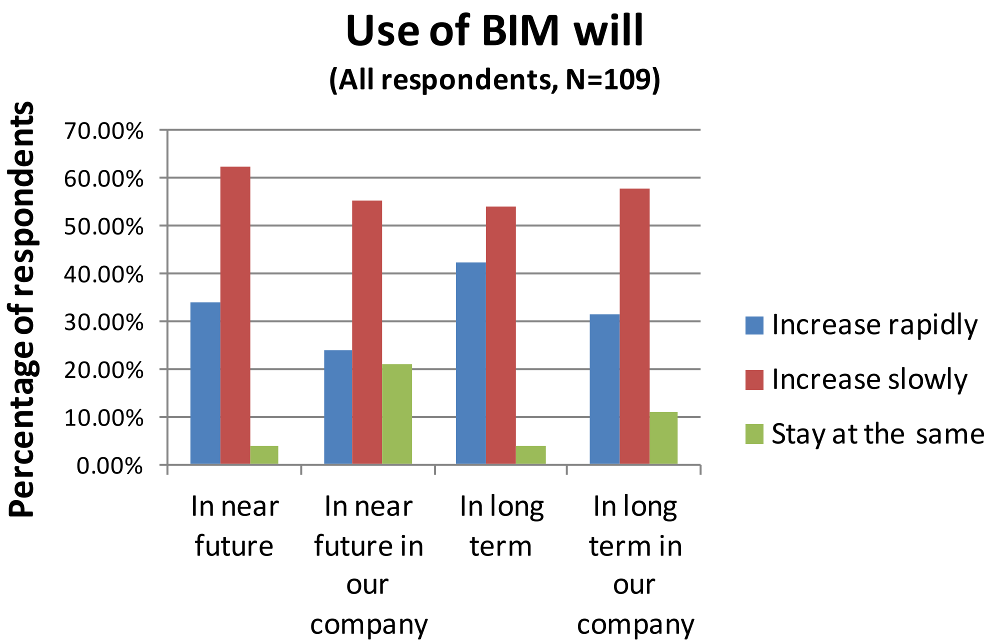

Figure 23. Future development of the usage of BIM. Results from Finland and Sweden combined.

Also all the interviewees believed in BIM, and that its use will continue to grow. Most believed that there won't be any major leaps in the development. This was based on the fact that software development is slow and the current software are difficult to use for someone who is not an modeling expert. Also the lack of competent personnel is holding back the development. Especially the usability issues could explain why the use of BIM is expected to grow more in general than in one's own company. There is a strong belief in BIM in general but usability issues are thought to slow down the development in one's own company. On the other hand in one company, which had started to use BIM about two years ago, the pace of development was fast. Also one interviewee with a long background with BIM mentioned that there is a high need for faster development.

No major risks related to use of BIM came up during the interviews. Risks related to the ownership of BIM data were seen minor because those kinds of issues are agreed on contracts made in the beginning of a construction project. Even though BIM models are used also by subcontractors information leaks weren't either seen as a problem by the interviewees because it is also clearly defined beforehand who is entitled to see and have the accurate models during and after the project. In one interview it though came up that the manufacturers of technical ETO products have recognized the risk of information leaks to third parties through the BIM models. There are examples of situations were accurate technical model of a product is added to the BIM model in international project and afterwards copies of that product have appeared to markets.

5.3 Potential of BIM for a building material supplier

In this subchapter the questionnaire and interview results are discussed and some more interesting points from the interviews are raised up. First the use of BIM and BIM tools from a material supplier's point of view is discussed. Next the material supplier's role in building information modeling is described. In this chapter it is also discussed what information from BIM a material supplier could exploit and what risks are related to BIM from a material supplier's point of view.

5.3.1 Use of BIM and BIM tools from a material suppliers point of view

In previous studies the utilization rate of BIM in Finland and Sweden has been on same level. Questionnaire conducted for this study also showed similar results as there was only a minor difference in the utilization rate of BIM in Finland and Sweden. The actual utilization rate of BIM varies in the previous studies and also when compared to this study. This is mainly because of different target groups of the studies. This study had a quite broad target group in the AEC industry and the amount of responses was quite good. Compared to Patoc's own prior study, which had partly the same target group as this study, the utilization rate of BIM had grown in Finland and Sweden from under 40% to over 50%. Though it has to be noted that in the Paroc's previous study architects were the main focus group, so direct comparison cannot be made. Based on the questionnaire results and interviews it can be said that nearly all the major companies in AEC industry in Finland and Sweden are using BIM and the smaller companies are also starting to use BIM. Also in Finland the interest towards BIM is quite high in those companies which are not using BIM. From a material suppliers point of view this means that it is important to be at least aware of BIM.

One interesting difference in results was that in Finland interest towards BIM by those respondents who weren't using BIM was much higher than in Sweden. One explaining factor could be that majority of the respondents from Sweden were from small companies whereas the Finnish respondents were more evenly distributed. Typically larger companies adopt new techniques and work processes first. But results showed that the difference was the same also between smaller companies. It was also revealed that Swedish small businesses are already using BIM more than Finnish ones. The differences can't also be explained by differences in the requirements for sub-contractors to use BIM tools. But from a material supplier's point of view it is important to notice that in Sweden quite many small companies are already using BIM design tools and in Finland there is a major interest towards BIM. This means that the use is spreading also to smaller companies and it can be expected that the overall utilization rate of BIM continues to grow.

The questionnaire results showed that quantity take-offs are a major utilization area of BIM. On the other hand representatives of design and engineering companies mentioned that they don't typically guarantee the accuracy of the quantity take-offs taken from the models. The traditional 2D documents are still the main documents for them. But from the material suppliers point of view it is more important how the contractors, who are ordering the materials, are using BIM. Questionnaire showed that contractors are using BIM also for cost estimation and scheduling purposes and somewhat to procurement purposes. Some of the interviewees mentioned that the quantity take-offs can be directly used as material list in request for quotations. But it was also noted that in such a case it has to be checked that the model is done correctly and with adequate accuracy. So some manual labor is still needed. Based on the questionnaire many contractors are already using BIM for scheduling purposes and according to the interviews this type of BIM utilization is growing. This means that in the future material orders and deliveries could also be scheduled through BIM systems. For example it was mentioned in an interview that installation of precast concrete elements is already scheduled based on the BIM model.

There could be potential for example for automated procurement processes between contractors and material suppliers by using quantity take-off information directly from the BIM models. Also material deliveries could be scheduled more accurately by using the BIM model like mentioned in the literature. It was mentioned in the interviews that in case of insulations this could be very beneficial because insulation products take a lot of space at the construction site. Problem is that automated processes need deeper cooperation between contractors and material suppliers which is not typical in highly competitive AEC industry. Representatives of contractors also mentioned that at the moment they still need to develop their own practices related to BIM. They have limited resources and therefore they don't yet have time to develop potential BIM usage applications outside their own organization. Problem with insulations is also that they are typically installed by sub-contractors. So this means that the sub-contractors should also be using the BIM model to schedule their work.

The interviewees also mentioned that more and more information is and will be added to BIM models. At the moment the computers and programs capabilities are limiting the amount of data that can be added to the model. Therefore it is always carefully considered if something new is added to the model. New additions to the model have to be somehow useful and the benefit from it must be higher than the cost of the work needed to add it to the model. Because of this type of reasons for example insulations are typically modeled just as a space reservation and the accurate technical information is linked to the model in some other way. For a material supplier this means that the most important thing is that the technical information of its products is available in such format that it can be linked to the model.

As the use of BIM continues to grow, the need for technical information of products and even readymade object for BIM models will grow. From Paroc's point of view it was also interesting that quite many respondents informed that insulations are fully modeled in some cases. This could indicate potential for readymade objects. But based on the interviews "fully modeled" can't be clearly defined so it might be that "fully modeled" was understood differently by different persons. The readymade objects of different products, which can be directly added to the models, can also be problematic. One of the interviewees representing a major contractor said that they are many times forbidding designers and engineers to use readymade objects because they typically interfere their quantity take-offs. Also many times the readymade objects work only in one software and they won't transfer to other programs even via IFC. So it is important for material suppliers to carefully consider what kind of readymade objects they will offer from their products. It is clear that the more complex the product is the more useful the objects can be. But it has to be always ensured that the objects can be transferred from the design software at least to IFC file and that the important quantity information is easily available from the object.

From the material suppliers point of view it is a good thing that there aren't that many BIM software which are currently used. This means that if technical information of products is available for the most used software it is available for most of the designers and engineers. At the moment the material databases and product libraries of the dominant BIM software are the most efficient way to provide the technical information. The open product libraries mentioned in the literature would be even more efficient. Those kinds of solutions have already been developed but the results revealed that at the moment they are rarely used. Also if readymade objects are created it is important to consider to which software they are made. This is because creation of objects takes time and can be expensive. It is clear that at the moment Tekla and MagiCAD are the main software in which the technical information about material supplier's products should be. In longer run the development of Revit should be carefully monitored. But as one interviewee mentioned, future BIM software should develop into the direction which Revit is developing but it's not clear that Revit will be the solution for the next step in BIM development. So there are indications that some major changes to the BIM software might be coming. This possesses a risk from a material supplier's point of view. If new dominant software will emerge to markets investments in readymade objects for current BIM software might be wasted. But this is only a minor risk as the development of BIM software is said to be slow and it was also noted in the interviews that designers are slow to adopt new software versions and software.

5.3.2 The role of a material supplier in BIM

Based on literature there is a lot of potential in the use of manufacturer and vendor specific knowledge during the design process. By using the special knowledge of material suppliers about their own products the quality of designs and thus building quality could be increased. Based on the interviews at the moment the material supplier’s role in building information modeling is no more than to provide the technical information about its own products or materials if needed. In many cases the designers search the needed information by themselves for example from the material suppliers web pages. So the role of material supplier is generally quite small in building information modeling but it could be much bigger.

Quality issues were mentioned in the questionnaires as major realized and expected benefits and the interviewees mentioned that the accurate technical information would increase the accuracy and quality of models. So it’s bit surprising that the interviewees were typically only interested about the basic technical knowledge of the materials when asked what kind of information a insulation manufacturer could offer from its products. Typically it was mentioned that this information should be available directly from the BIM software’s material database but some thought that it is enough that the information is available in the manufacturer’s webpage. This is also bit inconsistent with the fact that contractors don’t require the designers and engineers to add the accurate technical information about the materials to the model in design phase. This isn’t the case even if contractors have annual contracts with material suppliers. This shows that the BIM design methods and procedures are still developing. But as the matter was discussed more closely typically some special cases arise where more precise information and knowledge from an insulation supplier would be needed. So there is a need for increasing the material supplier’s role as a source of accurate technical information.

There is couple of things limiting the possibility of using material supplier’s as a source of accurate technical information. First of all it has to be reminded that annual contracts are typically made only for contractors own production. So in most cases the selection of products and materials used in a building is done based on tenders after the design phase like it’s described in the COBIM. This means that in many cases the accurate information from material supplier can only be used as a reference during the design phase. Also even in contractors’ own production a certain product put into the model by a designer can be changed by the contractor. This is because typically the company responsible for designing the building is not responsible for building the actual building and as revealed in the interviews contractors don’t inform the designers about the annual contracts related their own production. This is also one reason way readymade objects of certain material supplier’s products are not always appreciated. So it’s not typical to put actual products to the model but for example certain insulation manufacturer’s product might be referred as an example.

So the current BIM processes and other business processes in AEC industry are limiting the possibility to utilize the accurate technical information from a material supplier to increase the quality of designs and construction. But from a material supplier’s point of view all this actually means that the availability of technical information is very important. Based on the accurate technical information designers can create generic models which best correspond with actual products. Also contractors can easily compare and pre select products and materials which fulfill the requirements set in the model before the tendering phase.

One major thing which was pointed out was that as the lifecycle projects become more common then the accurate technical information will be needed for the as-build models. Problem is that there aren’t yet good software for utilizing the as-build models for maintenance purposes and renovations. So it’s not known if the technical information added to the BIM model by the designer can be used or if it has to be added to the as-build model separately. But it is clear that as the lifecycle projects become more common then the material supplier's role as a source of information and knowledge will further increase.

Many of the interviewees mentioned that they are still developing their own work methods related to BIM usage. It was also mentioned by the contractors that a lot of time and work is still needed to ensure that the designers use the BIM tools and make the models in the way that they can be fully utilized by the contractor. For these reasons the focus has been mainly on developing the basic design methods and ways to utilize the models by the contractor. There hasn't yet been time to develop the cooperation with material suppliers and ways to better utilize their knowledge better in the design and construction process.

Few of the interviewees mentioned that it is highly important that as many stakeholders as possible from all disciplines are taking part to the BIM development. As buildings consist of so many materials and systems, this is the only way to have the most accurate and up to date information available all times. Another thing mentioned was that software developers tend to develop their software based on the feedback they get. So if they are not pushed to develop ways to add more precise technical information and knowledge from material suppliers to the BIM model, that kind of development won't happen or it will at least be slow. Therefore one role for a material supplier in BIM development could be to develop methods for more efficient sharing of its own technical information and knowledge. It was also few times indicated that involvement in BIM development by a material supplier like Paroc will help to raise the image of the company. But as mentioned earlier, in all BIM related development it should be carefully considered to whom it's targeted and that it won't disrupt other stakeholders work.

Only few risks related to BIM from a material supplier's point of view could be identified from the literature and the interviews didn't bring up any new risks. In the literature contractual issues related to ownership of BIM data were mentioned as a major risk but the interviewees saw this only as a minor risk. Also the risk of information leakages to third parties through the BIM model was typically seen minor but one interviewee confirmed that manufacturers of technical ETO products have recognized this risk. More technical the product is the higher this risk becomes. Thus it should always be carefully considered by suppliers of different materials and products is there need to protect the technical information of their products somehow. The liability about the validity of the technical data added to a BIM model is also an issue which a material supplier has to consider. If designs or material orders are done based on outdated technical information there is a major risk for disputes.

5.4 3D modeling in process industry

As Paroc is offering same or same type of products for construction and process industry, also the use of 3D product modeling in process industry was studied. The objective was to find out if there are similarities in BIM and product modeling in process industry which could be utilized from a material supplier's point of view. Next the questionnaire and interview results related to the use of 3D modeling in process industry are described and discussed. The main results of the questionnaire for process industry stakeholders in Finland and Sweden are presented in appendix V.

5.4.1 Main results related to the use of 3D modeling in process industry

The target group for the questionnaire was much smaller but it still clearly shows that 3D modeling is the standard design method in process industry. 14 out of 15 respondents from Finland and Sweden answered that 3D modeling was used in their company (appendix V, graph 1). In process industry modeling is also used more in project level than in AEC industry. 79% of the respondents informed that 3D modeling is used in more than 60% of the projects (appendix V, graph 2). The interviewees mentioned that 3D modeling is used basically in every project and all design work is done in 3D. The expected growth in the use of modeling comes from the more accurate modeling. The future prospects about the use of modeling in process industry were very similar as the future prospects about the use of BIM in AEC industry (appendix V, graph 10). No one thought that the use will decrease. The development was mostly expected to be slow which was an expected result as 3D modeling is already the standard design method and it has been used longer than BIM in AEC industry.

Based on questionnaire results insulations are modeled in most cases (appendix V, graphs 3 & 4). Only three out of 14 respondents informed that insulations are not modeled at all. Based on the interviews insulations are modeled always if there is a tight spot and possibility of a collision between insulation and other structures. In straight forward situations insulations are but in the model if the software creates the insulation automatically for example around a pipe. There seems to be differences between software in this case. Some create the insulations automatically around pipes and some don't. So the modeling of insulations is mostly dependent on the features of the software in use. Also only six out of the 14 respondents informed that there are insulation objects in the product libraries for 3D modeling software and no manufacturer specific objects seem to be available (appendix V, graph 9). Typically the quantities of insulations are calculated same way as in AEC industry based on square meters calculated from the dimensions of the insulated object and the thickness of the insulation.

3D modeling and information gained from it is used in process industry for same kind of purposes as BIM in AEC industry (appendix V, graph 5). Quantity take-offs were the main utilization are outside design and engineering purposes. Unfortunately clash detections was left out from the list do to human error but based on interviews clash detections are part of the design routine in process industry. This was shown also in the results about the benefits of 3D modeling (appendix V, graph 6) where error/problem detection through clash detection was most mentioned benefit along with better quality of design. The models and information gained from them are also used as basis for cost estimation, tendering and procurements. Also about half of the respondents informed that models are used for scheduling and different simulations and analyzes. Related to simulations and analyzes it came up during the interviews that they are a separate discipline. This means that simulations are done with separate software and not necessarily in 3D. So the technical information about the insulations is mainly needed for different software than the actual modeling software.

In process industry many different software are in use (appendix V, graph 7). All the software mentioned in the questionnaire were used by more than one company and in all sectors of design most or second most of the respondents selected the alternative other. Most mentioned other software were Microstation and Inventor. Also Vertex, MagiCAD and Tekla, software used also in AEC industry, were mentioned. So compared to AEC industry the range of software in use is broad. Companies were also committed to using the software which they are currently using. Only one respondent informed that they are not committed to using their current 3D modeling software. Based on the interviews the major equipment manufacturers in process industry have typically selected one modeling software as the main modeling tool and they have developed it for their own purposes for several years. Design and engineering companies in the other hand are using the software which their clients are using. So the bigger design and engineering companies in process industry are using many different software.

All respondents for the questionnaire also mentioned that they were using product libraries (appendix V, graph 8). But based on the interviews and the open answers in the questionnaire, most of the product libraries in use are libraries developed by the company itself. Also standard based libraries for piping sections, valves etc. are used. The interviewees were also skeptic about the potential of readymade objects for insulation products.

5.4.2 Similarities between BIM and 3D modeling in process industry from a material suppliers point of view

Based on the questionnaire and interview results there are similarities between BIM and 3D modeling in process industry but from a material suppliers point of view it’s problematic that many software are in use and that companies have their own product libraries. There isn’t same kind of potential in process industry than in AEC industry to promote products by adding technical information to certain software vendor’s material database or by adding a 3D model of a product to a product library. It also came up in the interviews that companies are not that interested in material supplier specific object for their design software. This is because process industry companies are typically global actors and many material suppliers aren't. Also in many cases there are different standards for different components and materials in different countries. For these reasons process industry companies want to keep their designs on a generic level.

Based on the interviews the process industry companies are pleased in the current situation where they can find the technical information about certain products and materials from the supplier's webpage when necessary. Some interest was towards calculation software which would automatically suggest certain insulation product based on process conditions. It's something that makes the engineers work easier in the procurement phase. Also the importance of price information was mentioned in the interviews. So from a material supplier's point of view it is as important to offer accurate technical information for process industry applications as it is in AEC industry. This information can't be provided efficiently through material databases or product libraries of certain software so some other way is needed.

6 CONCLUSIONS

The objective of this study was to gain information about how a building material supplier could benefit from the growing use BIM in the AEC industry. The subject was studied from an insulation manufacturer's point of view and the research problem was divided into six sub research questions. In this chapter the main research question, "***How building material supplier/manufacturer can benefit from building information modeling?"*** is answered by answering the sub research questions one by one. The answers are based on the results of theoretical and empirical study. Also conclusions are made from Paroc's point of view. After that recommendations about how Paroc should react to the growing use of BIM are given. Finally the quality of the study is evaluated.

6.1 Answers to the research questions

First sub research question was *"What is the utilization rate of building information modeling at the moment and how fast is the development?"* The goal of the first sub research question was to find out how widely BIM is used in Finland and Sweden and how fast the use is expected to grow. This was seen as an important factor affecting the material supplier's interest towards BIM. The literature research showed that Finland and Sweden are at forefront of BIM implementation. Based on the questionnaires for this study the utilization rate of BIM is quite similar in Finland and Sweden (over 50%). It was also clearly indicated by the respondents that the use of BIM will continue to grow. Based on the interviews it is clear that all major stakeholders in AEC industry are using BIM at least as a design tool and for related applications like quantity take-offs and clash detection.

Regarding the utilization rate of BIM it has to be noted that even though companies are utilizing BIM it is not utilized for all projects. 51% of the respondents in Finland and 40% in Sweden informed that BIM was used only in under 30% of the projects. Major reason for this is the fact that BIM is not used in renovations. Also lack of capable recourses and money are limiting the use of BIM. Based on the interviews the major stakeholders are using BIM in over 50%

of their projects. Some even had self set goals to use BIM for all design work. From Paroc's point of view the utilization rate of BIM in Finland and Sweden is already so high that potential ways for exploiting should be considered. Especially as BIM is already the main design method for major stakeholders in the AEC industry and there is clear indication that the level of use will continue to grow.

The second sub research question, *"Which software are being used and how compatible are they?"* was set mainly to find out if there are some dominant BIM software in use. Based on interviews and the questionnaires two major BIM software are in use. Tekla structures is a dominant software for structural engineering and MagiCAD for HVAC engineering. Other software are also in use and especially the growth of the use of Revit should be monitored.

Also the compatibility issues were dealt both in the interviews and the questionnaires because they can have a major affect the utilization potential of BIM. It is clear that IFC data transfer standard is widely accepted and in use especially in Finland but also in Sweden. IFC is a way to transfer BIM models between different software and it works quite well for that purpose. The compatibility issues mentioned in the literature have decreased based on the interviews and even though some problems were mentioned they were not seen so problematic. The frequent updates of different software were seen as a more problematic thing.

From Paroc's point of view it is important information that there are basically two major BIM design software in use one for structural and one for HVAC engineering. The possible technical information will be added or linked to the model mainly through these software. So if solutions and information are offered for these software it can be utilized by majority of the stakeholders in AEC industry. It is also important information that IFC is working and it's widely used. If readymade objects or the plain technical information can be compiled to IFC format then it can be utilized also in several other software. The frequent updates of different software can be problematic because it can mean that readymade objects and the format of technical information have to be updated also frequently. There were also indications that more major changes might be coming to the BIM design software. This could lead to increased use of Revit or some other software. This is one thing that Paroc has to observe and keep in mind when planning BIM strategy for longer run.

Third sub research question was, *"Can a material supplier provide useful information for building information modeling and at the same time promote its own products?"* Based on the literature the use of material supplier's specific knowledge about its own products could be very beneficial for design and construction process. Better design and material choices could be done and thus the quality of designs and buildings could be improved and costs optimized. But based on the interviews and open answers in the questionnaires for bulk products, like basic insulations, only the basic technical information was required. For these type of products and materials readymade objects were not seen beneficial as they would only increase the size of the model. It was also pointed out that readymade objects can interfere the quantity take-off process. But if the product is in some way more technical then the manufacturer's special knowledge could help the designer or buyer to select the most appropriate solution or product. Unfortunately the current BIM processes and other business processes in AEC industry don't support the use of material supplier's knowledge during the design phase. Also based on the literature the general trend in product information modeling is towards attribute based models instead of technically accurate models. At the same time these limitations make the availability of technical information even more important as the actual products have to be compared against the generic designs.

Based on the interviews the availability of technical information about Paroc's products in the major BIM design software would be helpful for designers and contractors. The availability of technical information would also help to promote Paroc's products. If the information is not available it can lead to a situation where Paroc's products are not considered as they cannot be easily compared with the designs and other manufacturer's products. Readymade objects are more problematic as they can cause problems for example in quantity take-off process and they might increase the size of the model dramatically. So it should be carefully evaluated what kind of benefits a readymade object would offer to different stakeholders and that it won't cause any problems.

Answer to the fourth sub research question, *"Does building information modeling produce information which a building material supplier can exploit in its own production or logistics?"*, was obtained from the literature and interviews. Based on the literature contractor's construction schedules, quantity take-offs from the models and other design information could be used by material suppliers to plan their production and deliveries. Also based on interviews this kind of information is available and already used in some special cases for scheduling deliveries.

So there is information available which could be used at least to better schedule deliveries. To have an effect on production scheduling the quantity information should be available earlier than it is now. The problem is that in many construction projects the material suppliers are selected based on tendering after the design phase. So there is no possibility to utilize the quantity information earlier. Also Paroc sells major part of its products through wholesalers and thus in those cases there is no direct contact to the customers. Paroc has also annual contracts with contractors related to their own production. In such cases preliminary quantity information could be obtained already during the design phase. This could be helpful for Paroc as construction work is quite seasonal but deeper cooperation between Paroc and its customers is needed.

Fifth sub research question was, *"What kinds of risks are associated with building information modeling from a material supplier's point of view?"* Two risks for a material supplier were identified based on literature. The risk of information leakages to third parties trough BIM models and the liability issues related to the correctness of information in the model. It was confirmed in the interviews that information leakages are identified as a risk by ETO product manufacturers. For most of the Paroc's products this is not a risk as the technical information about insulations is openly available anyhow. But in case of more complicated insulation solutions and especially new products this risk has to be evaluated. The liability about the correctness of technical information is a risk which has to be acknowledged. In Paroc’s case this is not a new thing as technical information is already freely offered.

Creating readymade objects also possess a risk from a material supplier’s point of view. As readymade objects can interfere for example the contractor’s quantity take-off process and therefore contractors sometimes forbid the designers to use the readymade objects, providing poorly designed readymade objects or solutions for BIM can be a risk. It might have a negative impact to company’s image. From a material supplier’s point of view also not being part of the BIM development can be a risk. Especially as it seems that the need for accurate technical information about different products continues to grow. This can lead to situations were only the products which technical information is easily available for BIM software are considered.

The final sub research question was, *“Are there similarities between BIM and product modeling in process industry which could be utilized?”* There are similarities between BIM and product modeling in process industry. When providing products or materials for building a process industry facility the availability of technical information is at least as important as when providing products for construction industry. The availability of this information through the design software could be useful for designers and engineers in process industry and thus it would simultaneously promote the supplier’s products.

Major thing limiting the potential for utilizing the same solutions in both process and AEC industry are the different software in use. In process industry many different design software are used and companies have developed their own solutions into them. Process industry companies are also more global actors and thus any part of their designs cannot be based on more local material supplier’s products. For that reason they want to keep their designs on more generic level. So the technical information in single modeling software would reach only limited part of process industry stakeholders. Therefore from the material supplier’s point of view the benefit compared to the investment might be small.

Also same kind of information is available from the models in process industry than from the BIM models. So there is the same potential for utilizing this information to enhance the supply chain. At least the construction schedules could be used to better schedule deliveries. This of course requires cooperation between the material supplier and the customer. So the question is if a global process industry solutions provider sees enough benefits in this kind of cooperation with a more local material supplier.

The sub research questions provided clear answers to the main research question, "***How a building material supplier/manufacturer can benefit from building information modeling?"*** By providing accurate and up to date technical information in a way that it can be easily added to the BIM model, a material supplier can promote its products to a wide group of stakeholders in the AEC industry. At the same time taking part into BIM development work can help to boost the company's overall image. Material suppliers could also utilize at least the BIM based construction and installation schedules to better time their deliveries. This would also be a step towards lean construction. In order to gain these benefits some investments are of course needed but the benefits could be far greater. Also closer cooperation with customers is needed. Same approaches could be used also in other industry sectors but the possibilities are limited because solutions are typically software specific and different design software are used in other industry sectors.

6.2 Suggestions for first steps for Paroc to benefit from the growing use of BIM

Because of Paroc's wide product range, separate approaches to BIM and product modeling are needed for different products. Based on the interviews it came clear that the availability of technical information in the main BIM software would be beneficial for Paroc. The technical information would help designers and contractors to choose the most appropriate products and at the same time it would act as an advertisement for Paroc's products. This is especially important in situations where Paroc's sales takes place through wholesalers and Paroc has limited contact to the end customer. Not being in the BIM software can even be a risk from Paroc’s point of view. If the BIM development continues to direction where designers and contractors start to compare different products against the generic attributes in the model by themselves, it can lead to situation where only the products which technical information is easily available for the BIM software are considered.

So the first step for Paroc would be to contact the software developers of Tekla structures and MagiCAD and discuss what is needed to add the technical information of Paroc’s product range to their software. Also the growing use of Revit is interesting from Paroc’s point of view as it was indicated that Revit has marketed itself strongly to smaller design and engineering companies. These smaller design and engineering companies are mainly responsible for designing the smaller construction projects to which the insulations are bought mainly from wholesalers.

One major thing to discuss is the responsibility of keeping the information up to date in the design software. One possibility is that Paroc would create a product database from which the information could be automatically updated to material databases of BIM software. This way for example the process industry stakeholders could use the same database to find out the technical information they need.

For the more technical insulation products and solutions also readymade objects could be considered. However it should be first more thoroughly discussed with designers and contractors what kind of readymade objects or solutions would be helpful not only for designers but also for contractors. As ultimately the contractors are responsible for selecting and buying the products. First step for Paroc could be to select one more technical insulation solution and start a pilot project to create a readymade BIM object of that product or BIM application related to it. This development work should be done in close cooperation with related designers and contractors to ensure that the object or application truly helps the designer’s work and at least doesn’t interfere contractor’s use of BIM data.

To leverage the BIM data in its own operations material supplier like Paroc should be in closer cooperation with the customers. This is not so typical in AEC industry and especially difficult in cases where Paroc's products are sold through wholesalers. So the biggest potential would be in building insulations were major part of the products are delivered based on annual contracts. The most obvious way for Paroc to start discussing the possibility of utilizing the BIM data would be with the customers under or negotiating an annual contract. First step would be to utilize the contractors' BIM based production schedules for just in time type of deliveries. As the basis for information sharing and deeper cooperation is established more challenging applications for leveraging the BIM data can be considered.

6.3 Evaluation of the quality of the results

The response rates for the questionnaires varied from 17% to 48%. Response rates were not that high but adequate for this type of questionnaires. To evaluate the reliability of the questionnaires there should have been questions measuring the same thing more than ones. As the questions were very simple this type of approach would have been too transparent and thus it might have affected the respondents' interest towards the questionnaire. Also the goal was to keep the questionnaire as simple and short as possible so that as many respondent as possible would truly read and consider all the questions before answering them.

For the BIM questionnaire 109 responses were received in total. This is a good amount of responses and I believe that it gives a good overview to the situation. The respondents were also quite evenly distributed to different age groups with a small emphasize in the more mature age groups. This is in fact good thing as most likely older respondents are also more experienced and thus they can give more reliable answers. The distribution of the size of the companies which the respondents represent doesn't exactly flow the general size distribution of AEC industry companies. The larger companies are emphasized but this was expected as emphasize of the study was on larger companies. I am also happy with the validity of the questionnaire as it measured what it was supposed to measure and thus helped to answer the research questions.

The questionnaire for process industry stakeholders was already targeted only to major stakeholders and smaller companies with some connection to Paroc. So the goal was to cover only the major stakeholders from Paroc's point of view not the whole industry sector. This goal was reached as 15 responses out of 39 contacts were obtained. Like the BIM questionnaire, the process industry questionnaire measured the thinks it was supposed to measure and thus helped to answer the research questions.

There is no indication of dishonest answers. As most of the contacts were obtained from Paroc's CRM system some of the respondents might not have been the most eligible person from their company to answer the questionnaire. This might affect the reliability of the answers but only few indications of respondents with poor knowledge about the studied subject were distinguished. As the questionnaire was executed anonymously multiple answers from same company could only be filtered out based on the first question. Unfortunately the amount of "I don't know" answers for that question was quite high. So the possibility of multiple answers from the same company affects the reliability of the results measured in company level like the utilization rate of BIM etc. Most of the respondents were from companies responsible for structural or HVAC engineering. This can skew the results if they are analyzed from the whole industry's point of view.

The quality of the interview results was maximized by planning the interviews well beforehand and by selecting the most appropriate and interesting interviewees with the help of Paroc's personnel. Also with one exception all interviews were made face to face. This increases the reliability of the results because it could be ensured that all the questions were properly understood. The researcher did all the interviews. The interviews were recorded and the transcription work was done also by the researcher. As the quality of the recordings was also good there is no room for misinterpretations. So the quality of interview data is high and thus the reliability of the data is also good.

More systematic ways could have been used to analyze both the questionnaire and interview results. This way more precise insight to the studied subject could have been obtained. But as the goal was to find practical ways for Paroc to leverage the growing use of BIM the practical analysis of the results already answered the research questions in hand.

The validity of the interview results and the whole study was raised by describing the execution of the study step by step as accurately as possible. The phases of the research process and the ways for resolving the research problems were described thoroughly. Also the chain of reasoning through which the study ended up to presented findings was logically presented. Thus it can be said that the study answered reliably to the set research questions.

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APPENDICES

Interviewees and the interview

In total 11 face to face interviews with 13 interviewees and one e-mail interview were conducted. The interviewees represented 10 different companies from four different business sectors and they had following backgrounds:

Structural engineering

Company 1: Head of design department. Over 25 years of work experience.

Company 2: Structural engineer/BIM coordinator/the main user of BIM software. 9 years of work experience.

Company 3: Project manager (IT engineer and structural engineer). Prior work experience; 18 years as a structural engineer and 8 years as a software developer for BIM software company.

HVAC engineering

Company 4: Development manager. 10 years as a development manager. Over 30 years of work experience in total, from engineering and contracting.

Company 5: Project manager/ HVAC designer.

Building contractor

Company 6: Project manager (BIM development). Over five years in current position. Over 30 years of work experience from various positions in construction sector.

Company 6: Development manager (Building services). About 1,5 years in current position. Prior to this 2,5 years in BIM competence center. Earlier work experience as a development engineer in building services.

Company 6: Currently project engineer. Prior to this position, six months as a BIM coordinator in major construction site. Has been using BIM models for five years.

Company 7: Development manager (Virtual design and construction). Seven years in current position. Prior work experience from architectural design.

Company 7: Currently project assistant (BIM research). Earlier work experience from construction sites, over 10 years.

Process industry

Company 8: Head of engineering department. Long work experience.

Company 9: Head of engineering department (Plant design). About one year in current position. Seven years of work experience.

Company 10: Head of engineering department (Piping and generic process design), also CAD administrator.

Company 10: Head of engineering department (Structural and HVAC engineering).

The interviews lasted from about 45 minutes to 1,5 hours, and they were recorded. Recorded interviews were transcribed. As theme interview was used, preselected questions weren't used but themes presented in appendix II were covered in the interviews. Different themes were emphasized according to the interviewee's background and things which arise during the interview.

Themes for the interviews

Interviews related to BIM

1. Background information about the interviewee
2. Use of BIM at the interviewees company
   - Level of use
   - Software in use
3. Challenges related to BIM
   - Data transfer
   - Contractual/copyright issues
4. Benefits related to BIM
5. Modeling of insulations
   - Readymade objects
   - Role of the supplier
6. Future prospects related to BIM

Interviews related to 3D modeling in process industry

1. Background information about the interviewee
2. Use of 3D modeling at the interviewees company
   - Level of use
   - Software in use
3. Challenges related to 3D modeling
   - Data transfer
   - Contractual/copyright issues
4. Benefits related to 3D modeling
5. Modeling of insulations
   - Readymade objects
   - Role of the supplier
6. Future prospects related to BIM

Structure of the questionnaire for AEC industry stakeholders

Questionnaire about the use of Building Information Modeling

Paroc is the leading producer of energy efficient insulation solutions in the Baltic Sea region. Customer and personnel orientation, continuous innovation, profitable growth and sustainable development are the cornerstones of our operations. The PAROC® product range includes building insulation, technical insulation, marine insulation, structural stone wool sandwich panels and acoustics products. Products are being produced in Finland, Sweden, Lithuania, Poland and starting from 2013 also in Russia. The company has sales offices and representative in 13 countries across Europe. Paroc Group is owned by a number of banks and other institutional investors, with a minority shareholding owned by Paroc employees. Net sales in 2012 amounted to EUR 405 million and the average number of employees throughout the year totaled 2,019 people.

Paroc is conducting a survey about the use of Building Information Modeling (BIM) and different BIM tools. The survey is part of a final thesis. The purpose of the questionnaire is to collect basic information about; the use of BIM and different BIM tools, into which purposes BIM and information gained from it is used, the use of standardized information exchange, the use of product libraries and the future prospects of BIM usage. The main interest areas are structural engineering and HVAC engineering. As the survey is conducted for Paroc, there is a special interest towards the use of BIM for modeling different types of insulations. Below is a short description about the view point to BIM in this study.

All data from the questionnaire is of course handled as confidential information, and the names of companies and people answering the questionnaire will not be published anywhere. The questionnaire is conducted anonymously, so the answers cannot be connected to a certain respondent.

Building information modeling

Use of building information modeling (BIM) has increased rapidly in the past years and it has brought up new possibilities and challenges for the architectural engineering and construction (AEC) industry. Many times BIM is seen only as new tools for designing and modeling the building in 3D format. Typically BIM is utilized mainly in the beginning of the construction project, for example to compare the appearance, costs or energy efficiency of different designs.

But BIM is also a whole new approach for the management of building projects, and possibly even for the management of AEC industry supply chain and the buildings whole lifecycle. This means that BIM and the BIM model would be utilized both throughout the entire construction project and throughout the whole lifecycle of a building. The use of BIM could enable for example;

- Detection of errors/problems early on through automatic clash detection
- The use of supplier specific knowledge early on in the design phase
- Enhancement of the supply chain through the use of automated quantity take-off
- Automated and fast change management during the construction phase
- The generation of an as-build model which can be used in facilities management and during renovations

The questionnaire

1. Background information

1.1 Are you the first/only person from your company to answer this questionnaire?

If more than one person from your company will answer the questionnaire, then only the first respondent's responses are taken into account when the use of BIM by companies is analyzed.

◯ Yes

◯ No

◯ I don't know

Background information about the respondent

First few questions for background information. Question 1.4 is important regarding the analysis of the results. If you are responsible for MEP engineering, then in this case select HVAC engineering.

1.2 Age:

◯ under 25

◯ 25-34

◯ 35-44

◯ 45-54

◯ 55 or older

1.3 Gender:

◯ Man

◯ Woman

1.4 Which of the following best describe your areas of responsibility in your company:

- ☐ BIM expert (Structural engineering)
- ☐ BIM expert (HVAC engineering)
- ☐ BIM expert (Architectural design)
- ☐ Head of engineering department/ Lead designer (Structural engineering)
- ☐ Head of engineering department/ Lead designer (HVAC engineering)
- ☐ Head of department/ Lead designer (Architectural design)
- ☐ Structural engineer
- ☐ HVAC engineer
- ☐ Architect
- ☐ BIM expert (Building contractor)
- ☐ Head of engineering department/ Lead designer (Building contractor)
- ☐ Building contractor
- ☐ BIM expert (Precast concrete manufacturer)
- ☐ Head of engineering department/ Lead designer (Precast concrete manufacturer)
- ☐ Precast concrete manufacturer
- ☐ BIM expert (Prefabricated house manufacturer)
- ☐ Head of engineering department/ Lead designer (Prefabricated house manufacturer)
- ☐ Other ________________________________

1.5 Job title:

____

Background information about the company

1.6 Number of employees in the company:

○ >250

○ 100-249

○ 50-99

○ 20-49

○ 10-19

○ 5-9

○ <5

1.7 Fields of operation:

☐ Architectural design

☐ Structural engineering

☐ HVAC engineering

☐ Other MEP engineering

☐ Other engineering/design ________________________________

☐ Building contractor

☐ Precast concrete manufacturer

☐ Prefabricated house manufacturer

☐ Other ________________________________

1.8 Areas of activity:

☐ Finland
☐ Sweden
☐ Other Nordic Countries
☐ Other Europe
☐ North America
☐ South America
☐ Asia
☐ Africa
☐ Australia
☐ Other ________________________________
☐ Global

2. Use of BIM

Next questions are about the use of BIM in your company

2.1 Is your company utilizing BIM?

○ Yes, as a completely new operating model
○ Yes, in form of 3D modeling and other software
○ No, but interested/planning to start using
○ No

(Questions 2.2-2.8 were presented for those who are utilizing BIM)

2.2 In what percentage of projects is your company utilizing BIM?

○ under 10%
○ 10-30%
○ 30-60%
○ 60-90%
○ 90-99%
○ 100%

2.3 In which design/engineering purposes is BIM utilized in your company?

- ☐ Architectural design
- ☐ Structural engineering
- ☐ HVAC engineering
- ☐ Other MEP engineering
- ☐ Other engineering/design ______________________________

- ☐ BIM is not utilized for design/engineering purposes

2. Use of BIM

Next question is specifically about the use of BIM for insulation products. You can choose several options from one row. Take into account especially the option 4. If your company is not responsible for certain area of design, then choose option 6.

2.4 Are insulations modeled in your company in the following contexts?

	1. Insulations are fully modeled	2. Type of insulation is defined in the model	3. Spacing for insulation is reserved	4. Some vendor's product/solution is used as an example to define the insulation type	5. Insulations are not modeled	6. Our company is not responsible for this are of design/ engineering	7. I don't know
Foundation and base floor	0	0	0	0	0	0	0
Outer walls	0	0	0	0	0	0	0
Dividing walls	0	0	0	0	0	0	0
Intermediate floors	0	0	0	0	0	0	0
Roofs	0	0	0	0	0	0	0
Heating pipes	0	0	0	0	0	0	0
Water pipes	0	0	0	0	0	0	0
Sewer pipes	0	0	0	0	0	0	0
Ventilation ducts	0	0	0	0	0	0	0
Other	0	0	0	0	0	0	0

2.5 Is your company utilizing BIM and information gained from it for other purposes than design/engineering?

☐ Scheduling of a building project

☐ Scheduling of design/engineering

☐ Production scheduling (precast concrete)

☐ Scheduling of material orders

☐ Scheduling of material deliveries

☐ Quantity take-off

☐ Cost estimation

☐ Tendering

☐ Procurements

☐ Clash detection

☐ Energy analyzes

☐ CFD analyzes

☐ Other ______________________________

☐ None

☐ I don't know

2.6 Does your company require its sub-contractors to use BIM tools?

○ Always

○ If required in a project

○ Only from major/most important sub-contractors

○ Never

○ I don’t know

○ Our company doesn’t have sub-contractors

2.7 What type of tools are required?

○ Same BIM tools as your company is using

○ BIM tools compatible with your company’s tools

○ BIM tools in general

○ Use of BIM tools is not required

○ I don’t know

○ Our company doesn’t have sub-contractors

2.8 In your opinion which are the main benefits gained from the use of BIM for your company?

In general BIM is said to; increase the quality of design work and construction, shorten the time needed for design and construction processes and lower the overall costs. Below is a list of common benefits of BIM. Please choose the ones which are most essential from your company's point of view. You can also give comments about other benefits on the open answer field below.

- ☐ Faster design/engineering
- ☐ Possibility to simultaneous design/engineering
- ☐ Possibility to utilize product libraries
- ☐ Better quality of design work/engineering
- ☐ Better communication between designers/engineers
- ☐ Better communication with the client
- ☐ Possibility to compare different alternatives more easily and more accurately by using the 3D model
- ☐ Possibility to do different analyzes (e.g. energy analyzes)
- ☐ Errors/problems are detected earlier through clash detection and comparison of different models
- ☐ Automatic update of design changes to all stakeholders
- ☐ More accurate scheduling of a building contract
- ☐ Better scheduling of work
- ☐ Faster progress of a building project
- ☐ Better building quality
- ☐ More accurate cost estimation
- ☐ More accurate budgeting
- ☐ Possibility to use the model in maintenance
- ☐ Possibility to use the model in renovations
- ☐ Cost savings
- ☐ Other

If you chose the alternative other please specify here. You can also comment the other alternatives here.

____

(Questions 2.9-2.12 were presented for those who are not utilizing BIM)

2.9 Is your company considering to start using BIM for some design/engineering purposes?

- ☐ Architectural design
- ☐ Structural engineering
- ☐ HVAC engineering
- ☐ Other MEP engineering
- ☐ Other engineering/design ______________________________
- ☐ None
- ☐ I don't know

2.10 Is your company considering to start using BIM and information gained from it for other purposes than design/engineering?

- ☐ Scheduling of a building project
- ☐ Scheduling of design/engineering
- ☐ Production scheduling (precast concrete)
- ☐ Scheduling of material orders
- ☐ Scheduling of material deliveries
- ☐ Quantity take-off
- ☐ Cost estimation
- ☐ Tendering
- ☐ Procurements
- ☐ Clash detection
- ☐ Energy analyzes
- ☐ CFD analyzes
- ☐ Other ______________________________
- ☐ None
- ☐ I don't know

2.11 If your company is considering to start using BIM are you considering some particular software, which?

____

2.12 If your company is considering to start using BIM what benefits are you expecting? If your company is not considering to start using BIM, what kind of benefits would make your company to start considering to start using BIM?

In general BIM is said to; increase the quality of design work and construction, shorten the time needed for design and construction processes and lower the overall costs. Below is a list of common benefits of BIM from which you can choose freely. You can also give comments about other benefits on the open answer field below.

- ☐ Faster design/engineering
- ☐ Possibility to simultaneous design/engineering
- ☐ Possibility to utilize product libraries
- ☐ Better quality of design work/engineering
- ☐ Better communication between designers/engineers
- ☐ Better communication with the client
- ☐ Possibility to compare different alternatives more easily and more accurately by using the 3D model
- ☐ Possibility to do different analyzes (e.g. energy analyzes)
- ☐ Errors/problems are detected earlier through clash detection and comparison of different models
- ☐ Automatic update of design changes to all stakeholders
- ☐ More accurate scheduling of a building contract
- ☐ Better scheduling of work
- ☐ Faster progress of a building project
- ☐ Better building quality
- ☐ More accurate cost estimation
- ☐ More accurate budgeting
- ☐ Possibility to use the model in maintenance
- ☐ Possibility to use the model in renovations
- ☐ Cost savings
- ☐ Other
- ☐ Despite the benefits we are not considering to start using BIM

If you chose the alternative other please specify here. You can also comment the other alternatives here.

If your company is not considering to start using BIM, what are the main reasons for that?

---

3. BIM software

Next few questions about the BIM tools which your company is utilizing.

(Questions 3.1-4.4 were presented for those who are utilizing BIM)

3.1 Which software are you using for which purpose?

If your company is not responsible for certain are of design, you can leave that section plank.

Architectural design

- ☐ ArchiCAD
- ☐ Autodesk Revit
- ☐ Bentley
- ☐ AutoCAD
- ☐ Other ____________________

Structural engineering

- ☐ Tekla Structures
- ☐ Autodesk Revit
- ☐ Bentley
- ☐ AutoCAD
- ☐ Other ____________________

HVAC engineering

- ☐ MagiCAD
- ☐ CADS
- ☐ Autodesk Revit
- ☐ Bentley
- ☐ AutoCAD
- ☐ Other ________________________________

3.2 Is your company utilizing some other BIM software for some other purposes, like clash detection or for viewing the model in construction site? If so, which software for which purpose?

____

3.3 Is your company currently committed to using this/these software?

- ○ Yes
- ○ No

(Questions 3.4 & 3.5 were presented for those who are not committed to their current software)

3.4 To which software is your company considering to switch?

Architectural design

- ☐ ArchiCAD
- ☐ Autodesk Revit
- ☐ Bentley
- ☐ AutoCAD
- ☐ Other ________________________________

Structural engineering

- ☐ Tekla Structures
- ☐ Autodesk Revit
- ☐ Bentley
- ☐ AutoCAD
- ☐ Other ________________________________

HVAC engineering

- ☐ MagiCAD
- ☐ CADS
- ☐ Autodesk Revit
- ☐ Bentley
- ☐ AutoCAD
- ☐ Other ________________________________

3.5 To which software is your company considering to switch, related to other purposes than design and engineering?

____

3.6 Are the software, which your company is using, IFC compatible?

IFC (Industry Foundation Classes) is an international continuously developed ISO/PAS 16739 standard for object oriented data transfer between computer software in AEC industry. From a technical point of view it is a standard data transfer format and protocol, which can be used for example to transfer BIM models between different software.

- ○ All compatible with the IFC standard
- ○ Mainly compatible with the IFC standard
- ○ Some are IFC compatible some are not
- ○ Not compatible with the IFC standard
- ○ I don't know

3.7 If multiple software is used in a project, how the data transfer between the software is executed?

- ☐ By using IFC files
- ☐ By using data files in some other format, which?

  ____

- ☐ Some other way, how? ________________________________
- ☐ Only one software is used
- ☐ I don't know

4. Product libraries

Next few questions about the use of product libraries. Product libraries contain different types of readymade objects. They can be materials, components or products, and the objects can be utilized in designs by copying them directly to the model. Product libraries can contain general objects, like different wall structures, plumbing parts, doors, windows etc. Product libraries can also contain supplier specific precisely defined objects, like the window selection of a certain supplier or valves of a certain producer.

4.1 Is your company utilizing product libraries for BIM?

- ☐ Yes, product libraries containing general products/objects
- ☐ Yes, product libraries containing manufacturer/supplier specific precisely defined products/objects
- ☐ No
- ☐ I don’t know

(Questions 4.2-4.4 were presented for those who are utilizing product libraries)

4.2 Which product libraries is your company utilizing?

Regarding general products/objects

____

Regarding manufacturer/supplier specific precisely defined products/objects

____

4.3 Are there insulation products/objects in the libraries?

- ☐ General insulation products/objects
- ☐ Manufacturer/supplier specific insulation
- ☐ No
- ☐ I don’t know

4.4 What kind of information about insulations there should be in the insulation products/objects?

Would it be beneficial if there were manufacturer/supplier specific products/objects in the libraries?

____

(Questions 4.5 & 4.6 were presented for those who are not utilizing BIM or product libraries)

4. Product libraries

Next few questions about the use of product libraries. Product libraries contain different types of readymade objects. They can be materials, components or products, and the objects can be utilized in designs by copying them directly to the model. Product libraries can contain general objects, like different wall structures, plumbing parts, doors, windows etc. Product libraries can also contain supplier specific precisely defined objects, like the window selection of a certain supplier or valves of a certain producer.

4.5 Would you be interested in using product libraries?

◯ Yes

◯ Maybe

◯ No

4.6 If there were insulation products in the libraries, what kind of information there should be in the insulation objects?

Would it be beneficial if there were manufacturer/supplier specific products/objects in the libraries?

(Rest of the questions were presented for all respondents)

4.7 In what way the product libraries are/could be useful?

---

5. Future prospects of BIM

Finally I would ask you to estimate the development of the use of BIM

5.1 In the near future, the use of BIM in the industry will…

◯ increase rapidly

◯ increase slowly

◯ stay at the same

◯ decrease slowly

◯ decrease rapidly

5.2 In the near future, the use of BIM in your company will…

- ◯ increase rapidly
- ◯ increase slowly
- ◯ stay at the same
- ◯ decrease slowly
- ◯ decrease rapidly

5.3 In long term, the use of BIM in the industry will…

- ◯ increase rapidly
- ◯ increase slowly
- ◯ stay at the same
- ◯ decrease slowly
- ◯ decrease rapidly

5.4 In long term, the use of BIM in your company will…

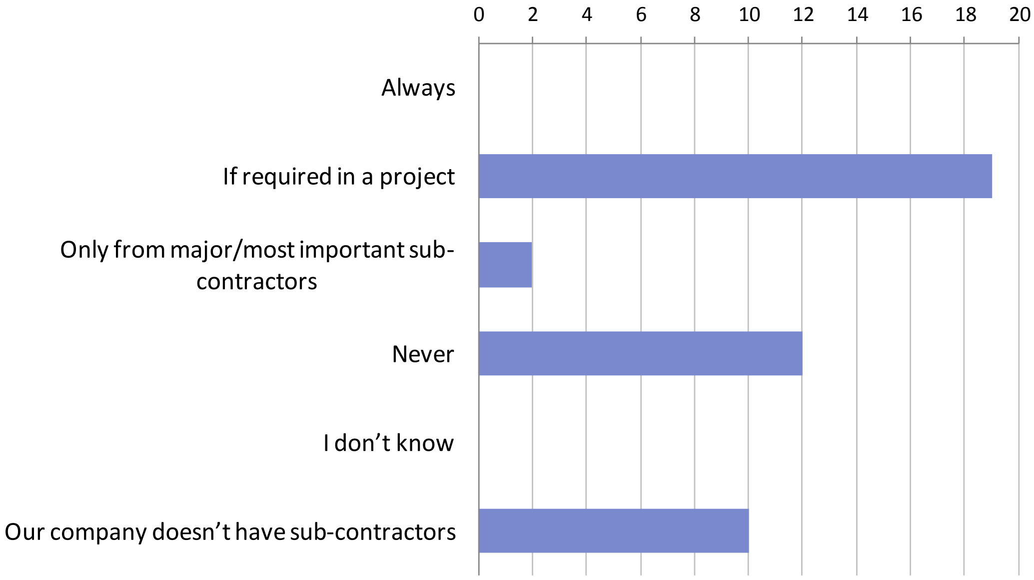
- ◯ increase rapidly
- ◯ increase slowly
- ◯ stay at the same
- ◯ decrease slowly
- ◯ decrease rapidly

5.5 Other comments related to the future prospects of BIM?

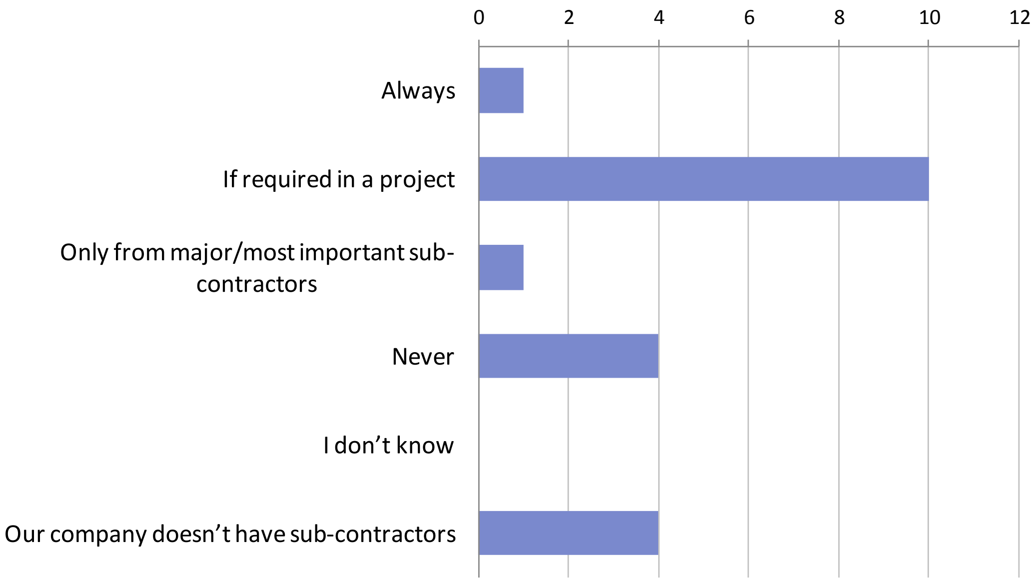
Other comments?

Result graphs from the BIM questionnaire

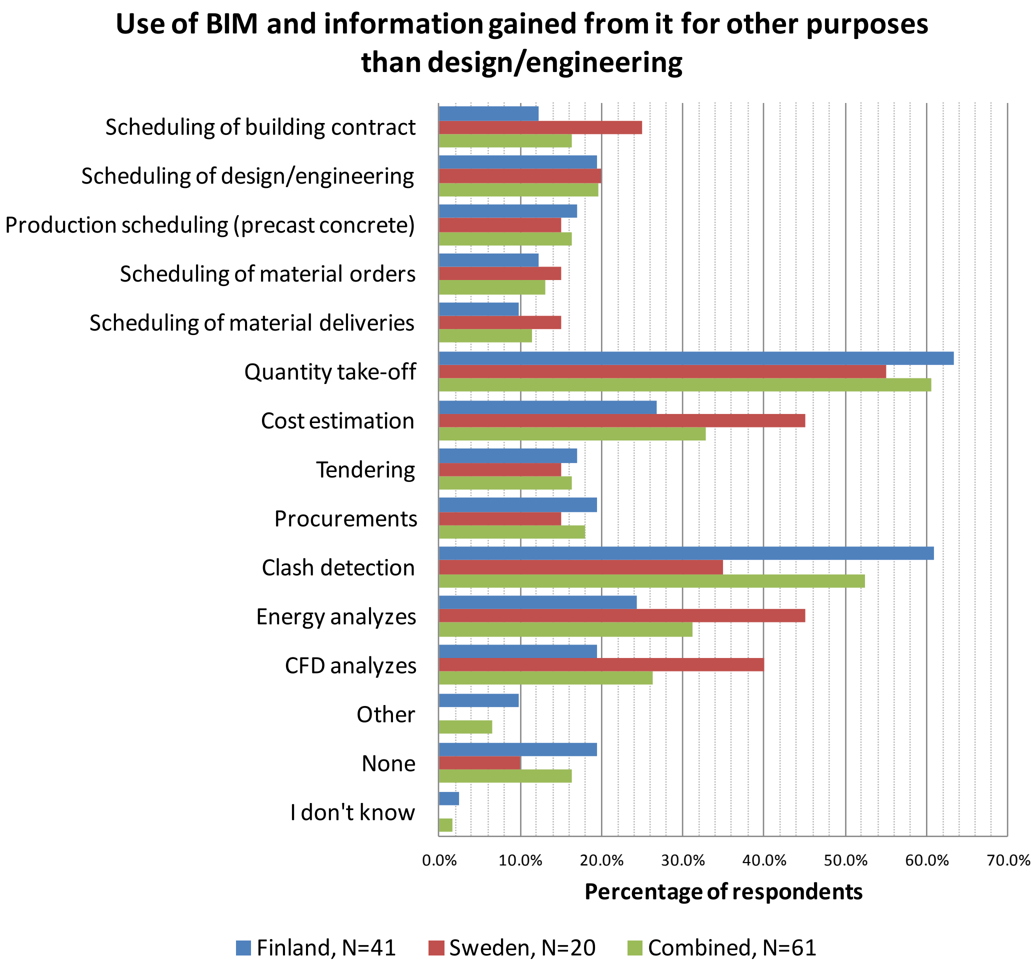
1. Does the company require its sub-contractors to use BIM tools? (Finland, N=43)



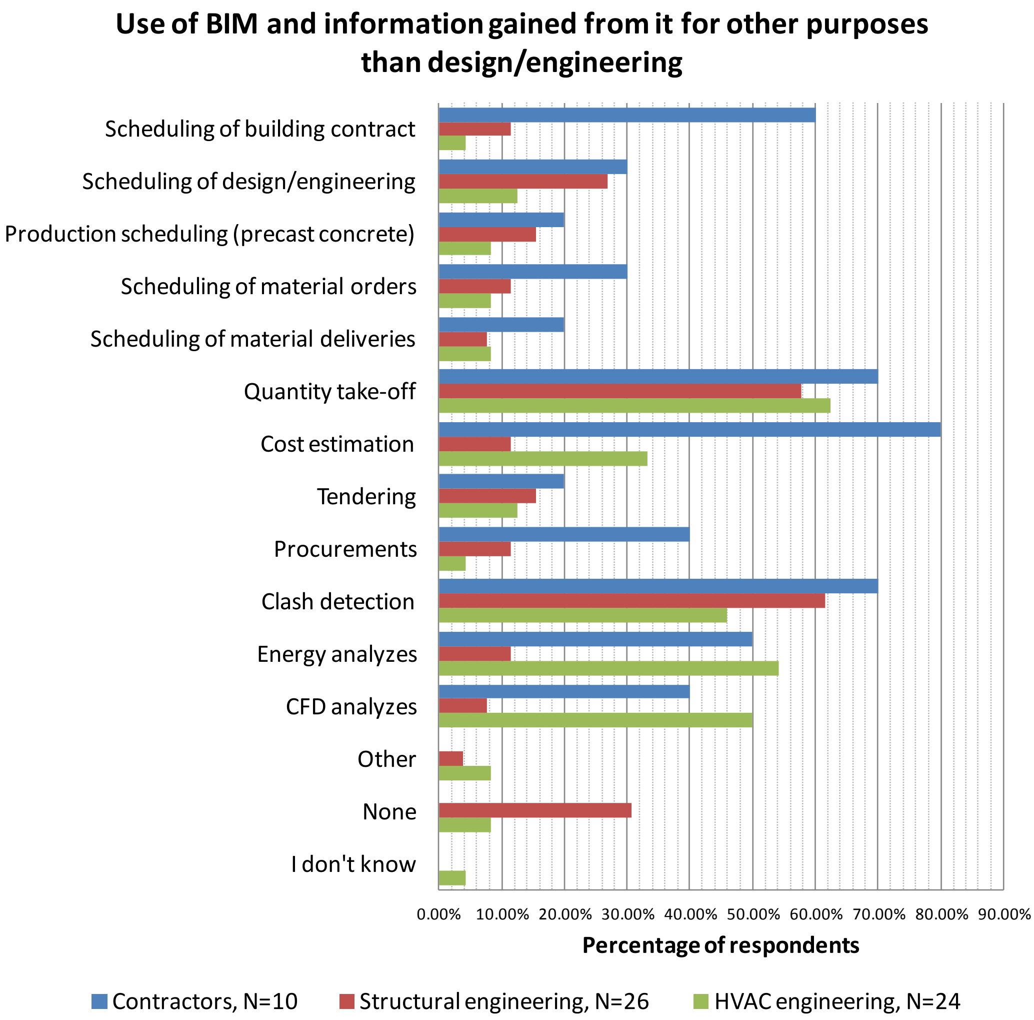
2. Does the company require its sub-contractors to use BIM tools? (Sweden, N=20)



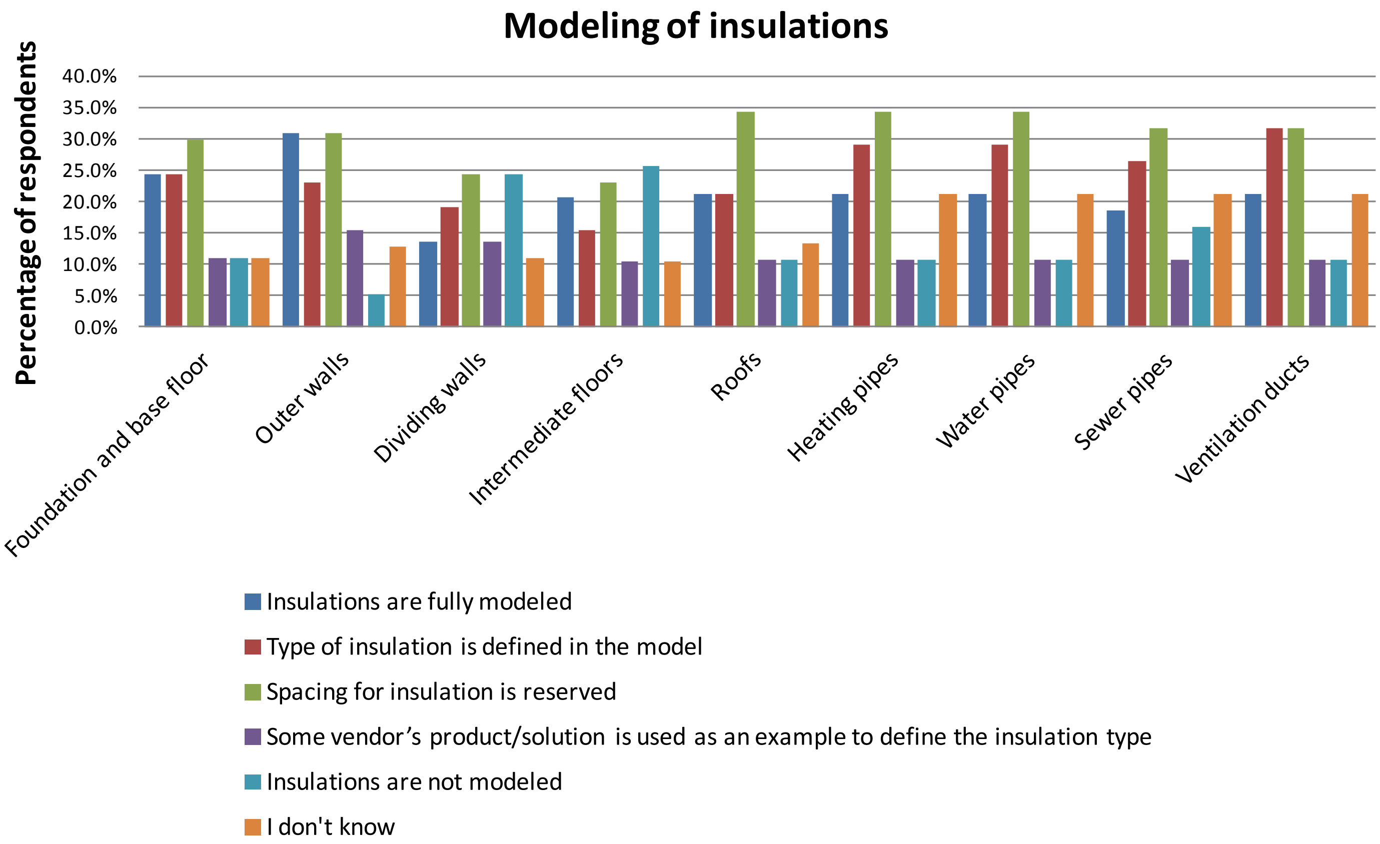
3. **To which other purposes than design/engineering is BIM used in Finland, Sweden and combined. The two respondents from Finland who informed that they aren't the first ones from their company to answer the questionnaire are removed from these results.**



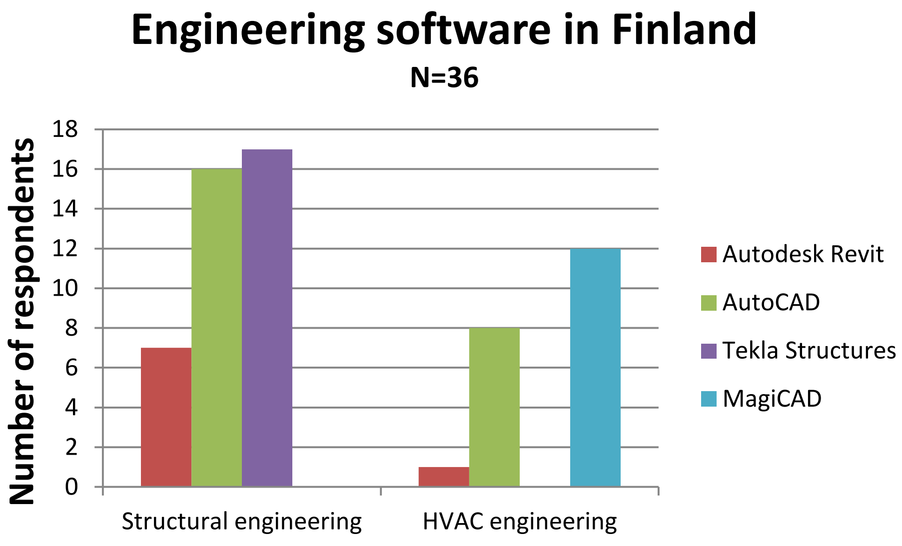
4. To which other purposes than design/engineering is BIM used in Finland and Sweden combined by contractors and companies responsible for structural or HVAC engineering. The two respondents who informed that they aren't the first ones from their company to answer the questionnaire are removed from these results.



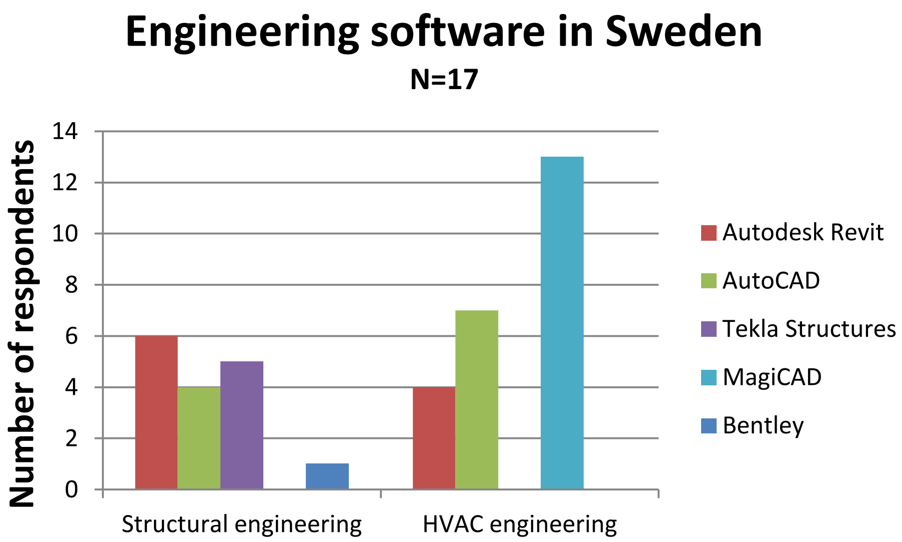
5. **In what level the insulations are modeled in Finland and Sweden combined. Percentage of respondents who are working for a company which is responsible for are of design in question. Respondents could select more than one response alternative per category. The two respondents from Finland who informed that they aren't the first ones from their company to answer the questionnaire are removed from these results.**



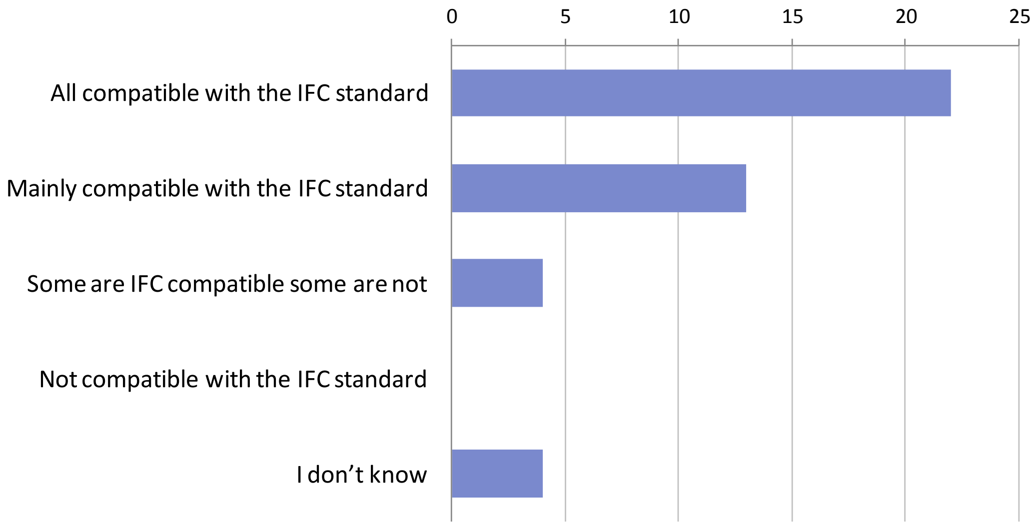
6. Which engineering/design software are used in Finland. The two respondents who informed that they aren't the first ones from their company to answer the questionnaire are removed from these results.



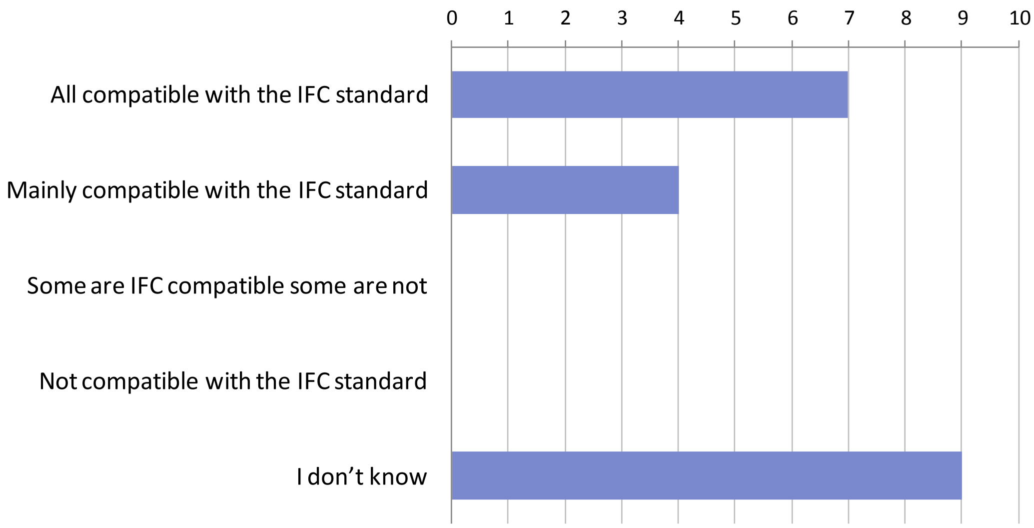
7. Which engineering/design software are used in Sweden.



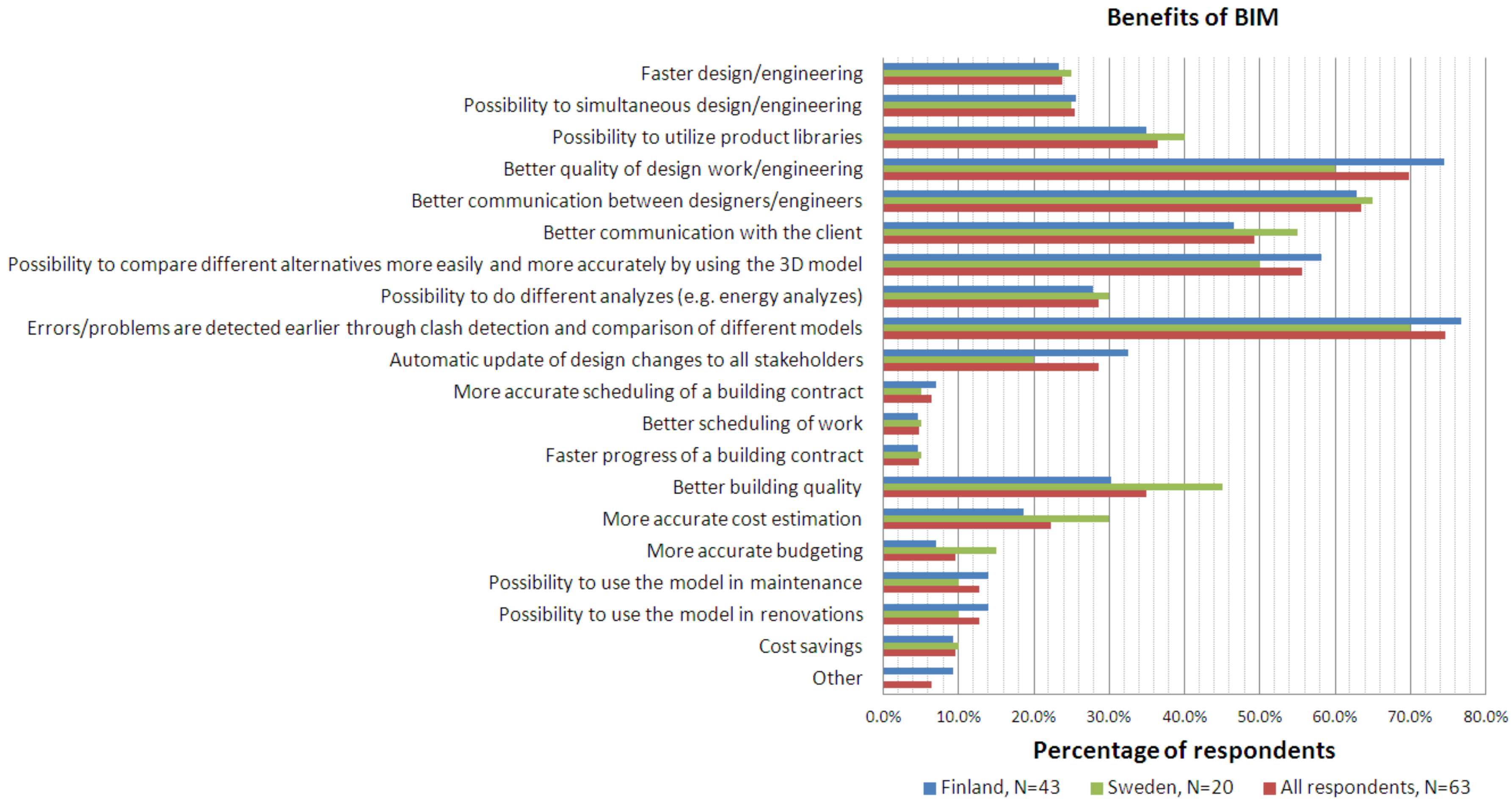
8. IFC compatibility of software used in Finnish companies, N=43.



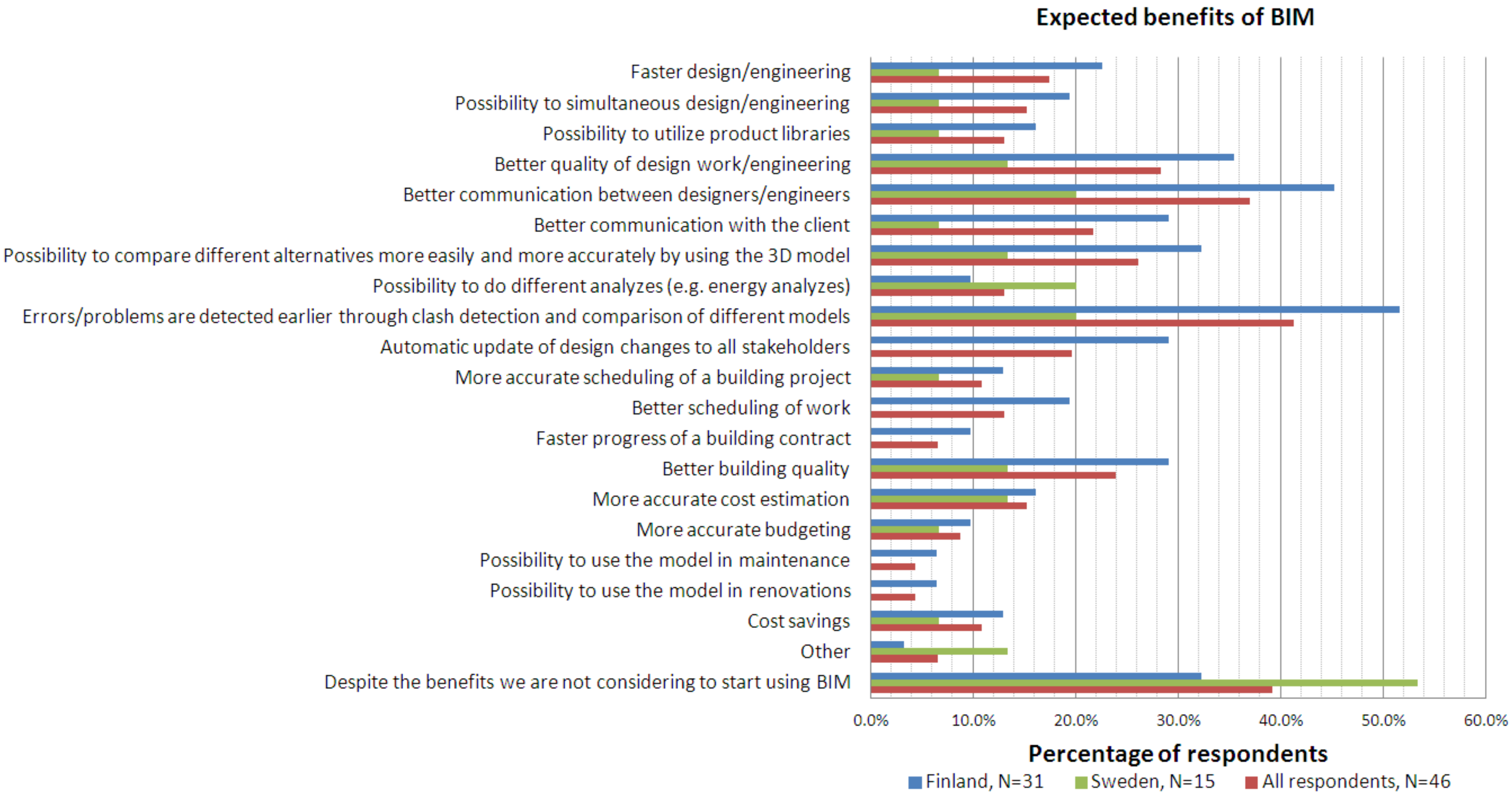
9. IFC compatibility of software used in Swedish companies, N=20.



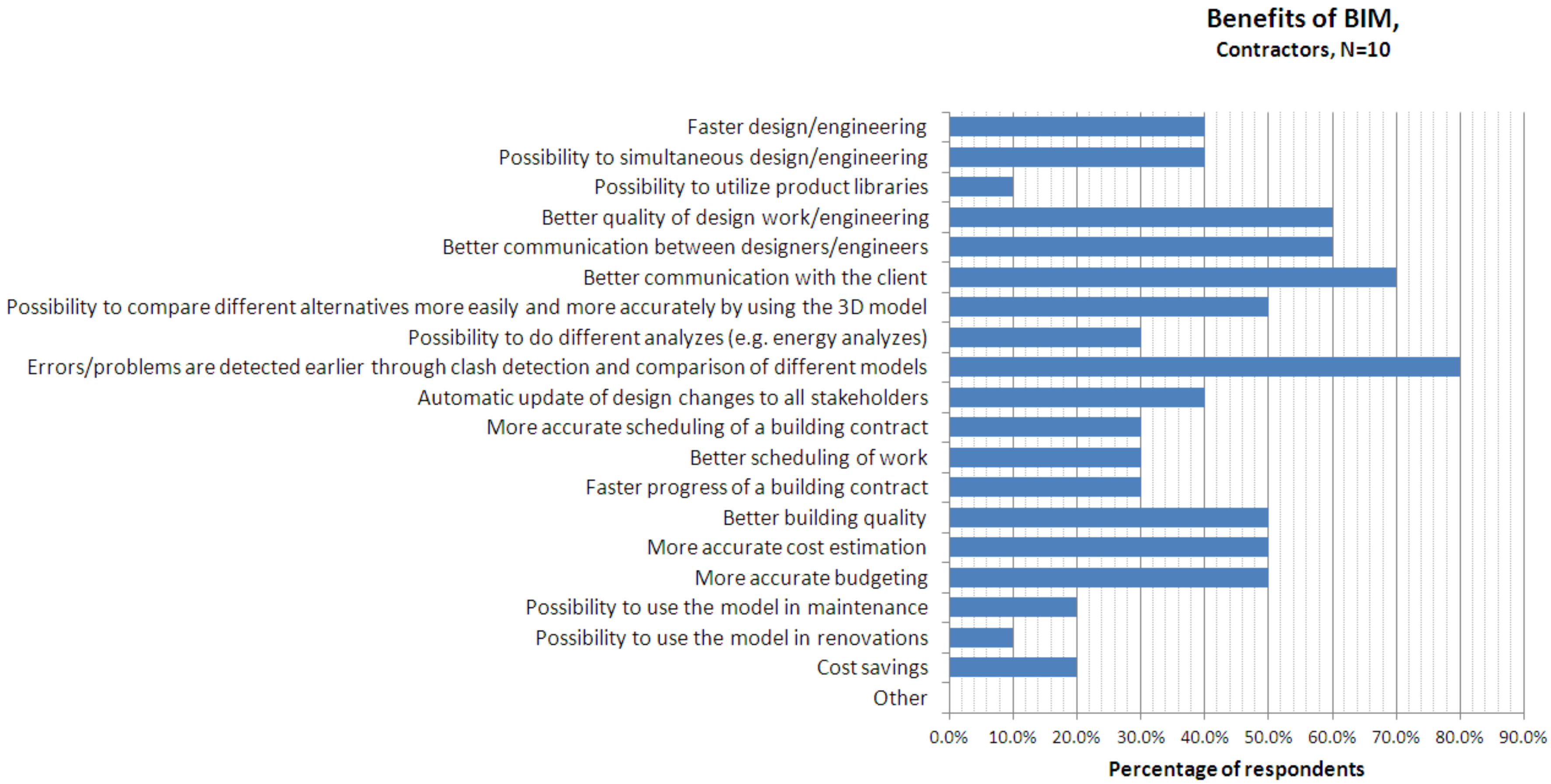
10. Benefits gained from the use of BIM, according to those who are using BIM. Results from Finland, Sweden and combined.



11. Expected benefits of BIM, according to those who are not using BIM. Results from Finland, Sweden and combined.

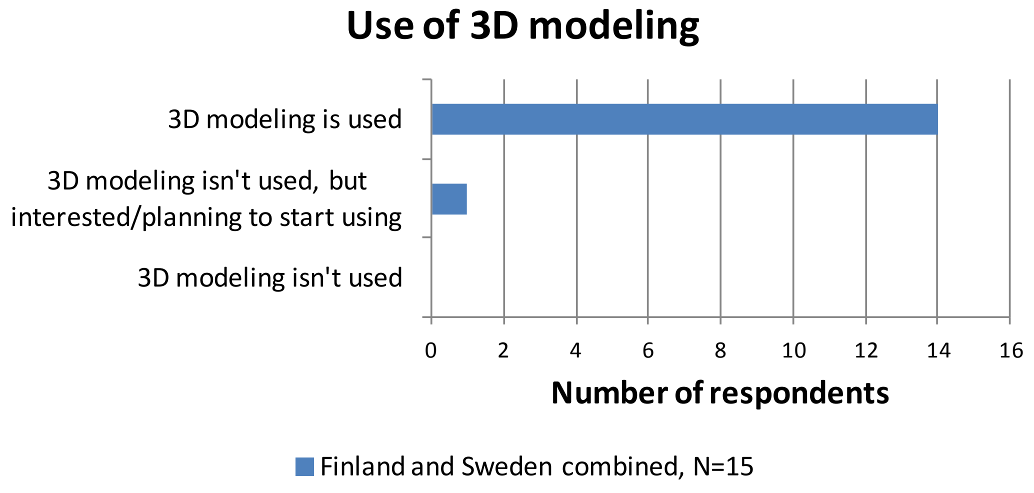


12. Benefits gained from the use of BIM, according to those contractors who are using BIM. Results from Finland and Sweden combined.

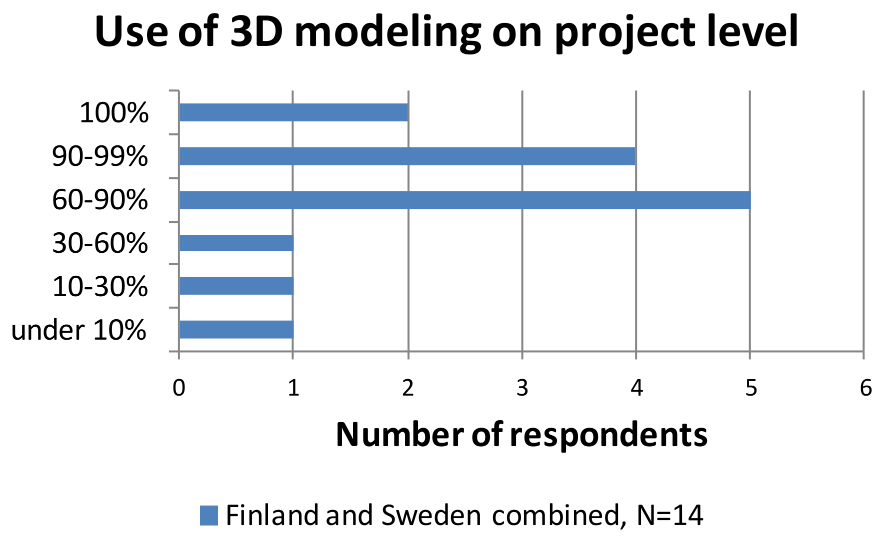


The main results of the process industry questionnaires

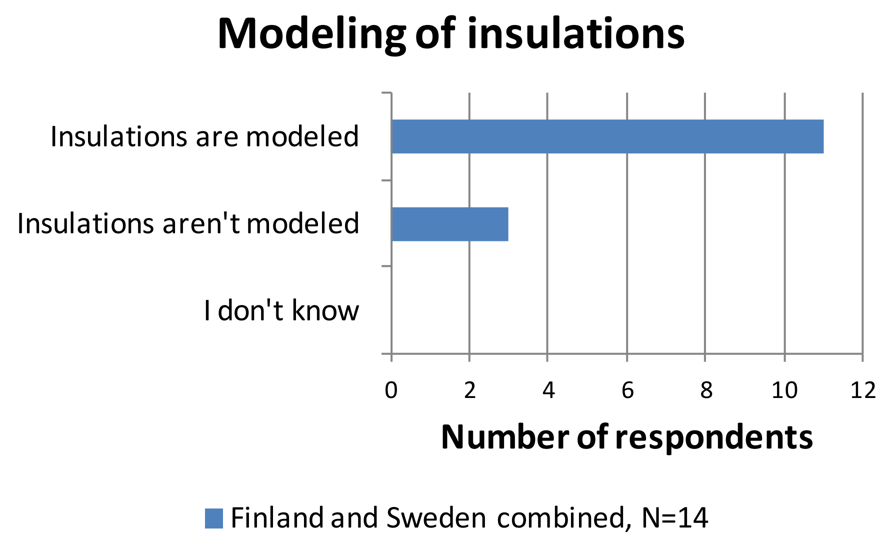
1. Utilization of 3D modeling. Results from Finland and Sweden combined.



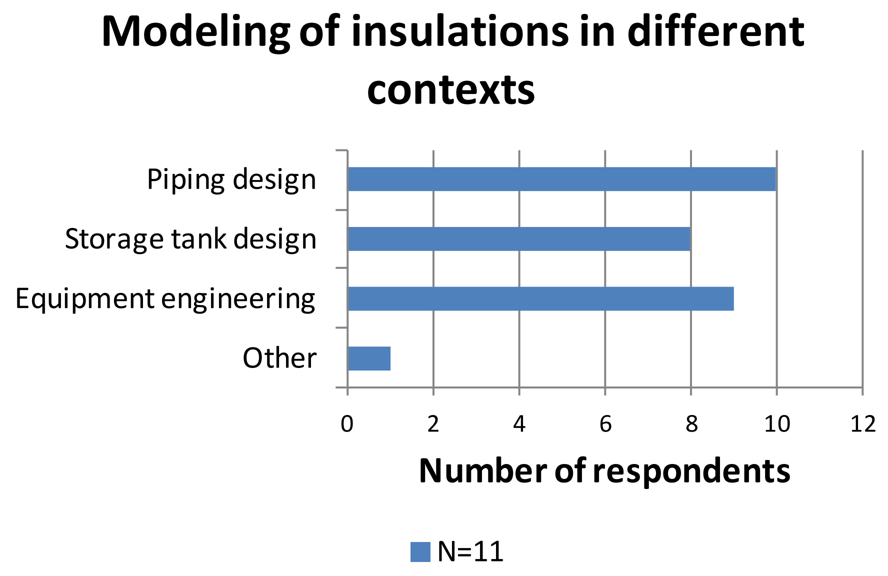
2. In what percentage of projects is 3D modeling used. Results from Finland and Sweden combined.



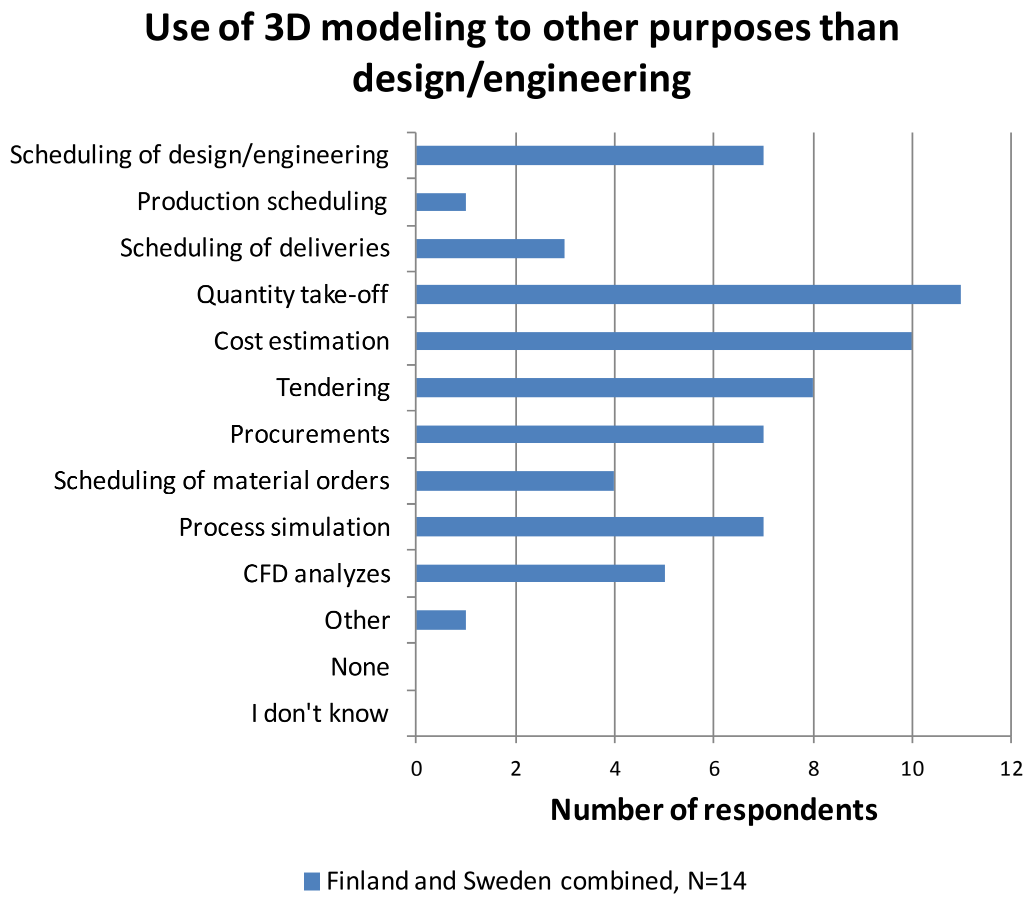
3. **Are insulations modeled. Results from Finland and Sweden combined.**



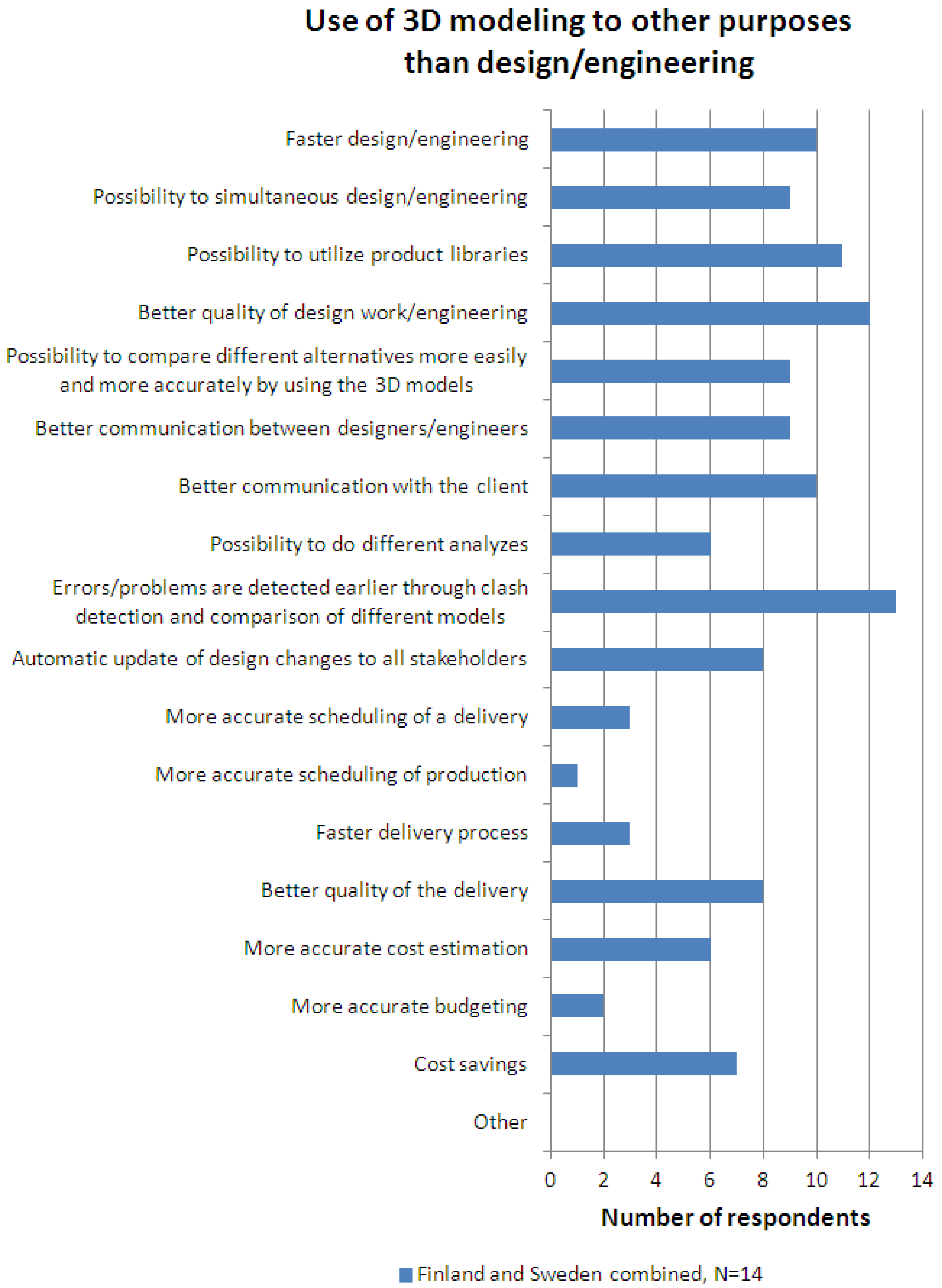
4. **In which contexts insulations are modeled. Responses only from Finland**



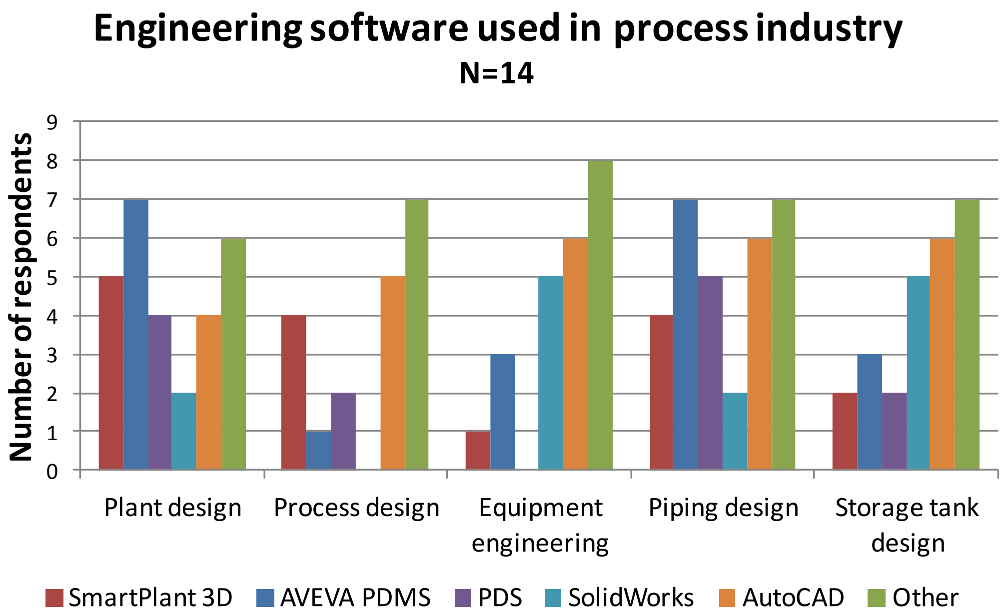
5. To which other purposes than design/engineering is BIM used. Results from Finland and Sweden combined.



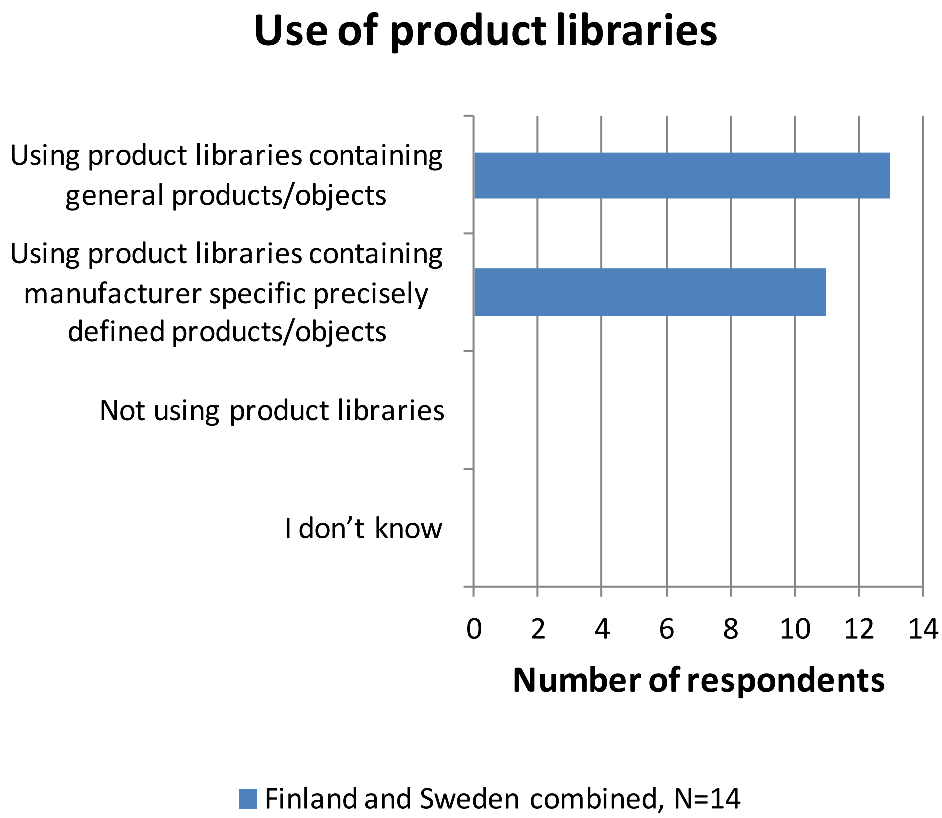
6. Benefits gained from the use of 3D modeling. Results from Finland and Sweden combined.



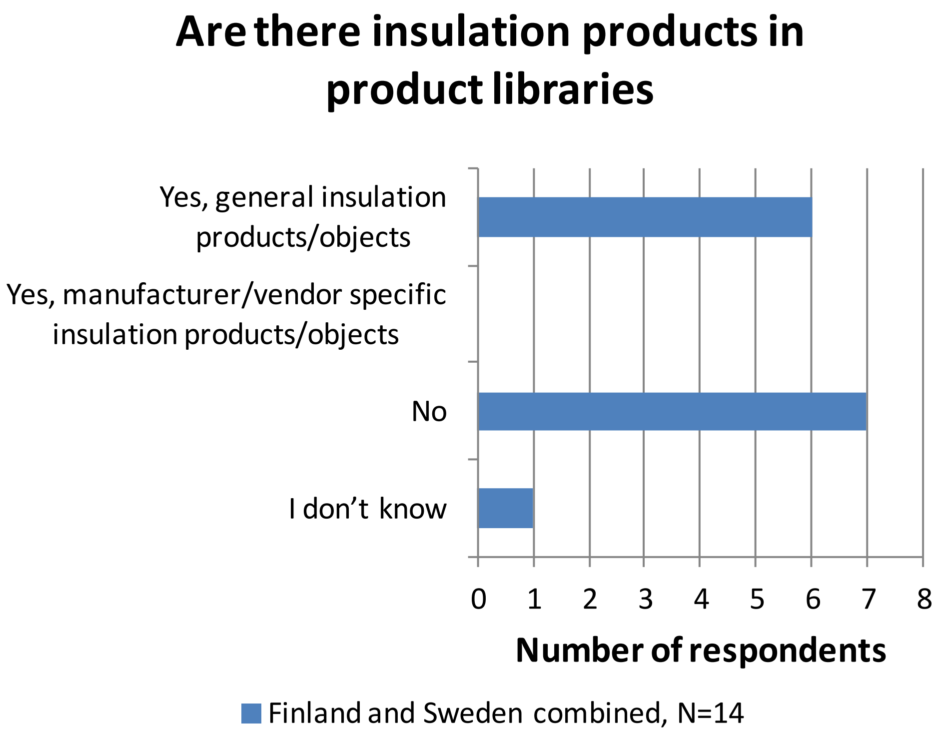
7. Which engineering/design software are used for different purposes. Results from Finland and Sweden combined.



8. Use of product libraries. Results from Finland and Sweden combined.



9. Insulation products in product libraries for 3D modeling software in process industry. Results from Finland and Sweden combined.



10. Future development of the usage of 3D modeling in process industry. Results from Finland and Sweden combined.