

# **Perceived Value of Building Information Model Quality Assurance/Quality Control Software**

Heikki Puska



<b>Author(s)</b> Heikki Puska	
<b>Degree programme</b> International Business	
<b>Report/thesis title</b> Perceived Value of Building Information Model Quality Assurance/Quality Control Software	<b>Number of pages and appendix pages</b> <b>45 + 4</b>
<p>This Bachelor's thesis discusses what kind of benefits and costs follow an investment in the quality assurance and quality control of building information model software. The aim was to gather experiences of using model checking software and the kinds of challenges companies using the software face from information in the models. The aim was also to see if these challenges can be solved with Solibri Model Checker.</p> <p>The study consists of a theory section and an empirical research project that was done by interviewing customers of Solibri, Inc. The theory section of this bachelor's thesis discusses the use of building information modelling, current trends in building information modelling, quality checking and the quality assurance of the models. The empirical research part focuses on the challenges faced in the reliability of the models, the benefits acquired by model checking for case companies in different stages and throughout the projects. The study was based on qualitative research. Interviews were conducted with 5 architect offices, 5 engineering offices, 5 construction companies and 4 owners to obtain a views on the benefits and return on investment in quality checking and quality assurance software.</p> <p>The research showed that companies that have implemented a building information model quality assurance/quality control software perceive it as a necessary tool to operate successfully. The interviewed companies do not actively follow the return on investment of the software but intangible benefits received from the software show it as a valuable tool in their design processes.</p> <p>According to the interviews, there is a significant influence by the new technologies on the process of designing and constructing buildings. However, as the interviewed companies are not involved with each other, the benefits in the changes in the design process are not shown completely. A research of a single project, where all parties would utilize similar technologies could bring out different results. Moreover, to get knowledge that is more thorough on the return of investment of the technology, qualitative research on the topic could provide knowledge on the fiscal benefits and costs of the technology.</p>	
<b>Keywords</b> Building information model, quality assurance/quality control, construction, return on investment, software, BIM, lean production	

## Table of contents

1	Introduction .....	1
2	Background.....	2
2.1	Research topic.....	3
2.2	Demarcation .....	4
2.3	International aspect.....	5
2.4	Anticipated benefits .....	6
2.5	Key concepts.....	6
2.6	Case company.....	8
3	Literature review .....	10
3.1	Building information modelling (BIM).....	10
3.1.1	Current trends .....	14
3.1.2	Industry foundation classes.....	17
3.2	Quality assurance/quality control .....	18
3.3	Return on investment .....	21
4	Research method .....	23
5	Key findings .....	24
5.1	Challenges.....	24
5.1.1	Architects.....	25
5.1.2	Engineering offices.....	27
5.1.3	Construction companies.....	28
5.1.4	Owners .....	30
5.2	Benefits.....	31
5.2.1	Architects.....	32
5.2.2	Engineering offices.....	34
5.2.3	Construction Companies.....	36
5.2.4	Owners .....	37
5.3	Costs .....	39
5.4	Influences to building process .....	40
5.5	Conclusion.....	41
6	Recommendations.....	42
	References .....	44
	Appendices.....	47

# 1 Introduction

Building information modelling (BIM) is a process where information of the designed objects that create a virtual building is usually visualized in 3D-format to improve efficiency of constructing a building. With the help of design software, object information like material is included to the models of the buildings to be utilized in different kind of analyses before constructing the building. These building information models are also used to improve the knowledge on construction site of what will be built. As BIM enables models of different designers to be combined and compared, it requires more cooperation between the designers, construction companies and buyers. This brings the designs of the buildings to more easily approachable format, which does not require a specialist to read.

This grows the amount of information within the models, and the users should be able to trust the information. To ensure the trustworthiness of the complex models Solibri, Inc. has created a Quality Assurance/Quality Control (QA/QC) software that checks the quality of the designs. With this program, it is possible to guarantee the overall quality of the design, and even compare the model to local construction standards, so mistakes can be minimized in the construction phase. These potential mistakes can be extremely costly, as they might stall the construction for long periods. The construction industry is used to these mistakes and solutions on site have become more of a habit, but these might cause a snowball effect to other parts of the building, as the parts will not fit together anymore.

It can be challenging to evaluate the value of fixing these mistakes, as they may require more than a quick fix on the construction site. This makes it challenging to evaluate the value of the software that finds these mistakes. The research concentrates on the perceived value of a QA/QC software for the different customer segments of Solibri, Inc. As the value of investing in such a software can vary in different user groups, all different customer segments have been taken into consideration. The benefits in this kind of software can be often intangible, so the focus of this thesis is to customers' experiences of the benefits.

## 2 Background

The building industry has been slowly changing from traditional 2D drawings and blue prints towards 3D modelling since 1970's (Eastman 2011 p.36). Change to modern technologies has been slow compared to other industries because of the need for high performance computers, as the 3D models can get large with a lot of information, and resistance from employees on the field. As computers have gotten faster the field has taken a step towards implementing information to the models. On top of the traditional 3D, the models have taken dimensions like time (4D), money (5D) and the latest of facility management (6D) (NBS 2014). Models that do not limit to only dimensional plans, but include also information of the objects are called building information models, and use of these models have become more popular since 1990's. This increasing amount of data raises more questions about the actual quality of the information.

For efficient utilization of the information in the models, there should be means to communicate the information between parties participating in the construction process. For these purposes, the Industry Foundation Classes (IFC) standard was created. This is an open and neutral data format for building information models (Buildingsmart, 2015) This format enables files developed with different software to be saved and read with other software, therefore making communication in projects easier. The common standard enables comparing models and checking of the quality of the models. The case company produces software that compares different models together, and checks the models against standards given for the model by authorities and company that ordered the building. The return of investment of this kind of software can be difficult to measure.

Benefits of investing in software are both intangible and tangible, and usually hard to measure. The purpose of this research is to find out the financial and operational benefits of an investment in QA/QC software for Solibri's clients, and compares these to the costs of the software. Tangible benefits acquired from software usually come during a longer period and are hard to link with certain software, like savings in projects or increase of efficiency. The costs of implementing a new software do not limit to buying the software, for example, employees have to be trained to utilize the software to get the greatest benefit from it. These opportunity costs in short term can be larger than the pecuniary cost of the software or training. The aim of this thesis is to find out these tangible and intangible benefits and costs of acquiring quality assurance/quality control (QA/QC) software that the case company offers.

## 2.1 Research topic

Use of BIM has been constantly growing since late 1990's despite the resistance of the industry. Building industry has been stated in many sources to be reluctant to change, and a complete solution like BIM takes time to be adapted. The early adapters of the industry have already implemented the process. This enables research of the benefits of BIM and quality assurance/quality control of the produced models. The transformation of the field has given an advantage for the users of BIM but the actual size of this advantage has not been fully covered yet. As the building information models are getting more complex, the importance of the quality of the information within the models has grown.

The purpose of this thesis is to research what kind of criteria influence the return on investment of building information model quality assurance/quality control software. As the research will be concentrating on current customers of the case company, the research questions already include an expectation of some kind of return on investment. The view to quality assurance/quality control is discussed through use of case company's product Solibri Model Checker.

Investigative questions (IQ's) have been used to divide the research topic. These investigative questions are:

IQ1: What kind of challenges do the clients face in building information modelling that the case company's software could help to resolve?

IQ2: What kind of benefits and costs companies working in different stages of building process face through quality assurance/quality control of building information models?

IQ 3: How does the use of quality assurance/quality control influence the design process as a whole?

The first investigative discusses the possible challenges that the clients have faced with building information modelling (BIM). This is studied through the stages that the client companies operate in the building process, separating architects, engineering offices, construction companies and owners (AECO) as separate fields. The research also concentrates on challenges the case company's product could or has resolved with BIM.

The second question concentrates on the benefits and costs that the company has achieved through successful QA/QC. This is also researched by comparing different sectors of AECO separately.

The third topic compares the results of IQ1 and IQ2 through the building industry. By comparing challenges of different stages, and does the successfully done QA/QC reflect to the next stage of the process.

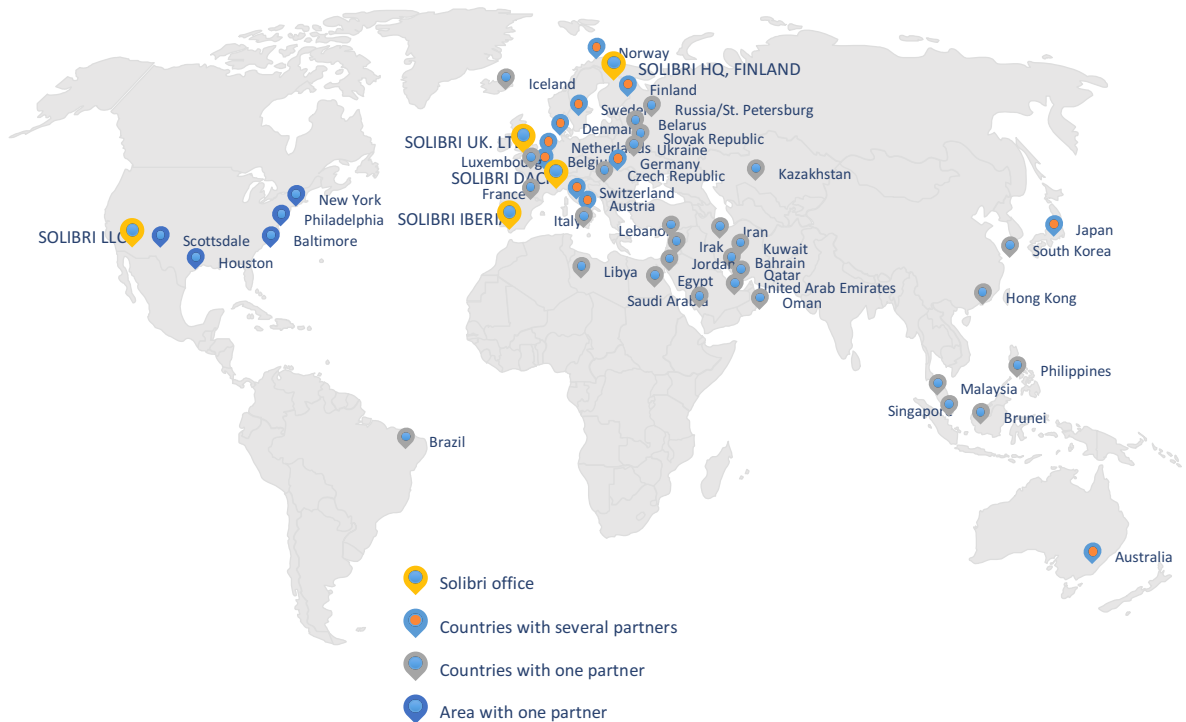
## **2.2 Demarcation**

The topic of this thesis has been demarcated to benefits and costs of investing in quality assurance/quality control (QA/QC) of building information models, as the case company offers its customer a solution for this. I will focus on operational benefits and take into account the financial benefits achieved by QA/QC, because of my concentration on international business and specialization in finance and accounting. The case company's target group is the building industry as a whole, including architects, engineering offices, construction companies and owners (AECO), so my study will include perspectives from all these sectors, and the use through the industry.

The study concentrates on quality QA/QC in building industry from the perspective of case company's product Solibri Model Checker (SMC), as all the interviewed companies are clients of the company and are expected to utilize the product in their work.

## 2.3 International aspect

Picture 1. Operations of Solibri, Inc. on a map (Kulusjärvi H. 2015)



The case company operates internationally and has clients in 70 different countries. (Kulusjärvi H. 2015) Majority of Solibri's sales are done through partner network. The company has succeeded in achieving partners around the globe as shown in the picture 1. The company is also operating locally through their own offices. Headquarter of Solibri is located in Finland, and it has offices in Germany, United Kingdom, Spain and United States of America.

Few of the interviewed companies operate internationally but the industry is mostly localize the construction sector, because of the different rules and regulations. To get international aspect to the research, some companies using SMC abroad were selected for the interviews. One company from the Netherlands was taken into account, and two of the interviews were done in English.



## 2.4 Anticipated benefits

Solibri, Inc. has shown need for information of the return on investment of their product, as this might not be so clear for their potential clients. Researches show that benefits from software investments are tangible and intangible, and usually show most benefit in the long run. Therefore, a thorough research of their product's return on investment would be beneficial for the company. The interviews with their customers give them a good opportunity to get feedback and customer experiences, to be utilized in future development of their service and marketing.

Building information modelling has been researched before, but as the company is a pioneer of quality assurance/quality control of these models, I have not found that the field would have been researched before so this study will hopefully benefit in future research of the BIM QA/QC.

The interviews with the company's customers give them a good opportunity to discuss possible challenges with the software and improvement ideas to the software. This would be a good opportunity to give the customers more information about the software, and possibly increase sales of the company in form licenses and training.

This research helps me to get information of a new field and deepen my knowledge of software's return on investment. As I have made a permanent employment contract with the company, this study is a good opportunity for me to get inside the company and the field it is operating.

## 2.5 Key concepts

**“Building information modelling (BIM)** is a shared knowledge resource for information about a facility forming a reliable basis for decisions during its life-cycle; defined as existing from earliest conception to demolition” (Building smart 2014).

**“Quality control (QC)** is the process employed to consistently meet standards” (Rumane 2001). One definition of **quality assurance (QA)** is that “All planned and systematic activities implemented within the quality system that can be demonstrated to provide confidence that a product or service will fulfil requirements for quality” (ASQ 2015).

**“Industry Foundation Classes (IFC) are the open and neutral data format for openBIM.”**  
(BuildingSMART, 2015).

**Software license pricing** works in a way that you buy the license to use of software. In this case, client pays the license on the first year and after that, they can utilize the software as much as they need. The restrictions are that only one user per license can use the software at the same time but there can be multiple user profiles per license. After the first year, the client has to pay only for the updates, customer service and maintenance per license and this is a lot less than the initial investment.

**Return on investment** is a basic financial theory that compares the costs of an investment to gains achieved from the investment. The basic variables in the equation are total costs of an investment and total gains from an investment. The parts of costs and gains are usually shown in the end equation, as these may vary a lot from of the investment that is measured.

**Return on investment for an information technology investment** is usually hard to measure, because the gains and costs can last for long period and the nature of them can be intangible. This thesis uses a set of evaluation measures that the investment in software should be compared according to Daniels C. This includes currency, content, quality, flexibility, importance and scalability. (1998):

- Currency – the information available is up to date and the data accessible and reliable.
- Content – this refers to the accuracy.
- Quality – this term must be defined in context. Quality considerations are concerned with the degree to which the system helps the managers to do his or her job well, or alternatively, inhibit the business process.
- Flexibility – the ease of use of the system, the ability to generate changes or ad hoc requests, and the business manager’s involvement in the systems process.
- Importance – the dependence of the business on the system and the level of security required.
- Scalability – A judgment of how the system will serve future business needs.

## 2.6 Case company

Solibri, Inc. is a company that develops and sells quality assurance/quality control solutions that improve the quality of openBIM-based design and makes the entire design process more productive.

The company was founded in 1999 and their headquarters is located in Helsinki, Finland. Solibri's revenue was 2 614 000 € in 2014, and they have been continuously growing. Most of their sales is done through their partner network that covers 40 countries in all continents. In December 2015 Solibri was sold to Nemetschek Group, which is an international company based in Munich Germany, and listed on German stock exchange. Solibri as part of their software portfolio they are able to offer complete BIM solutions, by offering design and checking software for their customers.

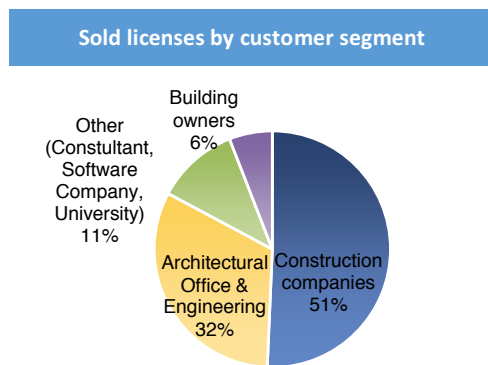


Figure 1 Solibri customer segments by amount of licenses sold

The case company's software serves the whole building industry. Most of the revenue is generated from construction companies, and architects and engineering offices cover almost thirty percent of the total revenue.

Solibri offers 3 products that are: Solibri Model Checker (SMC), Solibri Model Viewer (SMV) and Solibri IFC Optimizer. SMC is used to check the quality of IFC models and to communicate the flaws easily. It can also be utilized to take off the information for different stages of construction projects in excel format. SMV is a free software that enables opening information extracts from SMC and viewing IFC models. Solibri IFC Optimizer is a free software that is used to optimize heavy IFC models to more easily transferable sizes. In my research, I will concentrate on the SMC, as it is the only product, which brings revenue for the company. This product also gives greatest benefit for the customers, as SMV is

usually used only to view files saved with SMC, and IFC optimizer is only a tool to make the files easier to transfer.

### **3 Literature review**

This part of the research concentrates on key terminology, and concepts used in the thesis. For the reader to get a better picture of the research, this part clarifies what is commonly meant by building information modelling, and how commonly it is currently used in the markets. This will be followed by current standardized file format IFC, and introduce its current usage, as this will clarify challenges that companies face when changing from traditional 2D modelling to building information modelling. Quality assurance/Quality control (QA/QC) with a software like Solibri Model Checker is possible because of the common file standard. These topics will be supported with current trends and predictions for the industry for example:

- According to Finnish BIM Survey 2013 (2013) over half of Finnish companies produce 3D CAD models to almost every project or every project.
- 79% expect that they are using BIM within 5 years in most of the projects (Finne & co. 2013)

#### **3.1 Building information modelling (BIM)**

Some sources define BIM as the whole process (Eastman 2011), and some as an information system (Jernigan 2007 p. 22.) but both separate it from being only the software used. This thesis takes the point of view of talking about BIM as a process to separate it from software vendors, and to include QA/QC as important part of BIM.

## DESIGN SCHEDULE

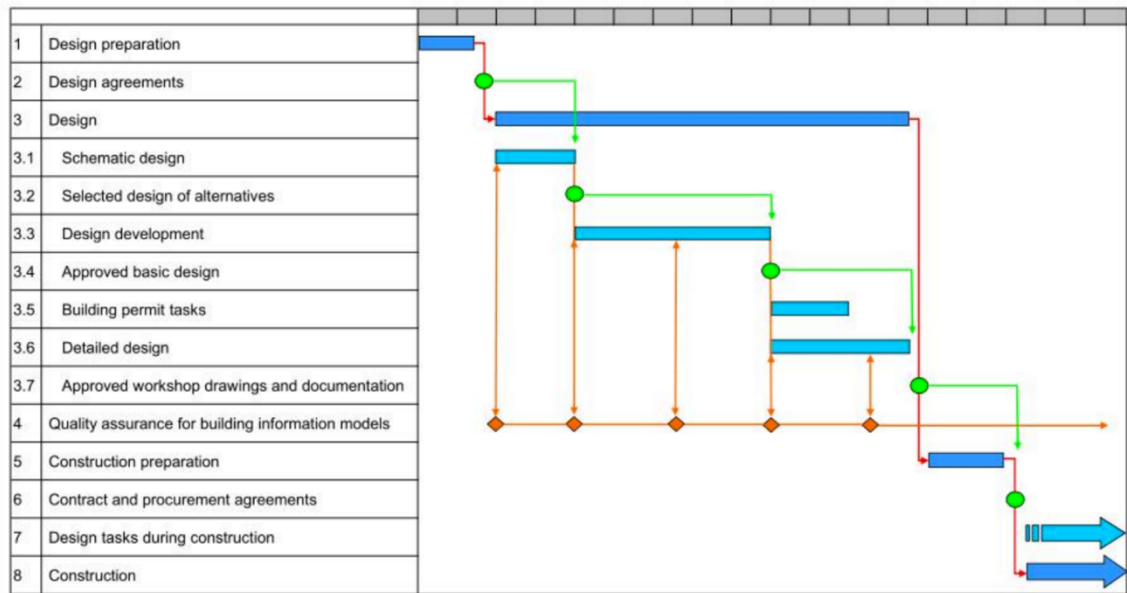


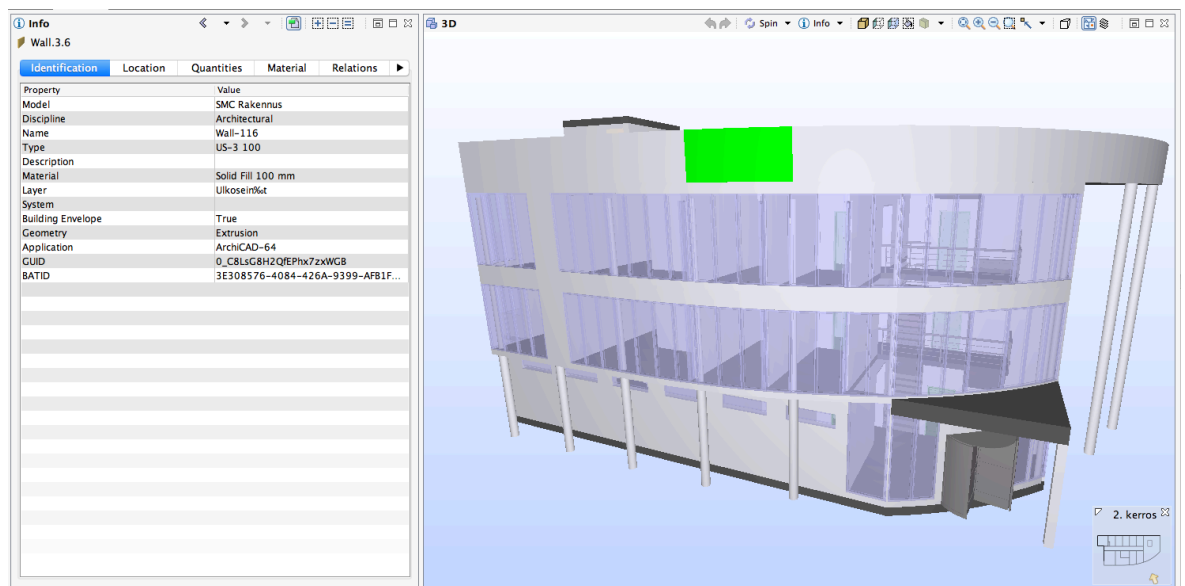
Figure 2. Example of BIM design schedule (Karjula J. & Mäkelä E. 2012 p. 19)

Adopting BIM process requires changes to the design process of construction projects. Figure 2 shows an example of design schedule for a BIM project. The new process brings designers closer to each other, and different design fields need to cooperate closer to each other to reach best solution. All separate designers should utilize 3D modelling, and specified information in model objects. Common design format makes the comparison of models easier, and designing can be assisted by visualization of the current progress. In Finland, the sharing of files is mostly done through project banks, which are accessible by all participating offices.

The information requirements change in different phases, and the principle should be that the information gets more detailed towards the construction phase. The quality requirements of the models get stricter the further the process proceeds. As shown in figure 2 quality assurance for building information models performs a significant role from the beginning of the design process until the end to ensure reliability of the models.

To separate building information models from 3D models, BIM includes relationships between objects, and more information that is attached to the objects within the model (Jerjigan 2007 p. 46). This information contains, for example material of the objects and where it should be installed. All objects created in the model have unique identifiers that separate them from other similar objects, and make searching of objects from for example a huge skyscraper model possible.

Picture 2. Solibri Model Checker: Model and information about the object



Picture 2 visualizes the building on the right side. The green highlighted object is selected, and the left side bar gives information related to the selected object. This information shows for example material of the object, location, quantities, and the objects relations to other objects.

The information in the models can be used for:

- visualization
- fabrication/shop drawings
- code reviews
- forensic analysis
- facilities management
- cost estimating
- construction sequences
- conflict, interference and clash detection

“BIM as a modeling technology and associated set of processes to produce, communicate, and analyze building models”. (Eastman C. 2011 p. 16) This information produced, can be utilized in different analyses already before the construction work begins. Which means that BIM, and lean construction have significant synergies if implemented together. Moreover, this process is recommended to be used throughout the whole lifecycle of the building. (Dave B. & Co. 2013 p.1) Once the owners and operators have understood the

value of what can be delivered through BIM, they will extract most value from it in the industry (Mills 2010 p. 2). This information would be useless without communication, and building information models “make it possible to share information throughout the entire building industry” (Jernigan F. 2007 p. 20).

The development and implementation has been a long process that began already in mid-80's, when first commercial software for creation of building information models were in use (Jernigan 2007 p. 37). Construction field has been slow with implementation of these software and we can say that from the late 90's they have been used actively. The adaptation of this new technology has been slow because it has been seen from designers' point of view as extra work that is not profitable. The created models and 3D rendering also demands a lot of processing power from the computers. In the late years, powerful enough computers have become widely spread and accessible for all parties involved. This means that more and more companies are taking their steps towards BIM. The trend has also been that the construction companies and owners of the buildings have started requiring valid building information models from their designers. This forces the designers to acquire technology and proficiency to provide valid models.

BIM includes significant financial possibilities. Azhar & co (2007) found out in their study of Hilton Aquarium Project savings of over \$200 000 savings could be achieved by resolving model conflicts with the assistance of BIM and Giel B. & Co (2010) reported that savings acquired through adoption of BIM are not dependable of the project's size. These savings take into consideration multiple different factors but do not necessarily give the whole perspective to BIM as its implementation can be also challenging.

BIM future challenges can be categorized in technical and management issues. Technical issues including exchange and computability of the data. Management issues on the other hand include difficulties in implementation process and lack of standardization of processes. (Azhar 2007) Many projects face lack of communication between different parties in the process as people in the field are used to concentrate on only their own design. BIM brings into the process complex models and demands of the quality of the designs grow because it can be measured. Real time communication through information systems and centralized information in federated model makes tracking of flaws easier but also helps communication about correct measures to fix them. This process takes responsibility to the correct person and reduces the need of quick fixes in the construction site.

These new processes have also raised issues with the ownership of the produced models as different designers share their models with others. The model can be utilized beyond



the construction process to facility management so will the owner of the building become also the owner of the design. This is a new contractual dilemma, which is followed by the shared models.

### 3.1.1 Current trends

Building industry is slow to adapt to new information technology solutions because of the complexity of the projects and old habits that die-hard. This has ended up in the situation that building industry has been one of the only industries where productivity has not increased during last decades. BIM offers possibilities to increase the productivity but for example, only 65% of Finnish companies are aware and currently using BIM (Finne & co. 2013).

As stated earlier BIM is not a new technology but in the field, people are still resistant to the change. For example, many architects still use 2D drawings and are reluctant to change from their old blue prints. This is still seen as easier way and it is true that the process can be seen difficult to approach. The designers do not see the benefits in changing their way as it would only require more effort from them. Different phases of designing a building are seen as separate processes although their results should be connected in the end. This means that architect wants to concentrate only on his responsibilities of designing the architectural model. The design is then sent for other parties, for example building engineers, which design their part. This means that active communication is not required between the parties. In the new process that BIM encourages the design work requires more communication and direct responsibility of each designs mistakes.

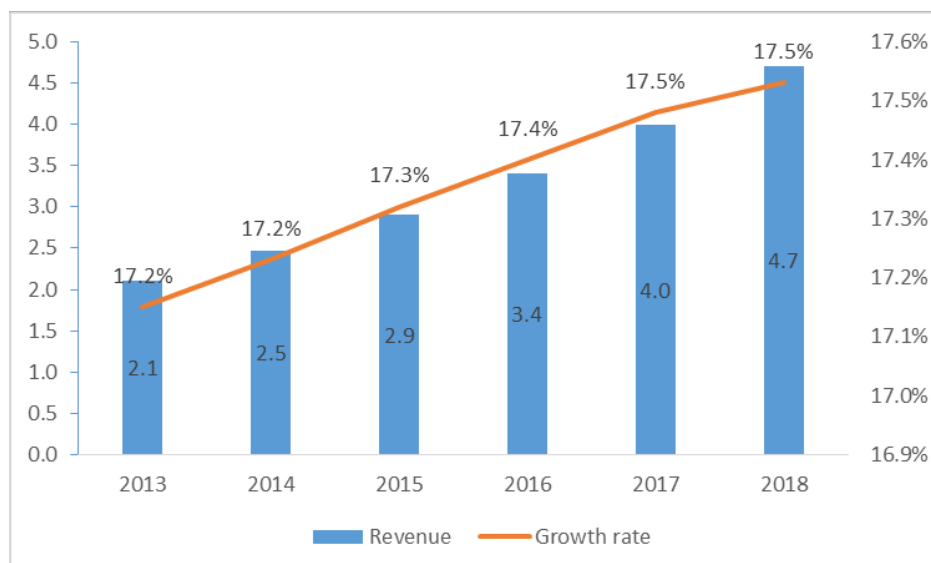
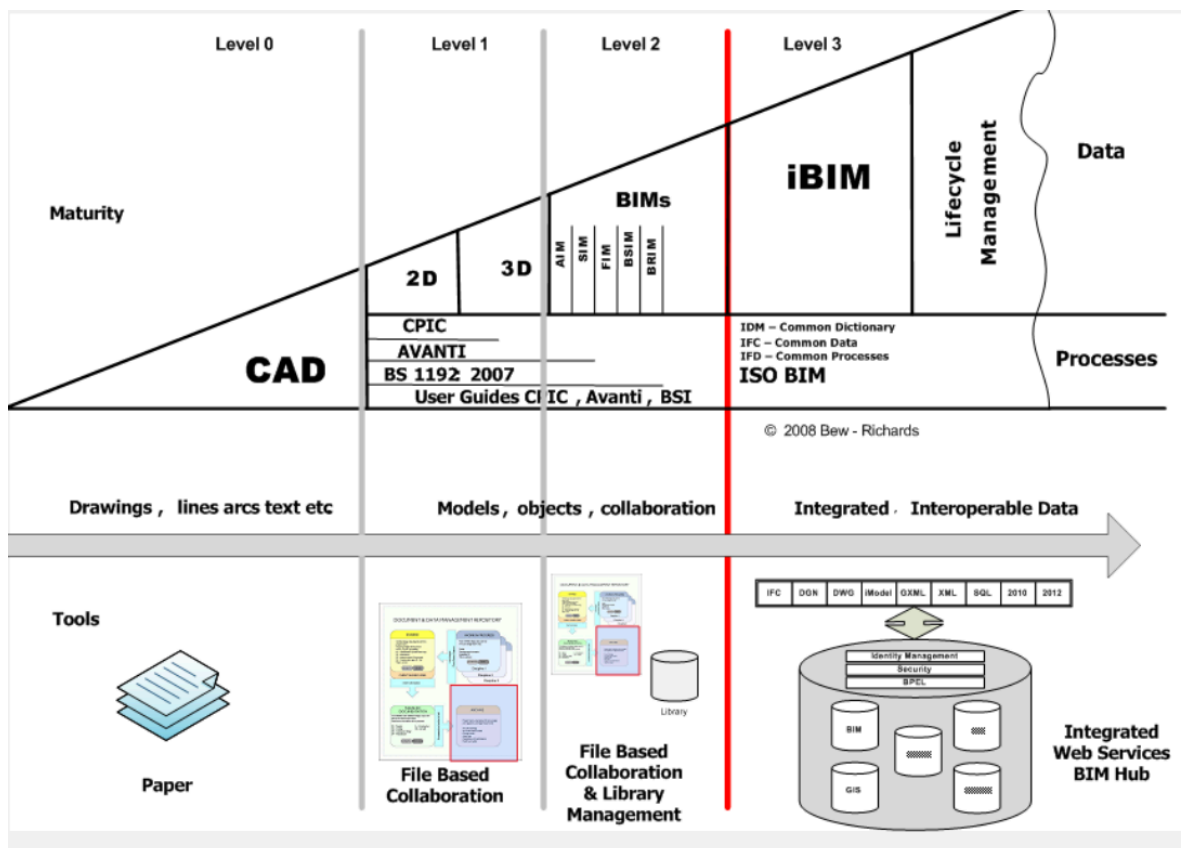


Figure 3. Global BIM Market 2013-2018 (US\$ billion) (Technavio 2014)

BIM market is expected to be steadily growing, despite the resistance, as shown in figure 3. More companies see the benefit of the technology and the age shift within the industry will open the markets. Compared to other industries that have seen a drastic change towards technology, building industry is still dragging behind. The growth has been bringing new companies to the software side and made new kind of services needed to the industry. The graph shows the global industry but the differences between countries are significant.

Picture 3. BIM Maturity Levels (BIM Industry Working Group 2011)

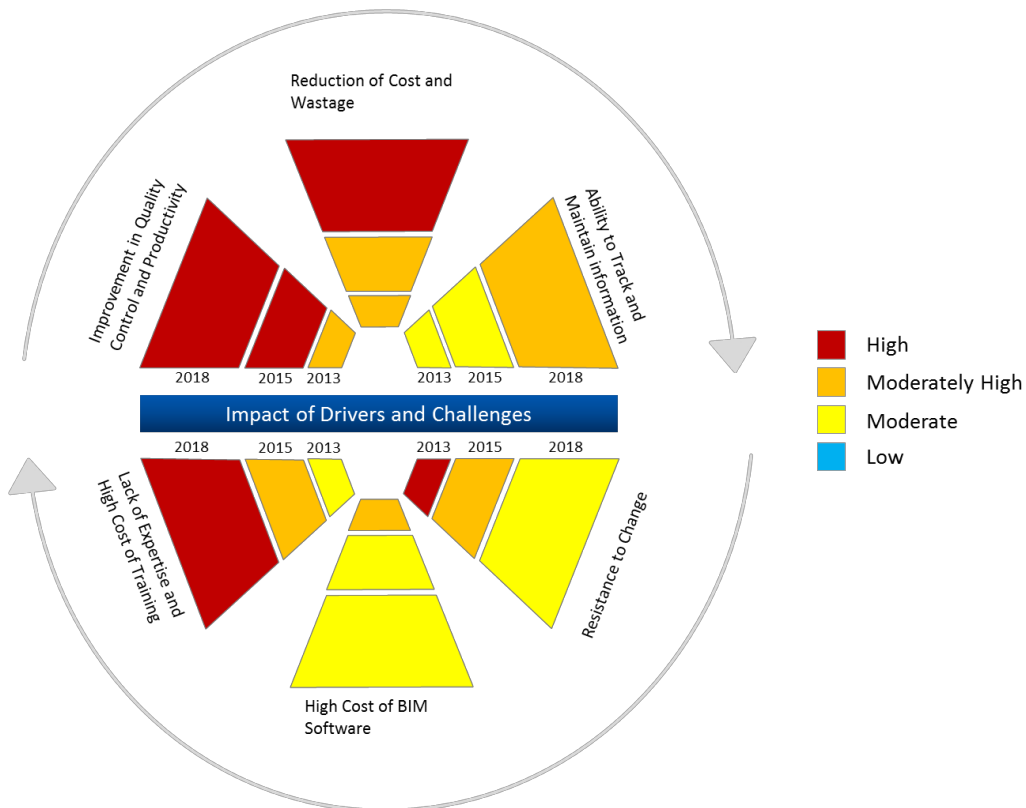


In 2011, United Kingdom published governmental strategy to adopt level 2 BIM as shown in picture 4 by the end of 2015. This means that all public construction projects should utilize specified objects, file based collaboration and library management. (BIM Industry Working Group 2011) In practice, this demanded great efforts from the construction sector that was not completely even utilizing 3D modelling. United Kingdom took great steps as the first government lead BIM strategy and it has brought results. The aim has been to cut costs of building projects by 20%, and in some projects, they have succeeded in this. This

project brought United Kingdom to the first line of BIM utilization. This has encouraged for example Spain to publish their goal of BIM utilization till 2018 (buildingSMART 2015).

Among these, the Nordic Countries and The Netherlands have been taking BIM further with or without government incentives. Although in 2013, only 35% of Finnish companies produce models to public formats in almost all of their projects. (Finne, Hakkarainen & Malleson 2013). The push in these countries is shown by the fact that Solibri's biggest markets are The Netherlands and Norway. In Asia South Korea and Singapore have taken huge steps towards BIM. On the other hand, in one of the biggest market of the world United States of America BIM adoption has been stalling partially because of the housing market crises in 2008. Although two of the largest software vendors in BIM, Autodesk and Bentley Systems, are from United States.

Picture 4. Impact of drivers and challenges (Technavio 2014)



Global BIM Market research by Technavio (2014) found out the drivers and challenges of BIM adaption. This research shows that from 2013 to 2018 the main challenges are going to change from resistance of change towards lack of expertise and cost of training. This will mean that the interest towards BIM is constantly growing but the markets do not answer to the demand of training. Many universities and other schools are teaching BIM but

there is a lack of training for the people already working in the field. Still in 2013, the market saw high cost of software also as a moderately high challenge but the importance of this is diminishing.

The markets will see the quality control and productivity as high-level driver in the future, which promises good markets for quality assurance/quality control software like Solibri Model Checker. This also reflects the slowly growing expertise of modellers as important for the market. Reduction of cost and wastage will be pushing BIM adaption forward more and more in the future as the importance of planning will grow in the building process and construction companies can minimize costs through BIM.

### **3.1.2 Industry foundation classes**

Among the main principles of BIM development have been sharing information. The building process is divided to different design phases performed by different companies, information exchange between these companies is crucial to the success of the process. The design work performed by the companies requires different software as the purpose of the design may vary, for example, architects use software created for architectural design and this is completely different from the software that engineers use. To make this information exchange easier the industry decided that need for common format for information exchange is needed. The current standard for information exchange is industry foundation classes (IFC).

Since change from paper drawings to computer-aided design (CAD), the industry had noticed the need for standard for information exchange. The standardization process for building information models began already in 80's. In the beginning, the standardization concentrated on the 2D CAD. The development towards CAD began already in 1950's but after the first level of standardization in 1980, called Initial Graphics Exchange Specification (IGES), the change from drawing table towards CAD hastened. In 1984, it was realized that the IGES was not advanced enough for flawless information exchange and construction industry was taken to the standardization process that covered several industries called standard of the exchange of product model data (STEP).

Development towards 3D modelling and implementing information to these models required a new standard for information exchange. For this purpose, companies operating in different stages of building process and software vendors formed an industry consortium called International Alliance for Interoperability (IAI) in 1994. The development process for

the new standard began in September 1995 resulted in IFC 1.0 published in January 1997 that focused mostly in architectural building model (Laakso M. & Co 2012 p.147). Compared to the technological maturity the industry began to develop on open data format relatively early (Laakso M & Co. 2012 p. 135). IAI has continued the development work of the standard according to technology development and needs by companies. In 1999, IAI opened the standard for designers outside IAI. The industry consortium behind IAI decided in 2005 to change the name of the organization to BuildingSMART and change the vision of the organization from only enabling software interoperability to wider approach taking into consideration the whole building lifecycle.

“IFC is an open and standardized data model intended to enable interoperability between building information modeling software applications in the AEC/FM industry” (Laakso M. & Kiviniemi A. 2012. p. 134) and it has been the universal language for information exchange in the field (Mills 2010 p. 1).

Adaption of the IFC-format was left to the industry to determine, as the consortium did not have the necessary resources to take care of the implementation. The new standard also had to compete with the old STEP standard that was in use simultaneously. This led to a complex situation and slowed down the implementation process. First significant national effort to push IFC-based BIM began in Finland in 2002. This took the name of ProIT project and the focus of this broad joint venture of different stakeholders was to increase market awareness. This first formal interest in IFC and BIM resulted also to modelling guidelines for architectural and structural modelling. (Laakso M & Co. 2012 p. 149)

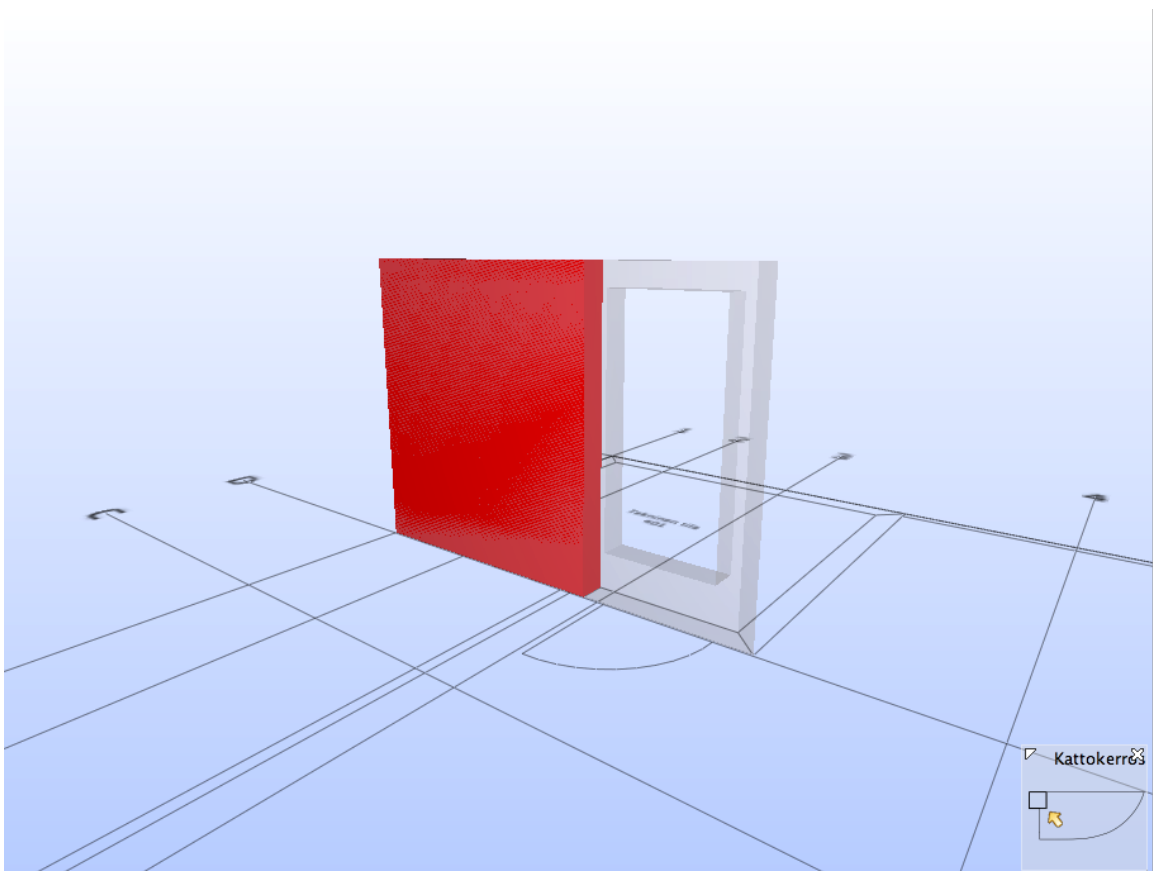
Constructing a building is a common effort from different companies and it applies to the designing process. Designers can extract their building information models from different software to one common standard that is supported by almost every software vendors' product. “The BIM quality assurance mainly refers to the validation of the IFC model...” (Kulusjärvi 2012) This means that the quality assurance of BIM is done by comparing IFC models to each other by a software or visually inspecting the models. The common file format is crucial for the industry, as a communication tool and so that quality assurance/quality control of the models can be performed.

### **3.2 Quality assurance/quality control**

IFC format enables quality assurance/quality control in BIM process but the model quality has been problem already in the 2D models and as the checking has been done by hand,

it has been really cumbersome and challenging. Conservative ways by architects, builders and owners lead to too many errors. (Jernigan F. 2007 p. 22) This has led to taking shortcuts in the construction sites and making quick fixes that can lead to further problems. This culture still continues in the industry and creates extra costs and delays in the process. Building industry has also changed lately to more prepared parts and modules that are not constructed on site. These modules require more specific information as possible changes on-site because of bad information can be extremely costly. Usually these costly modifications on the construction site could have been corrected on the design table if they would have been noticed early on in the process.

Picture 5. Solibri Model Checker: Components inside each other



Traditional quality control that is done by visual checking of the models is subject to human errors same as the designing of the models. The huge amounts of information implemented in the models makes it hard to find all mistakes from the models. These flaws can be for example millimetre variations in relations of the objects or objects that are on top of each other (Picture 5). Flaw like that can seem minor but as the building is constructed according to these models and material orders to suppliers are done according to the amounts extracted from the models, these flaws can lead to costs and delays during the

construction phase. Advanced clash detection done in Solibri Model Checker can detect these flaws before they are materialized in construction site.

Quality management has been ignored mostly in discussions about BIM (Mills 2010 p. 1) Jernigan (2007 p.45) states “BIM is not perfect.” This means that as humans put information to the models there happens mistakes but BIM makes finding these errors easier and for this purpose QA/QC software are necessary. If QA/QC is not implemented in the process the “product becomes garbage in garbage out” (Mills 2010 p. 2)

Kulusjärvi H. sees the main goals of quality assurance as to improve each designer’s own work and to improve information exchange between parties to improve overall design and to make the process more efficient. (2012) “A mandated quality management beginning at project inception and carried through to project turnover can assure the beneficial reliability and maximize usable value of facility information modelling, whether it’s called BIM, CIM, or FIM.” (Mills 2010 p. 3)

Most of the researches about the return on investment of BIM have found out that the biggest savings of the new process comes from scheduling and minimization of wastage. This means that if the information in the model is reliable and the schedule has been developed according to this information it is easier to avoid delays. Minimization of wastage comes from trustworthy information in the model so that no extra items are ordered from suppliers to the construction site. If the QA/QC is done correctly in the design phase, the scheduling can be counted on and orders made by utilizing the information within the model can be relied on. This means that there are no extra materials or lack of materials in the construction site. Extra materials usually grow the wastage as parts are created specifically for that building. Lack of materials can lead to long waiting times that might stall the whole construction process. This raises the risk of conflict of who takes the responsibility of possible flaws in the models. (Azhar 2007) This is although much easier to discuss in design phase than finding out about the mistakes when the building is being constructed or already finished.

BIM brings lean production to the construction industry. This means that the concentration will shift from things that are not relevant to the more important topics. Well-planned building will enable this shift and QA/QC software like Solibri could be described as bringing the Jidoka from Toyota production system to construction. Jidoka means, “Should a quality problem arise, the machine detects the problem on its own and stops, preventing defective products from being produced.” (Toyota 2015) Toyota production system’s aim is that only products that satisfy the specified quality standards are produced. By comparing

the design to local, company and owner's standards with a QA/QC software the designers and construction companies can be certain that the built structure will fill the needs. With Solibri Model Checker, you can compare the model to premade rules that can be found for many countries from the software but you can also change the rules according to your own needs. To simplify this: if the owner requires for all walls in the building to be 10 cm thick you can check that the design fills this requirement.

### 3.3 Return on Investment

Return on investment (ROI) is a way of calculating the value of an investment. The basic formula as shown in picture 6. compares gains from an investment to the cost of an investment. This formula is widely used in making investment decisions because it is easily approachable. The theory in this form takes into consideration only pecuniary gains and costs. It also ignores time value of money: meaning that the money loses purchase power when time passes.

Picture 6. Return on investment

$$ROI = \frac{\text{Gain from Investment} - \text{Cost of Investment}}{\text{Cost of Investment}}$$

The financial sciences have developed many ways to compare investments to each other and ROI is one of these. Other possible equations are for example return on equity, return on asset and internal rate of return. Because of the importance of intangible benefits of software investment, this thesis concentrates to one of the most simplified equations: ROI.

Gains from an information technology investment can be difficult to measure. This is because of the intangible nature of them. Companies may benefit from for example timesaving, simpler workflows or better communication with different stakeholders. These benefits give companies competitive advantage and create savings in the end, but it is hard to direct these to certain software.

The basic principle of investment is that investor expects it to generate a higher value than the initial cost. The return is rarely immediate and costs can be measured in various ways. Major reasons for an information technology (IT) investment are intangible outputs like



quality, convenience, variety or timeliness. (Westerlind 2004) Changes to existing procedures might be necessary to hasten the return period. As an example returns of investment in BIM QA/QC software, like Solibri Model Checker, design procedures of architects can be changed to for example weekly checks of quality so that possible mistakes can be fixed early on in the design process. This means that more time is put into design quality but the necessary standards follow during the whole design process.

Return on investment for an information technology investment used in this thesis is a set of evaluation criteria that the investment in software is compared to. This includes currency, content, quality, flexibility, importance and scalability. (Daniels, 1993) This thesis tries to find out how does customer experiences reflect these criteria:

- Currency – Reliability and accessibility of the data
- Content – Accuracy of the data
- Quality – How does the technology meet company's current processes
- Flexibility – Refers to usability
- Importance – How dependent the company is of the product
- Scalability – Current and future needs of the technology

Measuring the ROI of BIM project has been challenging because you cannot construct the same building again in traditional way to measure the difference. One of good example projects is the University of Colorado, Health Sciences Centre where two similar buildings were built with other one using traditional approach and other using integrated virtual design and construction process. The later resulted in "improved productivity, increased pre-fabrication, less rework, reduced RFIs (Request for information) and change orders, and was completed two months ahead of schedule and under budget." (Mitchell D. 2015)

## 4 Research method

The interviews were conducted using the same questions for all different interviewees from different sectors to get answers that could be compared. The Interviews were semi-structural. The aim was to collect the interviewees' experiences from their own perspective so that the discussions were allowed to wander from the topic. Sixteen out of eighteen of the interviews were done in the interviewee's office to get relaxed atmosphere and reliable answers. One of the interviews was conducted over the phone to the Netherlands because I was unable to travel there. Other interviewee did not see the interview necessary because of their own lack of expertise, and they only answered to the questions in written form. All interviews were transcribed for the data to be easier to process. The reactions and impressions of the speaker were not transcribed. The transcriptions were then structured to challenges, benefits and costs. As most of the interviewees were in Finnish, translation of the quotes was necessary.

Architectural offices were mid-sized companies operating in capital area of Finland. This creates an optimistic picture of BIM implementation, as it is easier for mid-sized companies to implement BIM. The architectural field is wide spread and most of the companies operating in this field are small companies with less than 10 employees. It is more expensive for them to acquire quality control software compared to their project sizes.

Engineer companies were big or medium sized companies operating in capital area of Finland that had implemented BIM to their design processes. Field of engineer design is not as fragmented as architect design but still there are vast amounts of engineer offices operating in the Finnish markets. Construction companies were big companies operating in Finland and it seems that the smaller the construction company the less they have implemented BIM. Two of the owners were governmental companies in Finland and one a private housing company in the Netherlands.

## 5 Key findings

### 5.1 Challenges

The challenges that the companies face are largely related to BIM as a process and not directed to the software in use. Although the interview questions asked for technology specific challenges, most of the answers relate to BIM in general. According to the interviewees, challenges can be divided to five categories that were used the structure the challenges part of my research:

<b>Challenges</b>	<b>Architects</b>	<b>Engineers</b>	<b>Construction</b>	<b>Owners</b>
<b>People</b>	Lack of expertise of people Reluctance to change Awareness of owners	Lack of expertise of the contractors	Lack of overall expertise of the process Generation shift in the construction workers	Their own lack of experience and routine to use the models Time used to other functions is out of use of BIM Reluctance to use new technologies
<b>Cooperation</b>	Communication New process has to be sold to other people Lack of long term contracts	Too much concentration to details	Quality of general guidelines Coordination in the early stages of design process	Long communication chains
<b>Technology</b>	IFC format Fast development	Lack of expertise to use technologies	Software are complicated Constant file transfer	

		File format compatibility	Technologies have not reached its full potential yet	
<b>Time</b>		Too tight schedules Wrong timings in the project schedule		
<b>Quality</b>	Lack of clear quality standards	Are the designs realistic Quality of laser scanned models	Varying level of details in the models Lack of quality in models they receive	Quality of received models

### 5.1.1 Architects

Architects see people as one of the biggest challenges in building information modelling. Expertise in the field is not high enough and this causes difficulties. Building information modelling brings change to the stagnant field. From the interviews, it can be seen that people do not know enough of the new design process and are reluctant to change towards it.

“Biggest (challenge) would be to get the other consultants to use BIM. Because they have been using 2D for years. So it’s quite a change for them.” The transformation from 2D modelling to building information modelling requires effort and a lot of work from more experienced workers. “Biggest challenge during my career have been change management...” This shows that most of the interviewees are experienced in BIM and they have been pioneers during their careers. They are facing reluctance from their own colleagues, other designers, construction companies and buyers. This shows in construction companies as distrust in their own workers’ expertise. “Most buyers are completely lost; they do not know what to order” and awareness among buyers should be increased as it influences the design process for example, the finalized model does not have contractual capacity.

People affect the cooperation that is seen as one of the most significant challenges. There are problems in communication with other designers and not everyone is aware of the transformed design process. The interviewees see that there is still a lot to do even within their own organizations and it takes a lot of energy to “first of all to get the whole process transformed into BIM thinking”. Even when the architect office would have implemented BIM process, they have to sell the idea for the buyers and other designers. As the BIM process requires cooperation, architects still feel that “although you take care of your own role well, the cooperation is still not in the same level”. One interviewee has even seen that the communication has been on the level that parts have moved to production even when the design has not been ready. The process is evolving and this requires more cooperation between all participants and clearer communication, requirements and timetables. This has caused the more experienced architecture offices to take bigger responsibilities so that the delivered building would satisfy the needs of the buyer. As a project based cooperation, the projects are temporary and some of the interviewees would see it beneficial to create more long-term contract with the buyers so they would be able to share their knowledge and upkeep the models even after the building has been constructed. “Even though the construction and design has been succeeded to go well it happens that the model ends up in a drawer afterwards and in the worst case it has to be modelled again after few years” as the buyers do not utilize the models in the upkeep of the building.

The technology has brought the designer offices, construction companies and buyers closer to each other, architects still feel that it causes challenges. There are still problems in the IFC format, that affects combining the models, and some fields do not support the IFC format yet. It is mostly seen though that the biggest technological challenges have already been overcome and the solutions are already familiar for the architects as one architect said: “I remember in 2006 first attempts to combine models and to get them in same coordinates and it was almost impossible. Technologies still keep advancing and keeping up with the development can be challenging. “Then there might be feature that are useful but you haven’t had the change to step back and learn them and put them into practice.”

Quality is seen among the architects as surprisingly minor challenge. As the models might get complex the designer might accidentally click to wrong place and create double pillars or mistakes might be left from the previous version. The careless design work creates

more workload for the coordinator that has to be gone through in BIM coordination meetings. Clear quality standards and agreeing on the level of details in projects could solve this challenge.

### **5.1.2 Engineering offices**

Engineers' challenges with people reflect to the expertise of participants of the building process. The contractors are seen as inexperienced in utilizing the models. They require a too high level of detail and give up easily when the level of detail does not meet their expectations. The reason for this is experience of the management of the projects as they as decision makers do not know the full potential of BIM processes.

Cooperation has progressed a lot from the past when there were challenges that different designers were in different coordinates for example too high so combining the models was challenging; there were no clear guidelines or rules for the design team. The engineers are usually not responsible of the process and it has been challenging to acquire enough information. This has resulted in doing the "same tasks over and over again as there have not been clear rules or phasing in the projects". It is seen that when the process is not clearly defined it results in too much concentration to details that leads to extra work. Engineers see that small conflicts in the models are acceptable. As in 2D design process, these mistakes should be solved in the construction phase.

Unlike the architects, the engineering offices see a major challenge in the timetables. It is not clearly enough defined what should be done in certain steps and these results in conflicts.

Engineers state that the timetables should not be defined in a way that their drafts should be delivered at the same time as architects, as they need to utilize the architects' designs in their work. The BIM design work requires more time than the traditional design work and it should be taken into consideration when scheduling and pricing the design work. Because of the tight schedules, engineers do not always have time to check their models beforehand.

Technology creates challenges for the engineers and they feel that they do not utilize all functionalities of the software. Engineers feel that there is a lack of expertise to use the technologies properly. One of the interviewees feels that one of their biggest challenge

was the compatibility of their software's native files to the Solibri Model Checker. He reported that this was fixed for them and they are currently able to utilize the native files in checking, as IFC export takes a long time. All the interviewees felt that the technological challenges have narrowed down because of development but it is still not perfect and there is a need in the field for training.

Solibri has brought certainty to the design quality and trust to their own work has grown. Engineers worry if the designs are realistic and could the designs be installed in the field. Quality of the laser scanned models in renovation projects cannot be trusted and they see that it should be scanned twice in different phases to get trustworthy information. Engineers should be able to trust to the quality of the models that they receive, as mistakes in them might cause double or triple work for them.

In general, the engineers stated that the BIM process is already familiar for the designers and IFC is no longer a new thing.

### **5.1.3 Construction companies**

For the construction companies according to the interviewees there is a lack of experienced people to use the models effectively. There is a great variation between the experience in the design phase and the success of the projects depends on many people. This means that "if there are good designers but a bad project manager it goes wrong. If there is a good project manager but bad designers it goes wrong, if all falls into place we can utilize BIM". It seems that especially in the construction sites there is not enough experienced BIM users to implement the new process. This has influenced the speed that these new processes are implemented. According to the interviewees, this lack is caused by generation shift and lack of training. Old personnel are more reluctant to change the process but there are exceptions from this also. The persons were afraid that the enthusiasm of the young talented personnel are going to be killed by the old processes.

The interviewed representatives see challenges in the lack of guidelines to succeed in the BIM projects. They see that the Finnish common BIM requirements 2012 does not fully answer the need for guidelines. Because of this for example the requirements for the building information model in different phase are not clear and this causes concentration to irrelevant details in the models. The process should be understood as getting more detailed towards the end and certain mistakes should be accepted in the early phases. People do not seem to understand what is crucial to which phase. One interviewee even

stated that people separate plans and building information model from each other and “this shifts the role of the building information model to secondary information and the aim is to produce paper pictures from the models”. Other thing that got critic is the role of the BIM coordinator in the process; that their role is to check the models and to print a report. “The title of BIM coordinator fades out the responsibility.” If there is a separate coordinator to find the mistakes from the models, it postpones the quality check of the models to later phase and constant quality checking is not utilized. It is seen that in the early stages, the processes should be coordinated and clarified for all participants to succeed in the designing and this enables the use of the models in construction phase.

Construction companies wish for an easier to use software that would be easy to implement. This would allow them to get the models in use for a wider group of users and this way get bigger benefits out of it. It is also stated as a challenge that there is separate software for each phase. Solibri Model Checker combines this phases but still separate software makes it harder to implement the BIM processes. Current processes require constant file transfer. As information has to be separately downloaded, uploaded or updated to the common project platforms this takes time in the projects. Especially the engineers’ design software is not agile enough and cause the models to become too heavy to use. It should be easier to cut unnecessary information from the models so that they would be easier to process and check. There is still software that cannot be trusted fully and seem to be in beta testing stage. The technology has come long way but has not reached its full potential. Cloud based software are seen as one way to solve these challenges as they would allow the processing of the models to happen on servers that would not require so much from the work stations.

About the quality of the information, the construction companies state that the level of information should be agreed early on. This means that not all details should be modelled to the building information models, as they are unnecessary for the success of the project. To solve this, interviewees suggest that same model with different levels of information should be produced as they only need the type of the objects and geometry although the facility management needs more information. “Two models should be delivered but the level of detail should be different for different groups.” Few of the construction companies still saw that the quality of the models is not high enough for them to utilize them. “All designers do good work in their own opinion but the buyer and contractor need certain information that they can use.” They check the models themselves and can easily see if the quality of it is high enough for them to use it. If it is not, they will just abandon the model.



#### 5.1.4 Owners

For the owners', people and lack of expertise are the main challenge in implementing BIM. They do not utilize the technology constantly as their tasks include so many other things. Because of this, it is hard to acquire routine to the technology. Building information modeling requires a big change for the buyers of the buildings. This is slowed down by the lack of experience to the new process and it has required a lot of effort to succeed in this. All of the interviewed owners were not that far in utilizing BIM and are still struggling with people's reluctance to change their current ways. Buyers face for example a challenge to keep up with the design process of others. "Now that the field has changed so quickly that design work is different than 20 years ago, how do we guarantee that we are up to date?" People do not have time to train the technologies as in for example governmental offices they are busy with their current tasks.

This rises the role of external BIM coordinators to check the model quality so the owners can trust the information and utilize it. The challenge has been the expertise of the designers and even big office sometimes do not actively check their quality according to the interviewees. In renovation projects, people are reluctant to utilize BIM technologies, as it is felt that the building is already there so they can see what is in it. One interviewee stated that; "people do not want to pay for what is self-evident although it is not self-evident". Companies participating still trust the actual building more than the model although the model might be much easier to view and inspect. So much of the core businesses of the companies is bind to the current technologies used and changing them is difficult.

As pioneers in BIM in their firms the interviewed persons still face obstacles in their own organizations and "another challenge is that how do I convince my own organization the benefits without exaggerating". They see great benefits in the new technologies but there are no examples in the field that would be comparable. For one of the interviewed persons there was a problem in the cooperation of the designers. According to the person in Finland, the tasks are delegated too many times in design firms especially with BIM. The persons who participate in the design meetings are not necessary the persons who actually do the changes and the long communication chain creates more misinformation. This leaves the relationship between the buyer and the designers distant and lowers the trust. This leads to buyers facing a challenge that they do not receive trustworthy models to be used in their analyses and calculations. The quality of the models still varies and this is one obstacle for them to implement BIM deeper into their processes.

## 5.2 Benefits

Most of the benefits that the companies receive through the quality assurance software are intangible. Daniels (1993) divides these to currency, content, quality, flexibility, importance and scalability.

<b>Benefits</b>	<b>Architects</b>	<b>Engineers</b>	<b>Construction</b>	<b>Owners</b>
<b>Tangible</b>	They are able to offer BIM coordination as a service Time savings from continuous checking Winning more deals because of quality of the design	More projects because of better quality Saving hours because of internal checking	Time saved in calculations One mistake that is found early on can pay the license back	One mistake that is avoided can cover the cost of the license Time savings in checking built houses Avoiding bad investments
<b>Currency</b>	Minimizing their own mistakes Ensuring the model quality Checking the quality of federated models	Visualization of architects designs Certainty of other designers designs	Easy to access information They can count on the models after checking	They are able to open BIM models Easier to interpret than 2D models
<b>Quality</b>	Continuous checking in their process Helping them model better Helping with communication	Keeping the communication between the parties fluent Daily visualization tool	More efficient processes invented through the software	No need to order sectioning from architect Easier to negotiate pricing

<b>Flexibility</b>	Quicker than other modelling software When learned easy to use	Easy to use Combining models is quicker	Fairly good Requesting more intuitive technologies	One interviewee stated that it is easy to use
<b>Importance</b>	Seen as a necessary tool to operate successfully	They are dependent of a software that can combine models easily	“I can not see concrete other good option for those functions in other software that for managing the designs it is definitely the best solution.”	Only way to access the information in models
<b>Scalability</b>	Fills current and short-term needs		Hard to determine	

### 5.2.1 Architects

The direct benefits for the architects of using quality assurance software found out from the interviews are that they are able to offer a service of BIM coordinator. This concludes of federating the models and checking possible mistakes. They are able to save time from the design work when they can continuously follow the quality of their designs this also lowers the need for double work and BIM coordination. It was also stated: “if we do good job, we get more jobs”. The companies feel that they get better points for quality and reviews from the clients and this will benefit them in the future for “winning bigger jobs and it’s the investment paying off”. This is a benefit of using “combination of different software and management and people.” So it cannot be directed solely to certain software.

Importance of currency, or reliability and accessibility of the data, is high for the architects. As a quality assurance software, logically it is the main usage of the software. The benefits come from minimizing their own mistakes, which are not easy to spot in their current designing software. This is so strong that they even stated that if the mistakes can be

found early enough in the design process, it shows that the software has paid itself back. This does not materialize to their benefit straight away as usually the construction company or the buyer are the one benefiting from the models without mistakes. It is still seen that “if the mistake is corrected in the designers table it takes 15 minutes if it is found later stage it takes the whole design teams time for the period of one meeting” so they can also save time through this. “By having the checker we can ensure that the quality is good and we are getting good points for quality so maybe that has something to do with it.”

The software helps to take care that their own models fill the quality requirements, but also to federate their models with other design fields. Checking and comparing with for example, mechanical, electronic and plumbing designs, will guarantee the overall reliability of the final delivered model. The management and accessibility of the data was mentioned in the interviews. The reporting tools of the mistakes and information within the model bring the data accessible for everyone. The combinations of information and making it visual makes it easier to access. The fact that this information saved with the paid software can be accessed in a software that is free is seen as a benefit that rises the accessibility of the data.

Quality, or how the technology meets companies' current processes, is harder to determine through the interviews. As one of the architects said, “You don't know if the process has adapted to the software or the software adapted to the processes”. Most of the companies have implemented it widely in their current processes and for example check their models before they are submitted. According to one architect, the knowledge that the models will be checked has increased the quality of the designs for their employees. “They do better work, because they know that it will be checked, it is a part of the routine and this produces better quality.” Another interviewee says that “it's just helping me model better”. Therefore, in internal checking, it improves the process to keep high quality, and motivates employees to aim for better quality with their design, but this can be seen as a threat for some people as all mistakes will be found, and this can create an unforgiving environment if implemented too harshly.

When used in checking of federated models use of the quality assurance software brings the different designers closer to each other. “It helps with communication.” Combining the models helps to visualize the actual problem and to point it to correct person. “When checking is done with some other than architect's software it helps the whole design groups operations, as it is a combination of all plans that come from different sources.” This creates a more neutral approach to the quality checking. Architects see that the role of BIM coordinator who checks the models should be separated from the designers and

prime architect, to give more neutral tone to the conversations. However, the architects would still wish to see that everyone in the design process would do their own checking and thus lowering the importance and work of BIM coordinators. Therefore, BIM coordinator would not have to concentrate on internal mistakes of certain design fields.

Flexibility or the usability of the software is perceived as easy to use compared to many other BIM technologies. "In the beginning it might be hard to use but when you have learned it is fairly straight forward." As most of the interviewed persons were experienced users, they felt it as a familiar tool but stated that, it is sometimes challenging to learn because of the complexity and differences from other technologies. The clear benefit from the usability perspective was, that it is quicker for visual checking and "it can take tens of large IFC-models and still work smoothly". This quickens finding information from the models.

The importance of the software for the architecture companies is high. Experienced users see it as a tool in their process and not something which value can be measured. Three out of five interviewees stated that they are more or less dependent of the product. "We sell hours of specialists and they need their tools." One architect even stated, "I would not see it possible for us to work professionally without such a tool". This has to be put into perspective, that they are experienced users and it has been deeply implemented in their processes, and the fact that not all of the companies, which they operate with utilize the same software. This gives the impression that there is an alternative way.

It has been hard for the companies to specify their future needs of the technology as the change towards BIM is still in progress and they think that anything can happen. The construction industry has been slow to change in history, and similar ways of design have been used for a long time, so the architects perceive that the software at least fills their current and short-term needs. It seems that they are uncertain of their long-term needs, so it is hard to compare the technology to them.

### **5.2.2 Engineering offices**

The direct benefits from the use of quality assurance/quality control software according to engineers are that they feel that they get more offers if they use the software. It brings straight revenue, if they can assure the quality of the models, and the software enables them to design building information models because it brings a better visualization of the models. They have spared working hours from the use of the software as they can detect

the faults beforehand, and the correction in the later phases would take a longer time. One of the interviewees even stated that use of Solibri Model Checker takes away even four extra rounds of designing as they can check the results before submitting them.

The reliability and accessibility of the data shows in the interviews through more reliable design work. With a good visualization of the architects design, it is easier for them to design their parts. They can count on the reliability of their own produced data by the means of checking and visualizing their own models. Most of the engineers constantly visualize their design with architects' designs to make their work easier. They have even been in situations that they have first looked from 2D drawings that I am going to design it this way and second check from building information model has shown that this is not possible. The model checking gives them the certainty to other designers work as they can check the models themselves. The reliable data can be used in negotiations as they do not have to rely on assumptions and this helps them to explain their needs for other designers. "It can be used as a weapon in good and bad" when demanding changes.

The software seems to have met the processes of the engineer offices well as it can be used in internal quality checking and as a visualization tool to assist design process. "It has become a daily tool" in the work of engineers and "when the designer all the time looks at the building information model it helps a lot to realize what is been designed". It is useful in BIM coordination and keeping the communication between the parties fluent. The use of the software removes the need to ask for sections from the architects constantly and the designers can concentrate to their own work.

For the engineers the usability of the software was the most important factor according to the interviews. Almost all engineers felt that the software was easy to learn and "even for beginners it is easy to show the basic functionalities that you can survive with but then there is a lot more." Accessing the information through the software is much easier than to try to find it from the 2D drawings. "It is easier to rely to it than checking only visually the clashes from the models." "The interface has succeeded in that the information does not push through from it all though it has a lot of information." The engineers also state that the combining of the reference models is easier in Solibri model checker than in their original modelling software and the software does not get slow although there might be a lot of information within.

Three out of five interviewees stated that they are dependent of the product. "We can't get any work if we do not have the necessary tools and expertise." The dependence comes

from the fact that, through the software they can use the models from for example an architect as references for their own design. They are dependent of a software that can combine models easily, but still consider that could this be done with another cheaper software also.

### **5.2.3 Construction Companies**

Construction companies benefit from Solibri Model Checker decreasing manual work from evaluating the costs of the building. One of the interviewees told that the use of building information models does not directly decrease the time needed for cost calculations but it shifts the time used to calculating amounts to actually determining the prices for the objects. It was also stated that: "One step in the construction site and the license has paid itself back." This comes from avoiding the mistakes in the plans. When the quality of the designs has been checked beforehand, the design can be trusted and possible mistakes can be avoided in the construction process. The amounts can be trusted, so possible extra materials, and situations that the site is lacking materials can be avoided.

The use of the software guarantees the reliability of the data. The mistakes can be found already in the design table and this way they cause fewer disruptions in the construction phase. The job done in the design phase correlates to the overall quality of the building. All construction companies saw the value in checking the models before, but they could not put a price tag for this, as it is difficult to measure. They also stated that, it is still dependable of the people, and there can be mistakes in the construction phase although the designs have been checked. One of the interviewees stated that, "it produces information about the reliability of the data, and this determines how widely the information can be used". Almost all of the construction company representatives state that it is easy to access the information in Solibri Model Checker, and this is seen as one of the big benefits of the software. This quickens in pricing and ordering the necessary materials to the construction site. When used early on in the planning, it helps to evaluate the profitability of the buildings by easily calculating the usable spaces. The software is even used in some companies in the construction sites, and the construction workers have realized the value of reliable designs, which relieves them from extra hassle.

It fits the construction companies' current processes well and there has been developed new more efficient processes from it, so that in the projects the effort is directed to right things. For example, one of the interviewed companies uses so-called smart room work where mistakes can be minimized from the designs, together with all of the designers. As

stated earlier, it shifts time in pricing to more important matters as it decreases time to be used in actually calculating the materials. As not all of the construction companies are so far in using BIM, they feel that it takes time to measure the influence of this technology to their processes but they believe that it can make them more efficient. Few of the companies have projects in production phase, which have utilized BIM processes and they believe that they will have a better picture of the overall influence after these projects.

According to the interviewees, the usability of the software is good, but the buyers are requesting intuitive technologies so that people would be able to access the information easily. They stated that it is easy to show the benefits of the software for people that are not experienced with the use of 3D modelling because of the easy to use user interface. This helps them to show the benefits of the new way of designing, as it is not seen as a burden to access the information.

Same as the designers, the construction companies see Solibri Model Checker as a one tool among others so they can operate efficiently. One of the interviewees compared the software to an excavator, meaning that you cannot build a house without it. "I cannot see other concrete option for those functions in other software, and so for managing the design work it is definitely the best solution." The use of the software enables the companies to combine the models and by this, it can be seen that the companies are somewhat dependable of the product. They felt that Solibri Model Checker is the best solution for the function that it is used to.

It was hard to define the future needs of the technology but the interviewees felt that the software will transform their processes in future and they are able to get more benefits out of it. As stated earlier some of the companies were still waiting for the first BIM projects to be constructed in the near future and they believed that this will show them more benefits of the software. The new building process leaves more data of the buildings to be used afterwards and this data can show its value in the future.

#### **5.2.4 Owners**

Owners can receive direct benefits from the use of Solibri Model Checker and BIM though these vary a lot depending on the owner. The benefits easily cover the investment in the software. All the mistakes that can be found beforehand can cover the cost of the license for the owners although they might not do the checking themselves. One mistake that can be avoided in the building is usually more than the price of the license and there comes



more than one of these per year. One of the interviewees stated that they even avoided a bad investment by the use of BIM as the building was well planned and this work cost 200 000 € but with this information they were able to evaluate the investment to be not worth the costs and they succeeded in avoiding a bad investment of 20 million euros. Other owner has noticed that the pricing of the pricing expert has lowered 50% by the use of building information models, as the task requires less time from the expert than with the use of 2D-drawings. The same interviewee stated that the use of the software saves “2 or 4 hours a week” of work time from the personnel checking the quality of constructed buildings on site.

The benefits really concentrate on the reliability and accessibility of the data for the owners as all the interviewees used Solibri Model Checker as their only software to access the information in building information models. None of the owners does their own checking of the models but they have outsourced this function to external BIM Coordinators but the software enables them to access and follow the design process more actively. It is easier to access the information than in 2D-models and this way the owners can be more certain of the buildings that they have ordered. “It helps us to visualize what I buy.” States one of the interviewees. They are able to access the information in visual format that is easier to interpret. One of the interviewees also holds courses to BIM and he uses an example where he shows first a complicated 2D-model of a building and asks if it is correctly done. After this, he shows a building information model of the same building and according to him, you can notice with one glance that which duct goes where. He even stated that this one glance could cover the costs of the license because of the mistakes that can be prevented with it. Other owner says; “When you have a model at hand just with four clicks you are at the point that you want to look at. That is saving time, and you cannot calculate that.”

With the use of the technology, the owners are able to cut stages in their processes, as they no longer need to order for example sectioning images from the designers but can access this information on their own. The use of Solibri Model Checker helps the owners in negotiation of the pricing as it can be done more accurately and easily, and it does not require weeks anymore to receive a consensus of the prices. One surprising benefit, to do with the processes of certain owner, was that the software is not a cloud based solution and because of this, they were able to use it. Their company’s policies did not accept that there could be a risk of the information ending to a third party.

Only one of the owners mentioned that the usability of the software makes it easy to use and easy to train: “It does not take long if you dare to open the program to learn it.” On the

other hand, the software was important for the owners as it is the only software, which they use to access the information in the models. "Overall, that we can do BIM projects is the benefit in it." They also feel that the software does not have a competitor and "We use BIM and Solibri because we want to know what we own in houses". So according to the interviews, once the owners have decided to implement BIM and Solibri Model Checker they become depended on it.

### **5.3 Costs**

The cost side of the equation is very similar to all the parties, which participate to the BIM process. When asked about the costs of the Solibri Model Checker the most mentioned cost was the license of the software. This creates a bigger investment in the beginning as the license pricing requires a lump sum to access the software. After the initial investment, the cost is a yearly sum for support and updates for the software. Few of the interviewed persons felt that the license is expensive, but still the overall feeling among the interviewees was that the initial investment has paid itself back by the usefulness of the software. As the persons felt the software as necessity, and that they could not operate professionally in their field without it, they did not see the costs as major influencer. The fact that most of the personnel were not part of management in their organizations seemed to influence the fact that they do not actively consider the costs of their tools.

According to the interviews, the implementation and training to use the software professionally exceeds the cost of the software in most cases. The initial cost of the training is lesser than the license. Not all interviewees had had training to the software though they have to put their work time to learn the software. Training is needed in most software investments, and the opportunity costs from this can be high. As Solibri Model Checker is an expert level software, and the employees' time for service companies is a highly valuable asset, the hours put to learning can be costly. The full implementation of the software can take a long time, and this time is out of profitable work of the employees.

Especially in the companies that use Solibri Model Checker as their only BIM software, it might require powerful computers to use the software. These computers can be expensive, and according to the interviews, can create high costs for the companies. The companies that use other modelling technologies stated that other technologies require more from the computers, and this way they have not had to invest in better computers to use Solibri Model Checker.

As pioneers in BIM, the interviewees pointed out that the changes in the process has created costs for the company. Winning the reluctance and researching the topic requires time from the employees. There is still opposition especially in construction companies and owners, which has to be won before BIM can be implemented fully. This is easily tied as a cost to the software, as Solibri Model Checker might be the only BIM software in the company.

#### **5.4 Influences to building process**

The building process is greatly changed from use of BIM and active QA/QC. The new process brings the participants of the projects closer to each other. This creates challenges in cooperation and personal connections. The participants of the interviews were used to active quality control of their designs, and knew their responsibilities in the process. This creates a high demand from other participants. According to interviews participants tend to blame, other designers of bad quality as not all people in the process are in the same level yet. This creates bad rapport in the design process, which makes cooperation difficult.

The use of federated models and software based checking, makes it easier to communicate in the projects, as everyone's designs are checked bringing people on the same level. Some of the interviewed persons preferred the role of BIM coordinator as separate from the process so that it is kept unbiased. One of the construction company's representative suggested removing the role of BIM coordinator from the process, and suggested active use of model checking by all participants. If the designs are checked for mistakes before the comparison to other models it removes mistakes, and people can concentrate on challenges that are more important.

As BIM requires more work from the designers, it is seen as a challenge that the compensation has not risen. This is partially because the owners do not necessarily see the benefit from the modelling and are not willing to pay more. According to the engineers, the schedules of the design are too tight, and they lack the time to provide high quality models. The change to BIM requires more time and correcting of the mistakes takes long. This is not taken into account in compensations, and therefore the engineer companies cannot afford to put more effort in the modelling.

The construction companies receive the greatest benefit from the use of QA/QC according to the interviews. They also receive the biggest share of money in the building process.

The savings come through avoiding mistakes on the field and keeping the schedules. It is still a challenge for them to implement the new process and use of mistake free designs, as the personnel are hesitant to the new ways. The employees are used to not trust the designs and to make their own conclusions on the field. This means that the building might vary from the original designs.

## **5.5 Conclusion**

The ROI of Solibri Model Checker is not perceived as significant factor as it is seen as a necessary tool in BIM process. Buyers see it as necessity tool to visualize the models that they receive, and to visualize the buildings for their customers or to check the quality on site.

Construction companies receive the most benefit from the use of quality checking and data export, as they usually face the costs of bad quality models. It is still seen by designers that the contractors do not get the most out of the software, because of inexperience or reluctance by the management to change their process.

Engineers see it as a visual tool to help them design necessary quality through visual checking and comparing their designs to other models. They are usually in a situation that they need models from the architect to complete their work. Through the combining the models, they can also use it to discuss improvements.

Architects join already in the early phase to the design process, and model checking in these mid-sized to large companies is structured well, but they feel that the well-designed models are not used well enough by the construction sites. They see Solibri Model Checker as a necessary tool to operate in the sector, and to win the deals.

Most of the benefits of quality checking and BIM are intangible and divide in a long period so the benefits are not seen as directly financial. The projects take years to complete and include many different stages that affect the success of the project. Human factor can still be seen as a main variable in the projects that is shown in cooperation. One reluctant person in a crucial phase can influence in the success of the process. According to the interviews, projects where BIM has continued throughout the whole process, from planning to upkeep, are still rare. This means that the interviewed persons feel that they have not seen the full benefit of the BIM. Many companies have these projects in construction or

planned for the future so they believe that within five to ten years the full potential of BIM and model checking can be seen better.

According to the interviews, the investment in BIM QA/QC software pays itself back. Only one architecture company representative stated otherwise, and continued that this is because they have used it for so short period. The intangible benefits bring biggest share of the return on information technology investment, and all the different variables of the theory are found from the interviews.

## **6 Recommendations**

The research process of this thesis began with discussions with a member of Solibri, Inc. and they requested a thesis to be used in marketing purposes, and to get experiences from their customers of the benefits of their software.

For further development, the thesis topic discussion was held with a German BIM professor that gave comments to the thesis. He suggested that the research should be more focused to certain design phase of the BIM process, to show clearer benefits of the software and to narrow the topic down.

There were few different ROI theories that I compared to find the most relevant one. These would take more into consideration actual tangible benefits compared to tangible costs. As the case company requested, to research the benefits of their software, an intangible approach was chosen as the main theory of this thesis.

Different research methods were discussed during the writing process, and one suggestion was a combination of qualitative and quantitative research that would have given comparison and more research material. This was rejected as the target group was seen as large enough, and the event suggested for performing the quantitative research, was not seen suitable.

To get a fiscal numbers of the benefits of the Solibri, Inc.'s software, it would be interesting to see a research concentrating on a certain project. This would follow the process workflow and communication within the project that utilizes BIM. It would give a good perspective of different companies' use of the software.

A qualitative research of the topic could give a different result on the topic. The data could be gathered from Solibri, Inc.'s customers, and a question of actual ROI evaluation could bring numbers that could be compared. This would give a wider perspective to the research and offer more statistical approach.

It would be interesting to see a research on the topic that would take into consideration companies that are reluctant to BIM. This would give more perspective to why the level of implementation of BIM technologies is still so low. Especially a research from the owners' perspectives would be interesting, as it seems that they are the most reluctant to implement BIM.

For the thesis, I wanted to combine my enthusiasm for customer satisfaction, and my specialization studies in accounting. Early in the process, I realized that it would be challenging to gather numbers from customers, as companies are not necessarily willing to provide return on investment numbers for a third party. This was solved by concentrating more on the intangible benefits gained from the investment in Solibri Model Checker. As the building industry was new to me, it required a lot of studying to write the theoretical part. It was challenging to find a ROI theory, which would take into consideration the intangible benefits of a technology investment.

With the help of Solibri, Inc.'s personnel, it was easy to find suitable candidates for my interviews, and the interviewees seemed interested on the topic so it was easy to find suitable time for an interview. Challenge in the interviews was that there were so much data after the interviews that had to be put into easier to research format. I decided to transcribe all the interviews that took longer than expected. Because of this and my other tasks, the thesis was 3 months late from initial schedule.

## References

American Society for Quality 2015. Quality glossary. URL: <http://asq.org/glossary/q.html>. Accessed: 19 August 2015. USA.

Applecore designs. About BIM. 2015. URL: <http://www.applecoredesigns.co.uk/bim/> Accessed: 28 October 2015. Birmingham.

Autodesk 2004. Return on investment with Autodesk Revit. Autodesk Building Solutions. San Rafael.

Azhar S., Hein M. & Sketo B. 2007. Building Information Modeling (BIM): Benefits, Risks and Challenges. Auburn University. Auburn.

BIM Industry Working Group. 2011. Strategy paper for the government construction client group. BIM task group. United Kingdom.

Bolpagni M. 2013. The implementation of BIM within the public procurement. VTT Technical Research Center of Finland. Finland.

buildingSMART 2015. IFC Overview summary. URL: <http://www.buildingsmart-tech.org/specifications/ifc-overview>. Accessed 19 August 2015.

buildingSMART 2015. Newsletter No 21: National BIM strategy launched in Spain. buildingSMART

Cresswell A.M. 2004. Return on Investment: In Information Technology: A Guide for Managers. Center for Technology in Government. Albany.

Daniels H.C. 1998. Information Technology: The Management Challenge. Addison Wesley Longman Publishing Co., Inc.

Dave B., Boddy S. & Koskela L. 2013. Challenges and opportunities in implementing lean and BIM on an infrastructure project. Proceedings. Fortaleza.

Davies R. & Harty C. 2013. Measurement and exploration of individual beliefs about the consequences of building information modelling use. Taylor & Francis Group. Berkshire.

Dehning B. & Richardson V.J. 2002. Return on investments in Information Technology: A Research Synthesis. Journal of Information Systems. New Hampshire.

Eastman C, Teicholz P, Sacks R & Liston K. 2011. BIM Handbook A guide to building information modeling for owners, managers, designers, engineers, and contractors. John Wiley & Sons, Inc. New Jersey.

Finne C., Hakkarainen M. & Malleson A. 2013. Finnish BIM Survey 2013. NBS. Finland.

Giel B., Issa R. & Olbina S. 2010. Return on investment analysis of building information modeling in construction. Nottingham University Press. Nottingham.

ISACA 2012. Calculating Cloud ROI: From the Customer Perspective. ISACA. Illinois

Jerning F. 2007. Big BIM little Bim The practical approach to building information modeling. 4Site Press. Salisbury.

Karjula J. & Mäkelä E. 2012. Common BIM Requirements 2012 Series 11 Management of BIM Project. Parties of COBIM project. Helsinki

Karnamo R. 2014. Määrätietoiset askeleet tietomallin käyttöön kiinteistöjen ylläpidossa. Jyväskylän koulutuskuntayhtymä. Jyväskylä.

Kulusjärvi H. 2015. Solibri Model Checker.pptx. Accessed 18 August 2015. Helsinki

Kulusjärvi H. 2012. Common BIM Requirements 2012 Series 6 Quality assurance. Parties of COBIM project. Helsinki.

Laakso M. & Kiviniemi A. 2012. The IFC Standard – A review of history, development and standardization. ITcon.org.

Manninen A-P & Kärnä S. 2011. Kansainvälinen state-of-art-selvitys rakennusalan BIM-käytännöistä. Aalto-yliopisto. Espoo.

Mitchell D. 2015. ROI on BIM: Where is the Evidence and Will it be Kept Secret? URL: <https://sourceable.net/roi-on-bim-where-is-the-evidence-and-will-it-be-kept-secret/#> Accessed 24 September 2015.



NBS 2014. BIM levels explained. URL: <http://www.thenbs.com/topics/bim/articles/bim-levels-explained.asp> Accessed: 27 August 2015.

PricewaterhouseCoopers 2007. Software Pricing Trends. URL: [http://www.pwc.com/en\\_us/us/technology-innovation-center/assets/softwarepricing\\_x.pdf](http://www.pwc.com/en_us/us/technology-innovation-center/assets/softwarepricing_x.pdf). Accessed: 19 August 2015. Australia.

Rumane A.R. 2011. Quality management in construction projects. CRC Press. Boca Raton.

Solibri 2015. About Solibri. URL: <http://www.solibri.com/contact/solibri/>. Accessed: 19 August 2015. Helsinki.

Technavio 2014. Global BIM Market. Infiniti Research Ltd. London.

Toyota 2015. Toyota Production System. URL: [http://www.toyota-global.com/company/vision\\_philosophy/toyota\\_production\\_system/](http://www.toyota-global.com/company/vision_philosophy/toyota_production_system/) Accessed: 29 August 2015. Tokyo.

Westerlind K. 2004. Evaluating Return On Information Technology Investment. Gothenburg University. Gothenburg.

Zheng W. 2013. A Comprehensive Analysis of Building Information Modelling/Model (BIM) Policies in Other Countries and Its Adoption Strategies in Ontario. McMaster University. Ontario.

## Appendices

### Appendix 1: Interview questions

Persons name, company, role in your organization, responsibilities

What is your background in building information modelling?

How do you utilize BIM and QA/QC software in your daily tasks?

What have been and are your greatest challenges in building information modelling?

What kind of challenges has Solibri Model Checker (SMC) solved in your processes?

Can you raise one case in which the SMC showed to especially useful?

What kind of tangible and intangible benefits have you gained from use of SMC?

How would you define ROI of SMC in terms of your business, what items should be included/excluded from the equation?

What kind of direct/indirect costs have you faced because of the investment in SMC?

Do you feel that the investment in SMC has paid off and how?

How do you feel that the software serves your business present and future needs?

How could customer service be improved and what would you expect from SMC in the future?

How do you see technology development, for example towards cloud based environments, affecting your operations in the future?

Anything else you would like to mention?

## Appendix 2: Interview questions in Finnish

Henkilön nimi, yritys, rooli organisaatiossa ja vastualueet

Minkälainen tausta sinulla on tietomallintamiseen liittyen?

Miten käytät tietomallintamista ja tietomallien laadunvarmistusta päivittäisessä työssäsi?

Mitkä ovat ja ovat olleet suurimmat haasteesi tietomallintamisessa?

Minkälaisia haasteita Solibri Model Checker (SMC) on auttanut ratkaisemaan?

Voitko mainita yhden tapauksen, missä SMC on osoittautunut erityisen hyödylliseksi?

Minkälaista konkreettista hyötyä SMC:n käyttö tarjoaa?

Miten määrittelisit SMC:n tuottoprosentin (ROI) ja mitä mielestäsi pitäisi ottaa huomioon ROI-yhtälössä?

Minkälaisia suoria ja epäsuoria kuluja SMC:n osto on aiheuttanut?

Onko sijoitus SMC:hen maksanut itsensä takaisin? Miten?

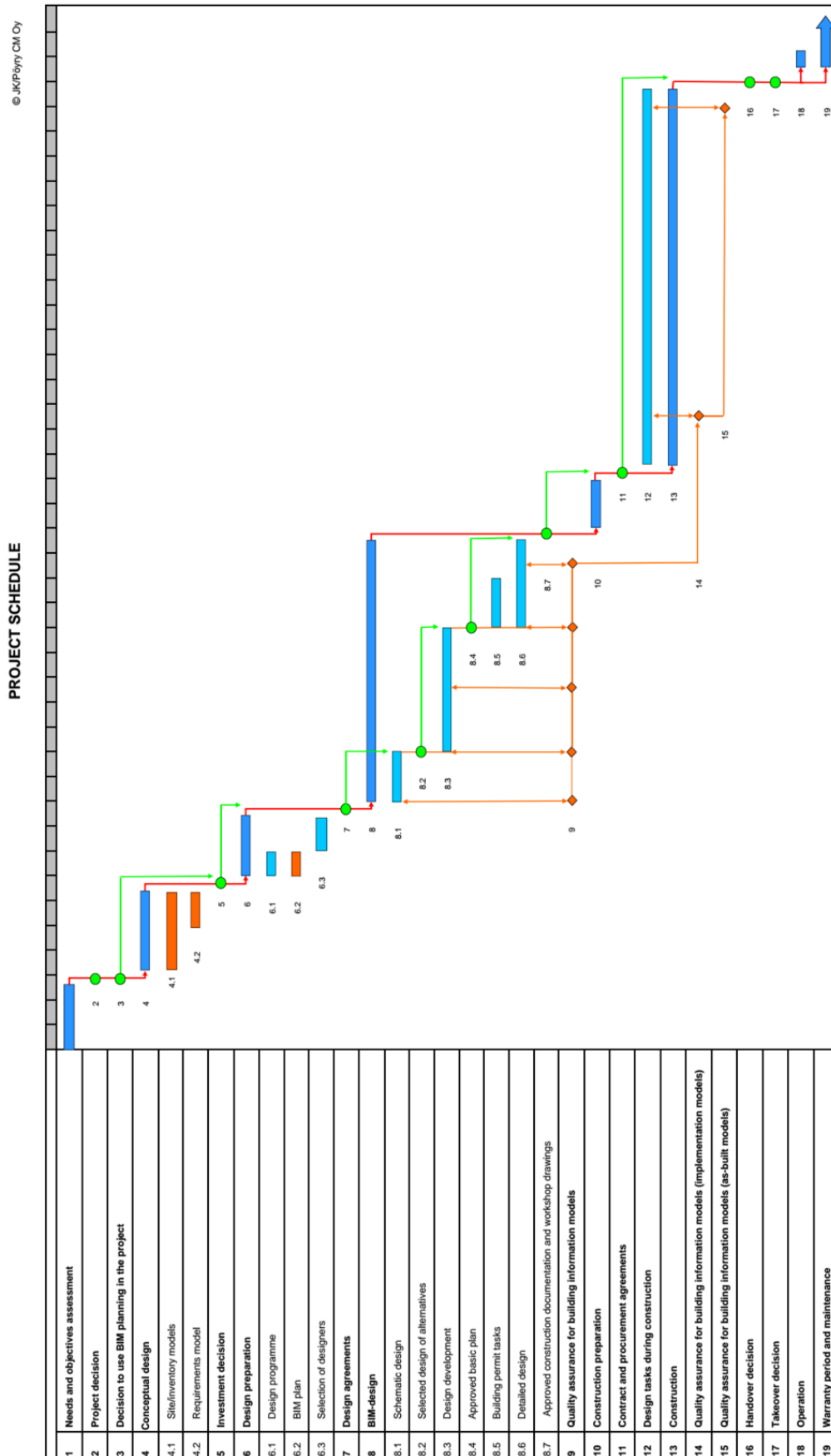
Palveleeko ohjelmisto yrityksesi nykyisiä ja tulevaisuuden tarpeita?

Miten parantaisit Solibrin asiakaspalvelua?

Mitä odotat SMC:ltä tulevaisuudessa?

Miten näet teknologian kehittymisen, esimerkiksi pilvipalvelut, vaikuttavan yrityksesi toimintoihin tulevaisuudessa?

Onko mitään muuta, mitä haluaisit mainita?



## Appendix 4: Dates of the interviews

### Construction companies:

1. 20.10.2015
2. 21.10.2015
3. 30.10.2015
4. 11.11.2015
5. 17.11.2015

### Architect offices:

1. 27.10.2015
2. 28.10.2015
3. 3.11.2015
4. 6.11.2015
5. 16.11.2015

### Engineer offices:

1. 22.10.2015
2. 11.11.2015
3. 12.11.2015
4. 17.11.2015
5. Answers received via e-mail on 18.11.2015

### Owners:

1. 5.11.2015
2. 6.11.2015
3. 18.11.2015
4. 24.11.2015