Master Thesis in MSc Management in the Building Industry Aalborg University, Denmark

BIM for building design and Building Commissioning

Combination of BIM and Building Commissioning as a link between client requirements and project participants during the design phase

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Synopsis

The following master thesis analyzes problems in the construction industry in connection to meeting client requirements and it is limited to base the researches only on the design phase.
The following project relies on qualitative data, interviews and analyses of scientific literature in order to investigate an area of improvement.
Such have been found in problems with collecting, managing and meeting client requirements.
The reason why focusing on this topic is important is due to the fact that the clients are the ones from which depends on the success of the project. Lack of client satisfaction in a highly rivalry market like the construction industry, a company could easily start to be behind the competitors and eventually be kicked out altogether.
Furthermore, this project report examined how best to collect, manage and communicate client requirements, by the use of Building Information Management tools and Building Commissioning.
When Building Information Management and Building Commissioning are implemented well, these tools can bring positive changes in every building project. Furthermore, meeting client requirements and providing satisfaction results are going to increase client satisfaction.

Preface

The following report is written by Antoaneta Kaneva as a master thesis in Management in the Building Industry at the Department of Civil engineering at the Aalborg University.

The subject of this master thesis is chosen as a result of the author's interests in Building Information Management. The following work is performed within the period of 5 months, between September 2016 and January 2017. During that time hundreds of hours of literature research, data analyses and writing in connection with Building Information Management and Building Commissioning implementation have been used.

The following master thesis is a qualified and interpretive work using a comparative analysis of the case, related work, and literature review, understanding the complex of the building projects regarding communication and information sharing between different parties by describing potential information sharing strategies.

The new build AAU building is selected to serve as an example of a complex building project. This case study is conducted to examine the factors that lead to not meeting client requirements. It is used as an example of how communication and information sharing is performed within complex projects and big organizations. Building projects require a great deal of collaboration between organizations due to their complex organizational structure, therefore a sufficient communication and management tool is required.

Attention is paid to the projects on which actors have to collaborate and share their knowledge to realize the desired end product. The collected includes interviews with client representative. The research methods, case description, and collected data are reported. The general outcome of the results is provided including a recommendation for solution and practice.

During the processing of this report, several limitations were met. Firstly, a language barrier was met, due to the international nature of the author. This problem is removed within the most effective manner possible, even though some uncertainties still remain in connection with data translation and understanding.

The scope of this master thesis covers only the design phases of a project because it is important at beginning of any project to consider all aspects of the project because in the future this could lead to unexpected costs. It is very important at beginning, that the design is accurate and fulfills client and regulation demands. The innovation at this stage is essential and can be reached with the use of Building Information Management, which consists of two main aspects – the working process and the tools (software).

During the analyses is considered the working process and possible challenges what could arise when project participants shift their working methods from traditional to Building Information Modeling.

In this master thesis, only one case study was used as a base of the whole project. It would be much better if were included more cases that represent different information transfer and translate client requirements. Having more cases would also provide additional information and could lead to more perceptions regarding the legal responsibilities related to different contract forms and their impact on information transfer.

Due to time, resource and information limitation the following report is based on analyses and researches only in connection with the design phases of a building project. Possible problems could occur during other phases, which brings deeper analyses for the whole building process. It is important to focus on each of the design sub-stages because then is clear to understand what is needed for each of them and how Building Information Management and Building Commissioning can support this needs and bring improvements for the whole building process.

The following report performs as a master thesis, focusing on meeting client requirements and provide organizations with the idea for improvement. It is limited to the design phase only and meanwhile limited to the time and resources. When answering the questions from the main problem formulation, the author is focusing on all type of building projects, no matter if they are public or private projects. Solution and a plan for implementation are provided, in order to improve communication between parties during project design stages. The plan for implementation is not real, just a suggestions of steps to be followed since it is a study project. Since it is not company based or case-based, a timeline and budgeting cannot be provided. The main reason is the difference between all projects in connection to size, complexity, and duration. Due to the limited time, the report does not include a follow-up and documentation summarizing the results.

In order for the problem analyses to be more precise more related works and case studies can be investigated. Meanwhile, further analyses can be made in connection with the transfer of information between Consultants and Contractors, and Contractors and Clients. Another limitation of the following master thesis is related to the limited observation house spend.

In the following report, the focus is moved from the legal aspects, which could bring other changes when implementing Building Information Management and Building Commissioning. Changes in connection to different types of contracts are going to change the responsibilities of the involved parties.

Abstract

The following Master thesis is made by Antoaneta Kaneva, who is in the program Management in the Building Industry, Master of Science in Engineering.

This work is a reflection and combination between analyses of scientific literature review, interviews and knowledge gathered during the study years. The process of work is done for the period of time from September 2016 to January 2017 at Aalborg University in Aalborg, Denmark.

The main focus of the following work is based on meeting client requirement during the project stages, and mainly focusing on the design phase. It is focusing on the advantages and benefits of the Building Information Management and Building Commissioning. A combination of these two is analyzed and implemented right leads to the desired results at the end of the building project. These results are meeting client requirements which should be clearly defined and set in the very beginning of the project.

This master thesis starts with an introduction to the initial problem, including an explanation about the general building project and its stages. It includes an explanation of the client requirements and how they are met during the design stage. The following analyses are made with the use of qualitative data, scientific literature and interviews. Based on these researches I have come up with the following problem statement:

How a link between client requirements (CR) and project participants during the design phase can be accomplished?

Furthermore, more analyses are made for deeper investigations. Building Information Management is represented to the reader including all details, advantages, and benefits. For a conclusion, a table for comparison and evaluation is provided, including important properties. Later on, Building Commissioning is presented. Building Commissioning is defined as a quality assurance process which aims to ensure that the final product meets the client's needs and requirements. The reason why Building Commissioning is proposed is due to the client dissatisfaction from the received final product.

At the end, a solution is given, as a combination of Building Information Management and Building Commissioning implementation.

Acknowledgements

The success of this master thesis came only after thorough the guidance from my supervisor Kjeld Svidt and his assistant Ekaterina Petrova. I, Antoaneta Kaneva would like to thank them for the encouragement, assistance, on time replies and guidance when help was needed. I appreciate all the given advice and the provided good suggestions.

Furthermore, my work was dependent on collaboration with the new Aalborg University client representative, which has been at a very high level. I am thankful to her for the provided assistance and valuable data in order to carry out my research. Also, I want to thank her for the help, the interesting discussions that have shaped parts of this report and agreeing on sharing her knowledge with me.

Readers guide

The following master thesis consists of chapters 9 which are following a logical order and can be seen in fig. 1 The following chapter outlines the key points of the entire report by showing each chapter and its purpose. The purposes of the reader's guide are to explain the structure of the report, so to make it easier to follow the paper.

1. Introduction and background

- The following chapter represents the perpouse of the master thesis and explain the importance of meeting client requirements.

2. Initial problem

- Introduction to the initial problem which is the base of the whole report

3. Methodology

- Provides an information how the work was perfomermed. Includes an information about thedata collection and analyses. Includes information about used methods and approaches

4. Problem analyses

- Provides an analyses of related work and case study, based on the initial probelm by focusing on the importance of information sharing between parties in large complex projects

5. Problem formulation

- It is an outcome of the problem analyses and defining the main problme statement with the use og LFA approach. Defines the desired objectives

6. Main analyses

- Includes an Building Information Management analyses and Building Commissioning analyses

7. Solutions and implementation

- Provides steps for both Building Information Managenement and Building Commissioning implementation

8 Conclusion

- Outcome of the performed work and conclusion of the made analyses

9 Discussion

- Information about what can be done further

Figure 1 Readers guide

Abbreviations

A list of the abbreviations used in the report is presented below, in order to help the reader, understand their meaning:

List of Acronyms	
Acronym	**Meaning**
AAU	Aalborg University
AEC	Architecture, engineer and construction industry
BCA	Building Commissioning association
BIM	Building Information Management
Client	person/organization
CxP	Building commissioning provider
Cx	Building commissioning process
CPM	Critical path method
DD I	Detail Design I
DD II	Detail Design II
Design team	Architects and Engineers
DWF	Design Web Format
GSA	General Services Administration
HVAC	Heating, ventilation and air conditioning
ICT	Information and Communication Technology
IFC	Industry Foundation Classes
MEP	Mechanical, Electrical and Plumbing
OPR	Owner's Project Requirements
O&M	Operation and Maintenance
RFP	Request for Proposal
RFQ	Request for Qualifications

Figure 2 Abbreviations

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1 Introduction and background

Every building project is a complex and challenging process. During this process, the client role is an important factor for the success of the final product. Every client wants to receive a high-quality building for the money invested while meeting all his requirements. Customer satisfaction is an important factor in the development of the building process. Since the construction companies are facing higher rivalry, the attention on the customer satisfaction is increasing. This factor enables companies to differentiate themselves from their competitors and create sustainable advantage.

The motivation for focusing on this topic starts with my own experience through the years of study at Aalborg University. During that time, I took part of group projects, where different building projects were analyzed as part of the study program. In each of these projects, I have noticed the lack of client satisfaction.

Clients are satisfied when the result is greater than the expectations. Meanwhile, a dissatisfaction occurs when the performance is lower than the expectations. Customer satisfaction in the construction industry can be defined as how well the final project meets the client's requirements. Therefore, the main task for the consultant/ designer is to stick to the client requirements, which would lead to higher customer satisfaction and opportunity to remain a customer's potential partner in the future.

Good project means to create a building that looks good, which is attractive and desirable to the people that are going to occupy it. Meanwhile, it is showing its function and role in relation to public space and structures. The building should have well-matched parts and proper details, to be energy efficient, sustainable and flexible.

Client requirements depend on the projects type, consist of more or less detailed information. This information often is in connection to the net area, activities, connections, security, materials, conditions, light, temperature and even a sound level. Prioritizing these requirements is an important part of the beginning of the design process because some of them can be in a conflict in case of a combination. Basic requirements are factors which often cause dissatisfaction when they are not realized and met, which often leads to re-design of the project. In most of the cases, there is a significant level of misunderstanding. The lack of communication and information exchange is an inspiration for the following project.

The objective of this research is to examine and analyze the understanding of customer satisfaction during the design phase. Further analyses are to be made so to get a better understanding of different design stages, different client requirements and their effect on the building process and decision making while following the transfer of information between users, CEO and design team. The main reason for focusing on the design stage is because this is the foundation of every project. In the case an improvement is needed, it is always good to start in the very first beginning, because later on, improvements increase the costs. In the following thesis, different researchers and scientific literature statements are discussed. Later, the results of these analyses are presented and a discussion and possible solution are given.

There are analyses focusing on client satisfaction and according to (Eley, 2003, p. 3), the client should understand the complex of the building project. He should get the best from all project participants. This is the moment when the client contributes his strengths, knowledge, care and commitment to quality that will get the best out of those working for him. The reason is altogether

to create the desired building. The consultant/ design team should be able to work by taking in consideration what the client wants and can afford, so to make a balance between time, quality, and money (see fig.3). The best value for the final product involves a balance between these objectives without sacrificing any of them, in case this happens the client is satisfied. (Eley, 2003, p. 11) The figure below represents this balance as an equilateral triangle.

Figure 3 Time, Cost and Quality triangle (Kelly, 2011)

Each of the sites has each meaning as:

- Quality – this is the quality of the building
- Time – This is the time needed for the building to be designed, build and ready for occupation
- Cost – This is the cost of the construction, materials and all related expenses including cost for use

Meanwhile, design progress is usually left aside and design changes are made based on the previously made design solutions. All small changes and continuous decisions in connection to these changes can lead to a solution that does not longer meet the original client requirements. (Kiviniemi, 2005, p. ||) This complexity increases the need for updating these requirements, by managing, documenting and tracking the changes to the design solution.

There are some factors that do not allow this step to proceed so easily. According to (Kiviniemi, 2005, s. 2), these factors are the complexity, the size and the duration of the project. Another factor that interrupts the process to proceed easily is the fact that many designers work simultaneously on many projects, so stakeholders are changing in different project phases. This leads to shifting design focus and moving from overall problem solving to detailed technical solutions. The reason is for this are the intention of the requirements definition and design activities, which are different in different project stages. A possible solution could be a requirement management system as seen on the figure bellow (fig. 4). This type of a system could be included through the whole building process and stages. It is actually doing the connection between each of them, so to assure the right design solutions are taken and client requirements are met.

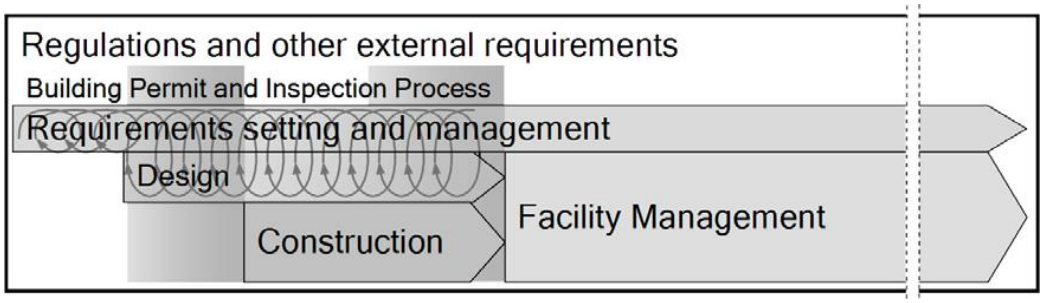

Figure 4 Parallel process view (Kiviniemi, 2005, p. 3)

Therefore later in the report different Building Information Management tools are going to be compared and analyzed with a combination of Building Commissioning. The advantages of BIM (including its all varieties) are increasing with all the developments through the years, which has a great impact on the client and consultant/contractor relationship. Focusing on each of the stages of the entire project is important to make sure that client requirements are well defined and met. There are different Building Information Management tools suitable for each of the parties in each of the project stages and analyses are to be made so to find out which option is more favorable and which one can be best combined with Building Commissioning.

This Introduction aims to provide background information for the following master thesis by identifying the research field of study. The main problem formulation is to be based on the background information in connection with the issues with meeting client requirements in the building industry, therefore the initial problem is to be identified and further analyzed in the following chapters.

2 Initial problem

During the design phase, it is happening the number of changes to increase, which leads to complex situation and problems. Usually, before the design starts, a documentation containing client requirements should be created and each of the involved party to have access to it, but very often this documentation is not updated accordingly. According to (Kiviniemi, 2005, p. 3), it is much easier if the project participants are able to manage and update all the changing requirements, so they can be easily tracked. All parties involved in the project make decisions on how to solve different problems and it is becoming an issue to notice all the reasons behind these decisions.

On the fig.3 bellow is represented a diagram explaining how different changes, trough the design phase, are pushing away the initially stated client requirements from the desired outcome and final goal. It is representing how decisions are made based on previous design solutions, not based on the client requirements. The reason for this is that not every party in the project is familiar with the original intent since they appear later in the process. Therefore further investigation is to be made later in the report.

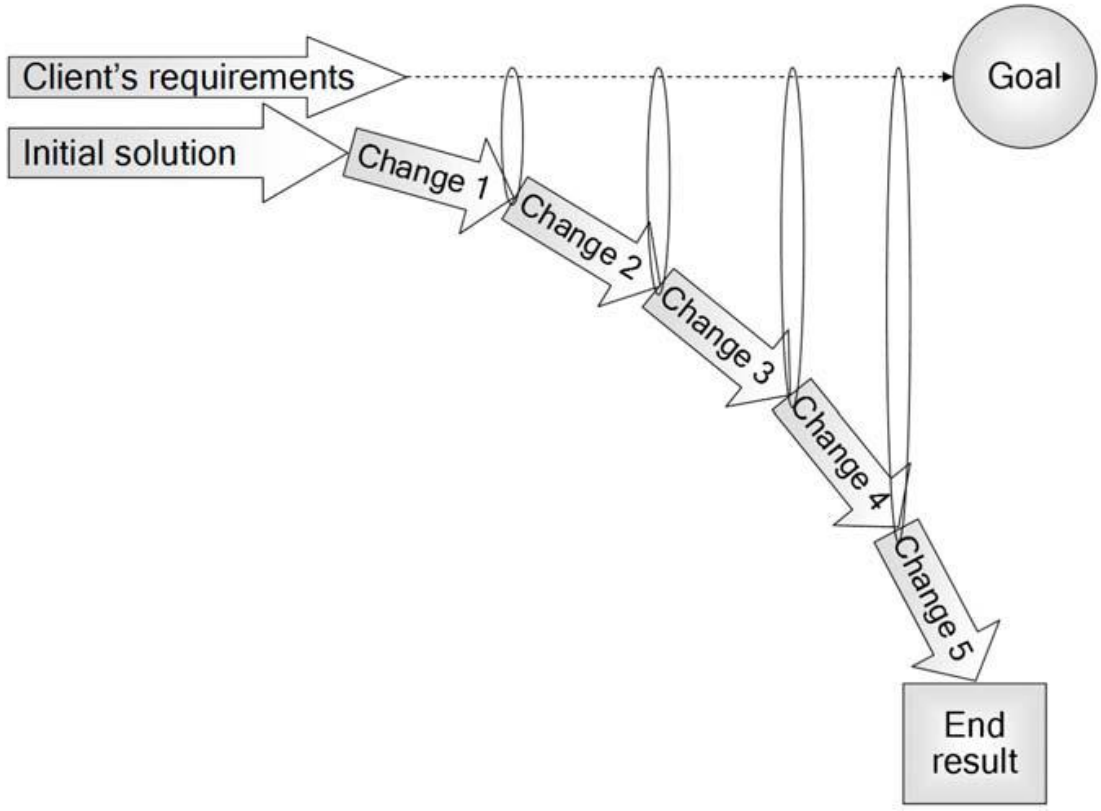

Figure 5 Shifting away from the goal. (Kiviniemi, 2005, p. 5)

A common practice is all changes to be recorded only in the memory of the participants during meetings or personal notes. This type of collecting and managing information impedes to find the latest updates of the requirements, which on the other hand leads to results that are significantly different from the client expectations. (Kiviniemi, 2005, s. 4)

Based on the overall literature review I have come up with the following initial problem:

'Final product does not meet client requirements, due to the fact that not all of the involved parties are familiar with these requirements'

This statement will be used later in the report as a base for further researches and analyses. Focusing on client requirements is important for increasing client satisfaction. Often there are some important client's requirements that are not satisfied. It is happening that even if the design process is based on agreed- upon changes in the scope and requirements, differences in the requirements documents and in the completed building could lead to doubts about the quality of the design and construction process.

Something that can help the consultants/ designers to get a better understanding of the interaction between the requirements and the design solution, is a link between the client requirements and design objective. This helps also for evaluating the design solution compare to the client's expectations. Therefore, it is important to be created a link between the client requirements and design process. This will increase the use of requirements documentation throughout the design process and facilitate necessary updates of the CR. (Kiviniemi, 2005)

Based on the information above and due to the fact that other authors as Kiviniemi are noticing the problem it is clear that there is a place for improvement. Meeting client requirements is a complicated process, during which information exchange plays an important role in the success of the project. In the following report deeper analyses are to be made in connection to design phase requirements, collecting, and exchange of information between different project participants. Building Information Management and Building Commissioning are going to be introduced and evaluated how beneficial they can be for both the client and the consultant during the design phase.

3 Methodology

The strategy used in this master thesis is to provide more detailed analysis for the initial problem from the academic perspective. With the use of a case study and related works, it is possible to prove the importance of focusing on this topic. Furthermore, the new AAU university building is used as a case study and it is a base for part of the analyses. This case study provides lots of answers and important information regarding the initial problem about meeting client requirements. Analyzing and understanding the initial problem shows that is it relevant and important to work with.

After introducing the topic of the report, deeper analyses and researches are made so to verify the importance of the communication and information exchange between project participant during the design phase. The initial problem and the case study are useful for identifying the main problem and its root causes. This is done with the use of the LFA (Logical Framework Approach), by analyzing the given problem with the use of a Problem Tree and after that showing the desired objectives with the use of Objective Tree. LFA provides with necessary information used for developing a problem formulation. The main problem formulation is the foundation for all further analyses.

After that, a solution reaching the desired objectives is analyzed and given, followed by a plan for implementation. The success of the solution is evaluated with the use of the Leavitt Diamond. Leavitt diamond is explained and analyzed in order to check possible consequences if changes are made in the four main areas, which are a task, people, structure and people.

During the research, both quantitative and qualitative data collection, including interviews and scientific literature analysis are used. The main topic of the interviews and the followed questions were prepared in advance and delivered to the interviewees before the meeting day. In total two interviews were conducted. Quantitative data collection is used for making statistical analyses, which allows to formulates some of the facts, which are used to prove some of the problems. The qualitative data is collected by the conducted interviews and own observations, which are useful for the paper development.

4 Problem analyses

In the following chapter, I have examined the current situation in the construction industry with the use of related work, case study and scientific literature review. The following analyses are made in connection with information exchange between different parties during the design stage. Authors like Sebastian (2010) and Kiviniemi (2005) are also investigating the problem in meeting client requirements, therefore the mentioned above initial problem (see chapter 2 Initial problem) is current for the building industry. It is important to identify the issues that limit the information sharing between different parties in the design stage and leading to not meeting client requirements. This is a conclusion that the mentioned above authors are coming with. It is interesting to see other authors point to view and their conclusions. I have used one of the related works done by Sebastian (2010) so to continue my researches and analyses.

4.1 Related work

During one of the study cases that (Sebastian, 2010, p. 177) is working on, he comes to the conclusion that most of the building projects are facing serious problems in connection to budget overrun, delays, end user's dissatisfaction, and energy inefficiency. According to him the main reason behind these problems is the lack of proper communication and coordination between all project participant. The communication between different stakeholders becomes critical because each of them has different requirements and demands. This is time-consuming and difficult processes for extraction, interpretation, and communication of design information from drawings and documents.

Unfortunately, there are still gaps in the practical knowledge on how to manage the building actors to collaborate effectively. Therefore detailed analyses are to be made further in the report. Improvement in BIM (Building Information Management) has great potential to increase the communication efficiency between project participants, which increase the need for a more detailed investigation. In order to be even more concrete that the problem occurs, a real-life example is provided in the next sub-chapter.

4.2 Case study

One real example for not meeting the client requirements is the new build University Building in Aalborg. During an interview with the client representative of the design process (12.2 Appendix 2 – Meeting with client representative #1), a lot of problems were noticed in connection to communicating and satisfying client requirements. The final product is not the desired result by the client and the end users. Further, detailed analyses are to be made to identify all the reasons for these issues and what solutions can be given in order to improve the design process. Below are listed a number of problems faced during the design stage of the new AAU university building.

Problem 1 No standard procedure for collecting client requirements *(12.2 Appendix 2 – Meeting with client representative #1 Q1)*

The client representative was part of the design process from the very first beginning as being the one collecting CR. The procedure is done without any supervision and the people responsible for this task did not have the needed experience. Moreover, the tools used for this important task were

personally done so they make sense only for the ones creating them, mainly word and excel files. This is not professional and not everyone can be clear with the idea since there is no standard way for providing this task. Experimenting is not a smart option for big and expensive projects. Missing a standard procedure for collecting and managing this information makes it harder for the consultant/ design team to understand the actual content and translate it to the other project participants.

Problem 2 There is no system that collects the basic requirements *(12.2 Appendix 2 – Meeting with client representative #1 Q1)*

There are lots of requirements concerning the utility rooms, ventilation systems or specific rooms needed in this building. There are a lot of different books for the public buildings that the client representative is supposed to read and collect all the relevant information. The campus service has an own book in connection to requirements. The HVAC has as well another one. Having all these information is not collected together and using only paper material is time and money consuming. According to the client representative, there should be a person in charge of this as a specialist, who is familiar with all these little needs and requirements that users are not aware of.

Problem 3 No distinction between Direct and Indirect requirements *(12.2 Appendix 2 – Meeting with client representative #1 Q5)*

Neither the design team nor the client makes a distinction between direct and indirect requirements. An example of this problem is the cupboard in the kitchen room where the space for a refrigerator is not enough, so the owner is supposed to order customized product. The designers' excuse is that the client did not state the right size for this cupboards even though the measurements are standard.

Problem 4 The chain for translating the user's requirements to the client requirements is too long *(12.2 Appendix 2 – Meeting with client representative #1 Q10)*

There are too many levels and people in the organization through which the information is transferred from the end users to the actual owner. This is particularly for the new University building in Aalborg, but in most of the big projects, the situation is similar.

Problem 5 Partly BIM implementation *(12.2 Appendix 2 – Meeting with client representative #1 Q11)*

According to the client representative, BIM as a design and modeling tool was not implemented properly and the project participants could not use its full potential. Architect and engineer 3D models were not combined. On the architect model, some columns were missing, as well as the information for the acoustics.

Having the mentioned above case study and the followed issues, it is easier to point that the issues with meeting client requirements actually exist and there is room for improvement. The new AAU building is going to be used as a base for further analyses in connection with information transfer and exchange between project participants.

4.3 Transfer of Information during design phase

The following report is based on the transfer of information between project participants during the design phase. The design is the foundation of every building project, therefore it is important to

make improvements in the very beginning. This would lead to improvements in later stages, by minimizing the possibilities for problems to accrue later on.

The design phase is a repetitive process, where the suggested solutions often lead to an evolution in the CR. Building project requests to have well-defined goals, mainly to erect a structure for a specific use and meet specific CR. Building project requires getting the right resources including labor, materials, machinery and funding. It also requires an organization structure and form of contract. Therefore it is important for the client to have an idea what exactly is needed during each design phase.

During the design phase, the information sharing is examined through real-life project example such as the new AAU building in Aalborg. In each field the perception of information exchange is different, therefore a distinction of the variety of approaches that deals with managing and communication information is going to be further analyzed. In a project environment, information communication enables individuals to solve problems, take decisions, and apply them to action. (P.A. Jensen, T. Damgaard, K. Kristiansen, 2009)

The building project is characterized by huge complexity and temporary involvement of many different participants within different fields of focus and interests. It carries a high level of complexity due to programs, collaboration forms, budget and required technical knowledge. In the design phases, a large number of organizations contribute to the projects with their domain knowledge in order to realize the technically and socially complex product, which integrates a multifaceted knowledge and information. (P.A. Jensen, T. Damgaard, K. Kristiansen, 2009)

The selection of information starts by generating knowledge from individuals who work within the design team while creating drawings, sketches, calculations, and reports. Through these artifacts, parties engage in design dialogues and externalize design solutions. Thus, information and client requirements shared between individuals or groups, integrated into the projects, and preserved within organizations during these processes. In the following master thesis, the process starts from sharing client requirements among actors and being integrated into the design process. (Bektaş, 2013)

In building projects, information sharing is crucial among design team actors. The design phase is a process in which actors solve complex problems and require information to solve them. Therefore, it is important to contain analyses about the way client requirements (CR) are communicated between different parties involved in this project stage. The figure below represents a simplified way for visualizing this communication chain. This graph is part of the graph shown in 12.1 Appendix 1 – Communication Chain.

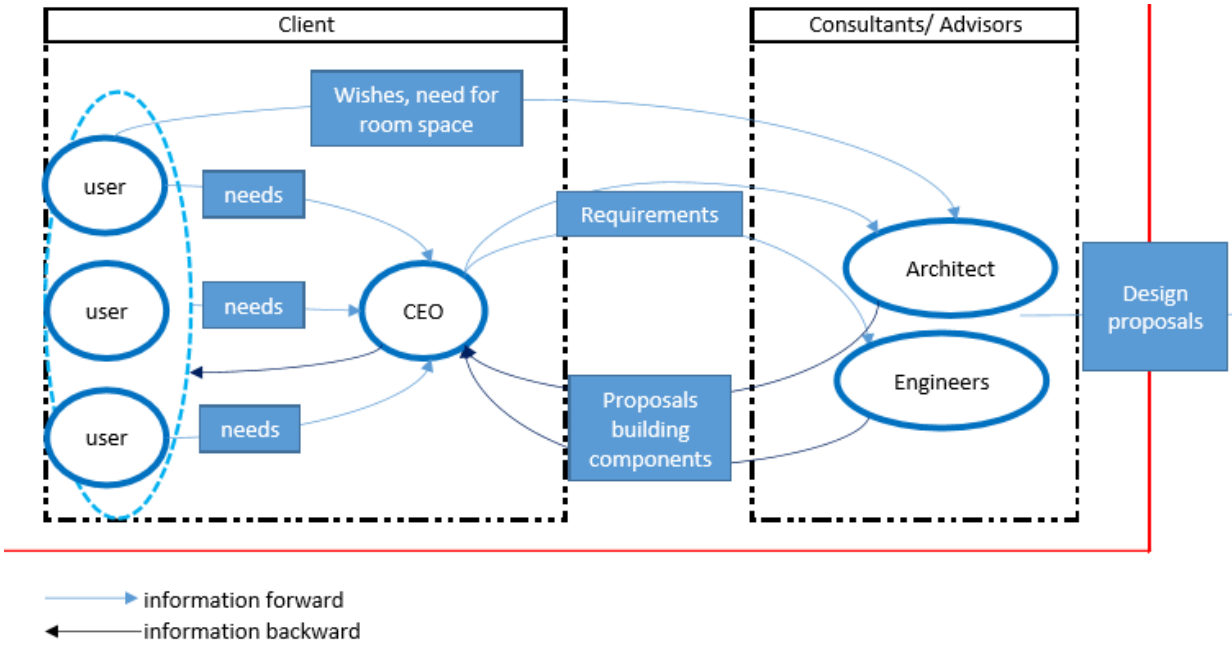

Figure 6 Communication Chain

As seen in the figure (fig.6) above there are 2 quadrants, one representing the client involvement in the project and the second one represents the consultants/ designers.

The 'Client' category includes all the users and CEO of the certain project. This part of the figure aims to provide deeper and understandable idea of how client requirements are communicated between the users and the CEO. Each of them has some needs, demands, and wishes. Very often there is a lack of distinction between these requirements, which leads to miscommunication and misunderstanding. There are organizations where the user's demands are almost the same, but there are organizations where users have completely different needs. An example for this is the new department building of the AAU, where there is a different kind of users. There are the students at Department of Civil Engineering, students from other departments who are having lectures at Department of Civil Engineering, the employees at the school, the employees at the Department, the Head of Department, cleaning staff and caretakers.(see 12.3 Appendix 3 – Meeting with client representative #2 Q1)

In this situation, each group has demands and wishes but it is more than obvious that not all of them can be satisfied. The CEO/ client is the one taking the final decision, therefore he should know which of them have higher priority. This increases the need for a system gathering, sorting and prioritizing this information the right way.

For example in the new AAU project the campus service and the special laboratories (see 12.3 Appendix 3 – Meeting with client representative #2 Q3) had strict requirements and the CEO had to be familiar of, in order for the whole process to perform better and all uncertainties to be minimized. Meanwhile, the students and the staff also have some needs and wishes which should be taken into consideration. Following the AAU university project, this information is collected on sheets of paper and later delivered to the CEO (12.2 Appendix 2 – Meeting with client representative #1). The person collecting this information should know the difference between wishes, demands, and needs, and later to prioritize them, so to avoid the future mess. The transfer of information between end users and CEO is a very delicate process because it is all about understanding each other. When the users state clearly their needs then it is much easier for the CEO to understand

them correctly. Therefore it is very important to be created a standard way of collecting, prioritizing and communicating this information.

As soon as the CEO gets all the needed information it is time to process it and translate it to the consultants. They have to receive clear and understandable information, so to provide the desired result. In case there is no standard procedure for this task some problems with understanding and communication might appear which later could lead to bigger problems. Again each party should understand what actually the interlocutor means.

The consultants are the ones turning the client wishes into something meaningful. They are providing the contractors with the necessary information about the project. Properly done this work could lead to a success of the building project. In order to be sure the consultants understand the client's requirements, they provide the CEO with materials which are a reflection of his stated needs. This time there is an information transferring back and the CEO has to understand why some decisions are taken, and why not everything that he wants can be done. Realizing this he informs the users about all takes decisions.

The consultant/ designers may have to return to the client several times so to get an approval. The whole process is a circle which can be repeated as many times as needed, but it is also time and money consuming. Therefore the shorter this process is the better for the entire budget of the project will be.

Often it is happening that end users are directly contacting the consults by placing their wishes and requirements, without informing the CEO. This direct communication places the CEO in a position where he is left aside and he is not aware of possible changes, which later leads again to misunderstanding and problems. For example:

- Extra time spent for informing the CEO of the taken decision
- Extra time spent for the CEO to approve these changes
- Extra time spent to inform the other users of the taken decision
- Extra time spent to receive and approval from the other users
- Time is money

Providing an overall idea of the information exchange between project participants during the design phase, answers lots of question in connection to the complexity of this step, and why issues and miscommunication occurs. In order to be even more precise analyses of the communication between the end users and the CEO is mandatory since in most of the big projects the 'Client' party includes a big number of stakeholders.

4.4 Communication chain in the 'Client' party

The following sub-chapter represents more detailed analyses about the transfer of information in the 'Client' party. In order for my work to be even more precise, a deeper investigation about the transfer of information through all levels of the AAU organization is made. Depending on the organization, it has different levels, through which the information has to be successfully communicated from the bottom level up to the top one and all the way back. On the fig.7 below are represented all the levels of the Aalborg University organization. Again I am doing the analyses based on the new AAU building since it is a realistic project and there is evidence for proving the existence of the mentioned above issues.

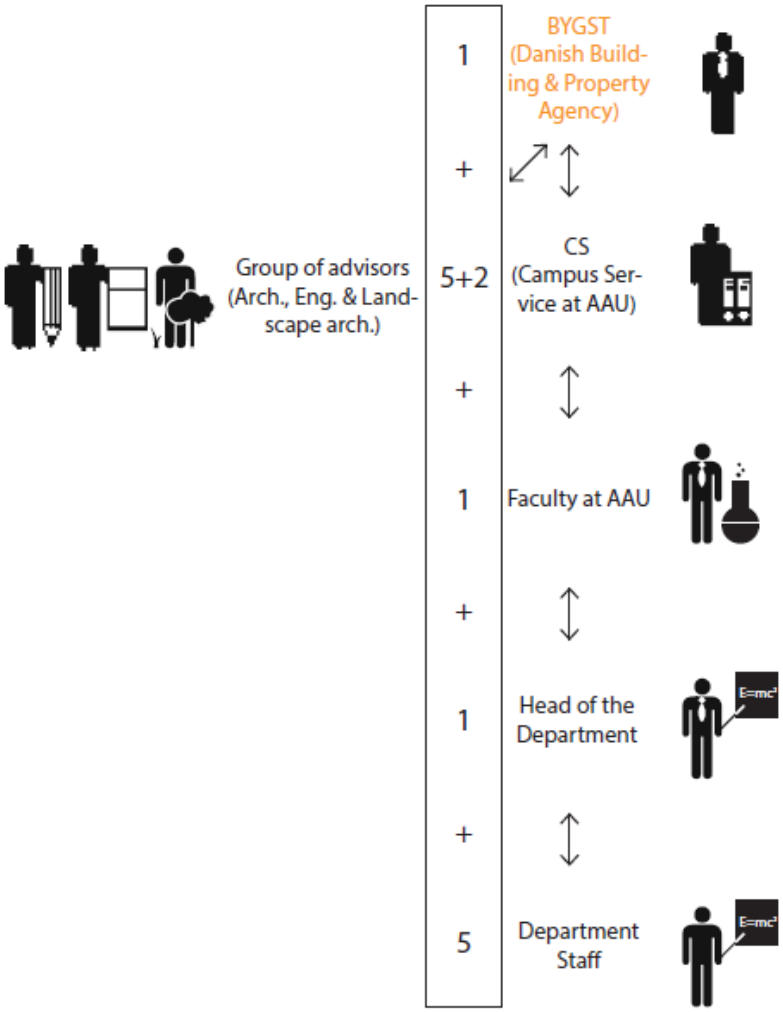

Figure 7 Involved participants (Mai Rasmussen, Rasmus Lund Jensen, Anna Marie Fisker, 2016)

As seen in fig. 7 above when information has to go from the end users up to the CEO it passes through different levels and people. In case this information is not delivered in a proper way it might be understood wrong. This situation would lead to wrong interpretation and deliver wrong information to the CEO, therefore proper communication is important for the successful understanding.

Communication

Communication is a process of transferring information between two or more individuals. It is a two-way street, where good listening skills are part of it, therefore it increases the need for better understanding. In the workplace, it includes oral, written, visual and digital discipline. Effective communication promotes services and products in organizations and it is essential to the success of any project and corporation. (Dr. Anjali Hans, Mr. Emmanuel Hans, 2014)

Professional communication mixes technology and software to improve it. Good professional communication requires skilled employee and technologies for more effectively transfer of information in the business world. Effectively done this process leads to better understanding and it can improve relationships at work by improving problem-solving.

Wasting time in communication is a waste of money in today's society. Properly done the communication in the company passes the information along, then people have a better

understanding and all it gets across without being misunderstood. Efficient communication leads to peaceful atmosphere. Most problems are caused by people, which are not communicating effectively and cannot negotiate with each other. (Dr. Shipra Agarwal, Mr. Ashish Garg, 2012)

Broken Phone-Chinese whispers

Broken phone or Chinese Whispers is a study game. The main task is to pass a whispered message around a circle in the expectation that, in the telling, it will become comically distorted or exaggerated by the time it completes the circuit. In different countries, it goes by different names, which are often variations on the idea of a broken telephone. In English, Chinese Whispers has become an idiomatic expression describing how an information passed from person to person will change few times in unpredictable ways. (Thomas, 2013, p. 33)

Therefore in case the end user requirements are not stated properly, the CEO might understand completely different things, which later will lead to unsatisfying results. One more time appears the need of having a standard way of collecting, managing and communicating CR so to be sure everyone understands them correctly. Improving this task would later avoid misunderstanding, miscommunication, and disappointment.

4.5 Requirements to Digital Construction

Based on the analysis above it is clear that the number of users leads to increase in the number of client requirements, which are different for different projects, therefore not all of them can be met. There are strict requirements to the use of Digital Construction (see 12.4 Appendix 4 – Requirements for Digital Construction).

According to the stated requirements in connection to Digital Construction, all digital projects should be hand in a structured and classified way, including naming, codes and identified uniform with same digital level. There is also a demand for the amount of information. During the design phase, there are demands for the model's preparation and for the ones responsible for the models. Last but not least there is the need for coordination of simulation, collision control, use of quantities, drawing material and specifications. (Pedersen, 2016)

Digital Construction is used by the Danish government, which requires public building owners to make a number of demands related to Information and Communication Technology (ICT). These demands ensure improvement in the information sharing between project participants. Digital construction is a system for digital communication and digital archive of all relevant information. It is used throughout the whole process while using building models. (Pedersen, 2016)

The used of Building Information Modeling is required when the client is the state and the estimated project sum is over 5mil dkk and in the cases when the client is a municipality or region and the project sum is over 20mil dkk. In both of the cases, the client has an advantage from today's Information and communication technology (ICT), so to provide better information to the future users.

ICT is useable by 3D-oriented modeling of the buildings and surrounding terrain, also in connection with supervision and planning activities, administrative task and information sorting. Before the project starts the owner's demands to use ICT tools in order to support work process. ICT tools are used for preparing both proposals and documentation of agreed solutions.

The design of the building is made by the use of modeling programs, visualization and simulation tools. The client is using visualization and digital models to deliver the visual expression of the project, planned progress and the potential use of the building in relation to the building stakeholders.

Digital process data can be accumulated, processed, copied, re-used and retrieved on the basis of a selection criterion. During this process, the architects, engineers, contractors and suppliers contribute to the establishment of the amount of data that constitutes the construction project. Relevant data can be used for calculations, specification, ordering or planning.

After giving a detailed information about the information exchange between all project participants during the design phase and analyzing the importance of proper communication between them, it is time to continue the researches. The problem with meeting CR is to be further investigated and a problem statement is to be created with the use of Logical Framework Approach.

5 Problem formulation

The following chapter contains analyses for the above-mentioned issues with the use of different methodologies and scientific literature. This step is needed in order to identify and understand possible problems in connection to meeting CR. Successfully done all these analyses could lead to narrowing down the problem and defining the thesis problem formulation. In order to reach this point a summary of the finding until now is mandatory.

5.1 Summary

Every building project is facing different issues through different stages. Depending on the situation some of them can be avoided but some cannot. In order to point these problems, more analyses are required.

Starting with reviewing a scientific literature and going deeply into real life example, it is possible to figure out important factors and point different problems. Chapter 4 Problem analyses leads to the conclusion that the communication and the new technology are affecting a lot the construction industry and the success of the building projects. Consultants/ designers and clients do not have control over the development of technology, therefore they have to learn new tools and be up to date in order to be successful. Meanwhile, the communication is also very influential for the success of a building project. These factors are leading, and it is important to choose proper communication management system that prevents the building process from misunderstanding and miscommunication.

The higher rivalry in the construction industry is something that consultants/designers cannot fully control but, they can get over it by providing better quality and meeting CR while taking advantage of different opportunities, such as BIM (Building Information Management). This suggestion is based on the fact that clients are not receiving what they have demand and often the final product is much different than their expectations. Meanwhile the success of the building project highly dependents on different parties' performance.

Most consultants/ designers are able to deliver the same quality and service, but not all of them can meet CR. I have tried to find the reasons to why client demands are not met, and what this could lead to. The following analyses are done with the use of LFA approach.

5.2 Problem and objective tree

In the following pages, the problem with meeting CR is analyzed with the use of a Problem and Objective tree. These tools are part of the Logical Framework Approach (LFA). The purpose of the problem tree is to analyze the causes and the effects and to identify the problem statement in connection to ***'Final product does not meet client requirements, due to the fact that not all of the involved parties are familiar with these requirements'***. Meanwhile, the objective tree is used to show possible positive results and desired long-term objectives. With the used of the causes analyzed it is easier to point suitable actions and solutions for the main problem. Meanwhile, without analyzing the effects, it is hard to see the need for finding and implementing an adequate solution (Örtengren, 2004, p. 9)

5.2.1 Problem tree

The Problem tree (see fig.8) is part of the analyses. It gives a clear idea of the effects and the causes of the problem and the way they are related. It is created using the information gathered from the findings until now, scientific literature, and interviews. (Örtengren, 2004)

Effects

Results different from the stated CR – Often final results are different from the client expectations. Paying for something different from the expectations leads to disappointment. This on the other hand results in **'Lower client satisfaction'**. Customer satisfaction is important because it provides business owners with a metric that can be used to manage and improve their businesses. (Beard, 2013) When clients are not satisfied with the product they receive they provide a **'Negative feedback'**. The construction industry has a high number of competitors, therefore, the negative feedback and **'Bad reputation'** could result in **'Losing potential clients'**. Meanwhile, often companies are trying to compensate and fix possible defects, so to avoid this negative feedback. Fixing possible problems and compensating clients, most of the time leads the designers to **'Increase costs'**. All the mentioned above results could be crucial for the consultants/ designers and would lead to **'Decreased profit'**.

Causes

Based on the interview with the new AAU building client representative (see 12.2 Appendix 2 – Meeting with client representative #1) and according to (Kiviniemi, 2005), parties do not make a distinction between direct and indirect requirements. The connection between direct and indirect requirements is important and meanwhile very difficult and complicated to be defined.

Example for Direct and Indirect requirements is a Room. This room has requirements for area, temperature and sound insulation. All these requirements are linked to the room itself, this is why they are direct. Direct requirements often lead to indirect requirements. For example, direct requirements are connected to space and materials, while the indirect ones can be walls, windows, doors. The indirect requirements can be in connection to sound or thermal insulation. They can be difficult to notice or remember because the detailed design related to them usually occurs later in the process and is often done by people who are not involved in the early stages when main decisions are made. Meanwhile, the design documentation does not include requirements documentation or relationship between them. (Kiviniemi, 2005, p. 7)

Even though the area requirements affect the space object itself directly, the other requirements affect the conditions in the room indirectly. What I mean is that the requirement about the sound insulation affects the bounding elements, such as walls and doors. Temperature requirement affects the HVAC (heating, ventilation, and air conditioning) system. It also depends on the design solution, which can also affect the bounding elements. (Kiviniemi, 2005, p. 65) Therefore it is very important both client and consultant to have a clear idea how indirect requirements can change the project scope, and to what decisions these changes are leading. Successfully implemented this step would eliminate misunderstanding and disappointment. The consultants and the client need to understand how direct requirements can transfer into indirect requirements and the other way around because the indirect requirements could lead to significant changes in the direct requirements.

During my work, it becomes clear that most of the consultant companies, as well as the clients, are not aware of the Building Information Management potential as a communication tool. Not all project participants are aware of its advantages, therefore investment in this improvements are not

proceeding. This lack of information does not allow improvement in communication. Therefore, an investment in workers improving education, competencies and the quality of their work is required. The core values of every party in the building process are quality and customer satisfaction and this improvement is always beneficial.

Difficult to find client requirements – Insufficient use of Building Information Management tools leads to the problem with finding CR. This involves an understanding of precisely what the client desires. CR should be processed due to the client expectations, project requirements and the need for collaboration between different project parties. Without proper management system, it is very difficult to find and point CR when decisions are taken, which leads to the next cause.

New project participants are not familiar with stated CR – Building project is a complex process which involves different professionals to cooperate. No matter what type of contract is used still different parties are involved such as members, consultants, contractors and sub-contractors, working on the project during different stages. Some are involved in the very beginning but some of them are included later in the project. Due to this movement of participants through the whole process, it is very important each of them to be aware of the CR and be able to access them without interrupting the ongoing work. Keeping different project participants uninformed the next causes are likely to appear. Essentially, the root causes leading to the insufficient use of Building Information Management is resulting in difficulties in finding client requirements and therefore the new participants cannot track them.

Different understandings and miscommunication - Misunderstanding, miscommunication and the inability to transfer information and CR to all levels in the organization, are all weaknesses which lead to the inability to agree on the common goal. Dale Carnegie, the author of "How to Make Friends and Influence People," said that "90% of all management problems are caused by miscommunication.

Lack of sufficient communication and wrong decision taking - Information sharing between project actors in the design process is limited and this creates miscommunication within the design team, which on the other hand interrupt them to achieve their project objectives. Tools do not support documentation of the reasons behind the design solutions, which results in wrong decision taking and design can shift away from the original goal.

Root causes

At the bottom of the problem tree (see fig.8) are placed the root causes **'Unawareness of BIM (Building Information Management) potential'** and **'No Standardization/system for collecting and delivering CR'**. They are both somehow co-related by the leading causes and resulting to the main problem. Both root causes are the reason for the listed above causes, therefore their improvement should be considered. Every building process needs to have a proper system in the first place in order to make sure that CR are managed and communicated properly. This conclusion is backed up by the interview with the client representative (see 12.2 Appendix 2 – Meeting with client representative #1) and by scientific literature (Kiviniemi, 2005).

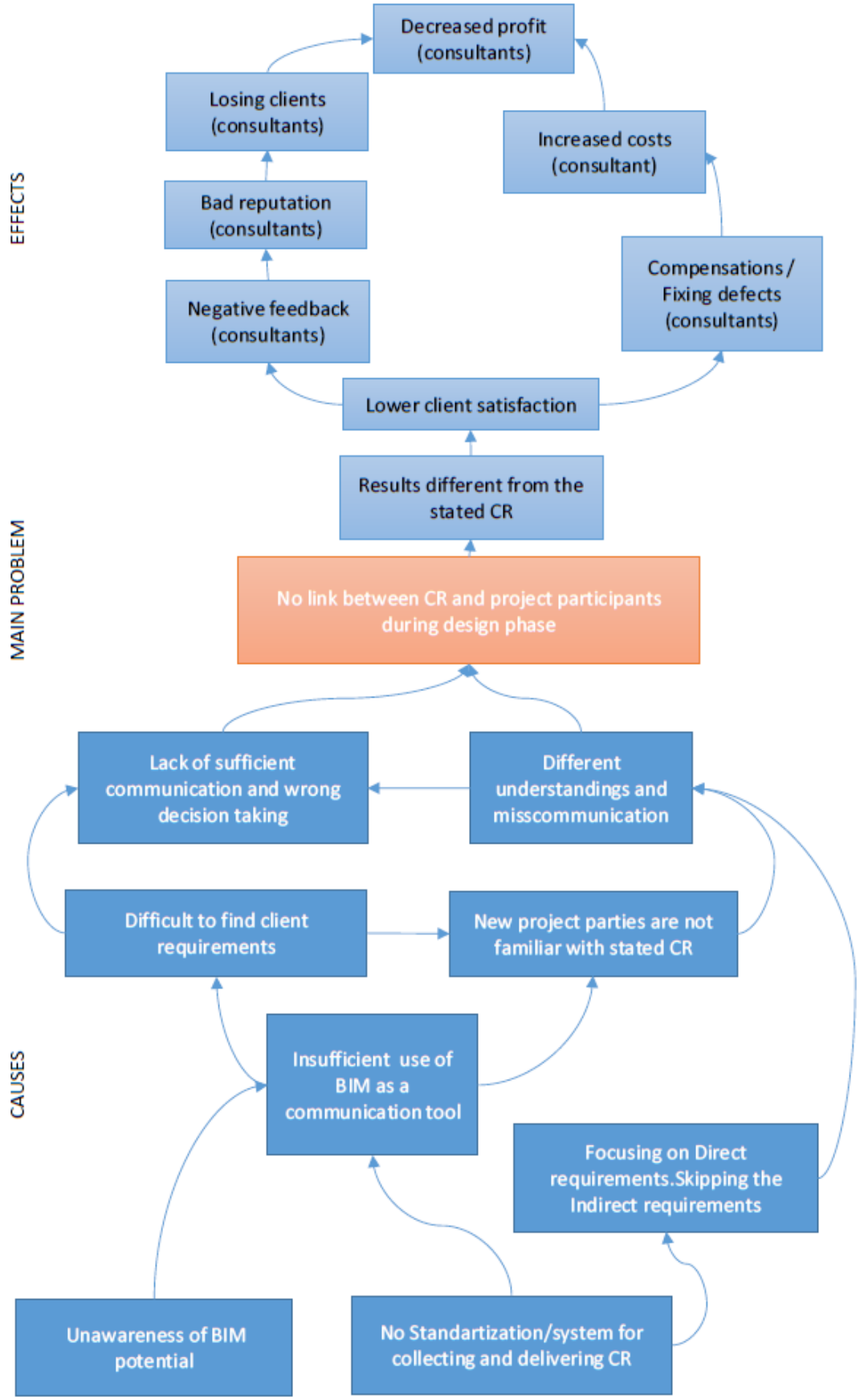

Figure 8 Problem tree

Main problem

The main problem **'No link between CR and project participants during design phase'** is presented in the middle of the problem tree, above are placed the effects of the problem and below are placed the causes and root causes. All listed elements should be used to support the communication and meet CR. What actually the result is that unawareness of the project participants indicates no link between CR and involved parties. On top of the focal problem are placed the effects it leads to. Some of them can be noticed right away, and others are long-term expected effects, in case no action is taken.

5.2.2 Objective tree

After successfully made 'Problem tree', the next step from the LFA is the objective tree including an objective analysis. An objective tree is a methodological approach for highlighting the desired outcomes by solving the problems. The objective tree contains three levels which are: Overall objectives, Project purpose, and Results. It is the opposite of the problem tree, where the negatives are turned into positives, effects are turned into development objectives, the main problem is turned into a project purpose and the causes are turned into output results (see fig. 9).

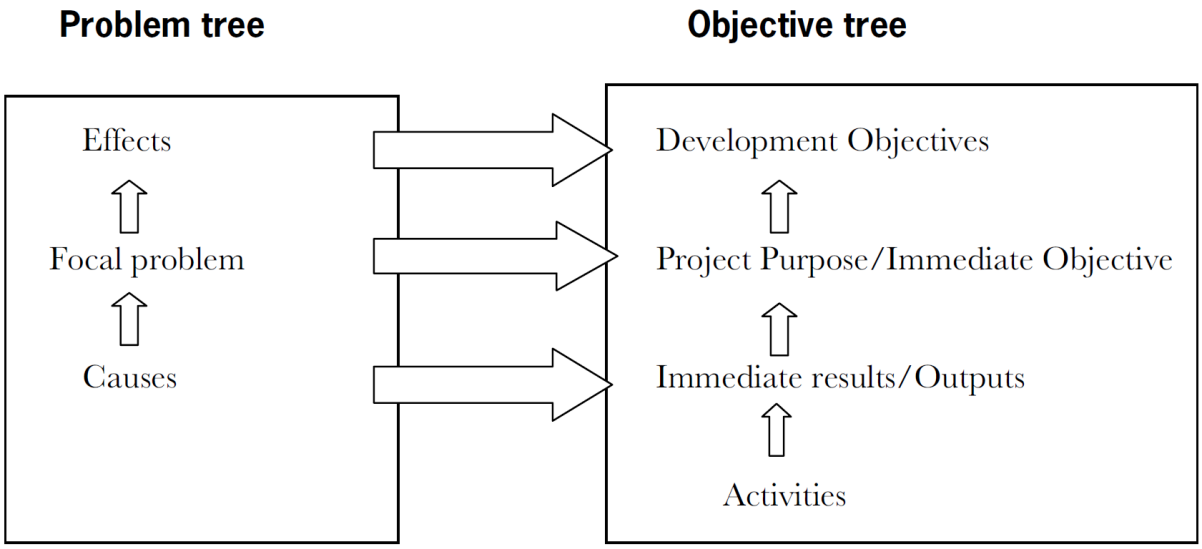

Figure 9 Relationship between the problem analysis and the objective analysis (Örtengren, 2004)

Creating an objective tree leads to deeply understanding the main problem, by finding solutions for turning the problems into desired goals. The objective tree includes an extra layer called Activities. These are the actions needed in order to turn the problems from the problem tree into desired outcomes in the objective tree. Activities in the following report are presented in the Chapter solutions and Implementations. (Örtengren, 2004)

The objective tree ensures that all the analyzed problems from the problem tree are considered. This approach is advantageous because all possible objectives and results are considered and the probability of skipping an important one is reduced. Meanwhile, it provides better overview and understanding of the problems and their solutions. After identifying the main problem and analyzing its causes and effects, the objective tree is created (see fig.10). Due to the analyses in the problem tree, the main problem is **'No link between CR and project participants during design phase'**. This problem can be solved by solving the root causes, which would lead to achieving the overall objectives.

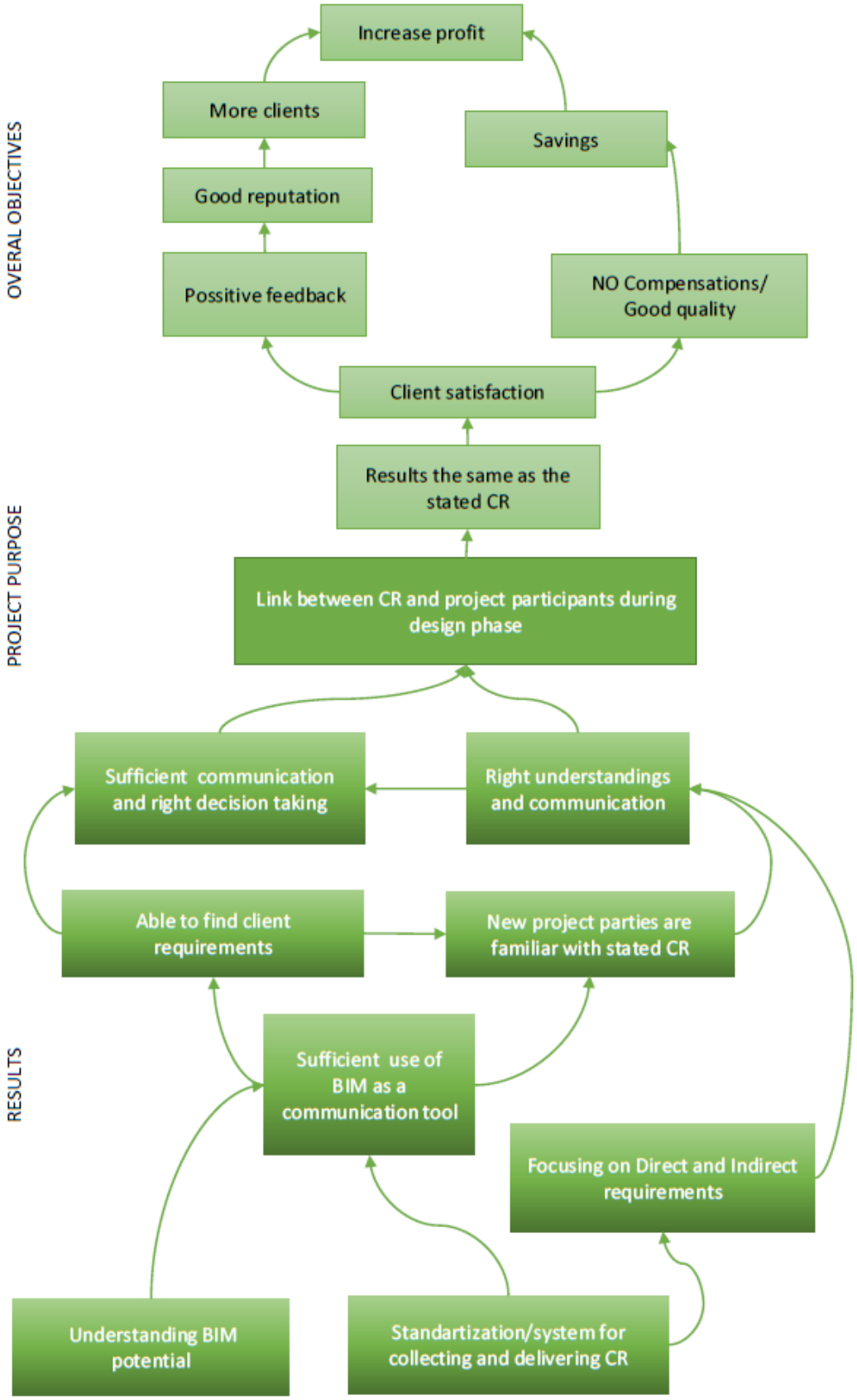

Figure 10 Objective tree

In order to be created a **'Link between CR and project participants during design phase'** points the need of **'Understanding BIM (Building Information Management) potential'** and creating or investing in **'Standardization/system for collecting and delivering CR'**. Successfully achieved both of these results would lead to further improvements. Parties involved in the building project will be aware of Building Information Modeling benefits and advantages as a communication tool and will be able to choose the most suitable one for the project they are working on. This on the other side will allow all project parties to have an easy access to the CR and stick to them through the whole process. Meanwhile, all the parties will be updated and will not lose time in finding this information.

On the other site investment in **'Standardization/system for collecting and delivering CR',** both client and the consultant would be aware of the difference between direct and indirect requirements, which mentioned earlier in chapter 5.2.1 Problem tree cause problems during the design phase and later during the construction.

All the mentioned above improvements will result in sufficient communication, understanding and right decision taking, which were some of the reasons for understanding, managing and meeting CR. Meanwhile, the following results would increase the possibility to create a **'Link between CR and project participants during design phase'** and achieve this leads to achievement of the objectives shown in fig.10 above and mainly the **'Results the same as the stated CR'** and what every organisation wants to achieve - **'Client satisfaction'** and all the others overall objectives shown in fig.10.

5.2.3 Stakeholder Analysis (Problem-Oriented)

Every building project is a complex process that takes a lot of time. In order for it to be successful, an interaction is required between municipality as authority, the citizens, and the owner. It is important to identify different stakeholders and understand their expectations. Stakeholders for building projects are the groups of individuals who are involved in the project and its outcome. Good communication in the early stages of the project is required to identify stakeholders' different demands and requirements. (John Nicolas, Herman Styen, 2012, pp. 63 - 91)

As part of the stakeholders' analysis is the stakeholder's matrix (see fig. 11). Stakeholder analysis is used to show the relation between a project and interest parties. These relationships have an impact which can be positive or negative on the project. This is where stakeholders are placed according to two variables: power and interest, in this case, in fixing the problem. This matrix provides a clear understanding of all the stakeholders and how best to engage them. This stakeholder analysis is useful for better understanding the relationships between the involved parties and what power do they have to solve the problem with meeting CR. (Newcombe, 2003)

After carefully analyzing the problem from the problem tree **'No link between CR and project participants during design phase'**, and the desired overall objectives with improving the work environment, I am focusing on the parties that are interested in solving the main problem. Stakeholders who have high interest and high power are highly important for the success of the building project. It is necessary to ensure an effective coalition of support with these stakeholders and provide them with the information that action is needed.

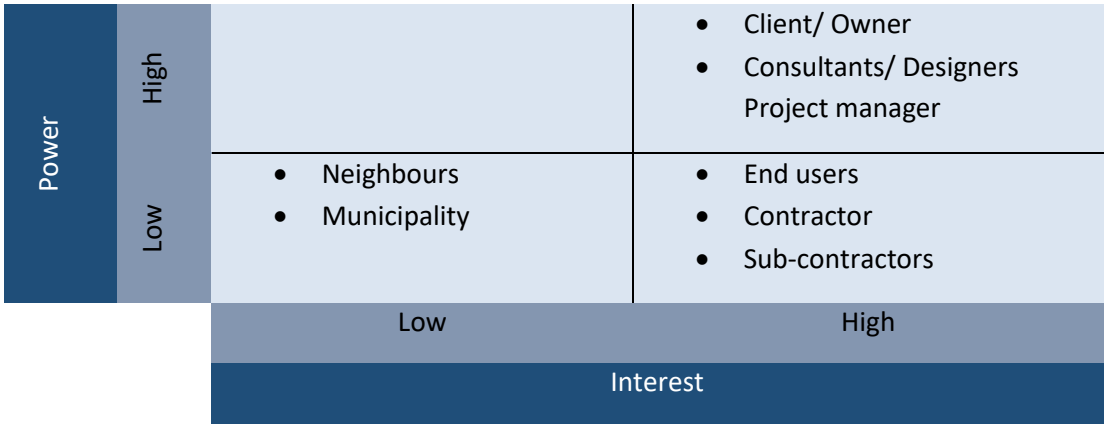

Figure 11 Problem-oriented stakeholder matrix

Stakeholders with **high power and high interest**:

- Client/Owner – It depends on the client if he is willing to invest in communication management tools that are going to collect and communicate the CR. Meanwhile, he is very interesting to receive a product that meets his expectations.
- Consultants/ Designers/ Project manager – they are interested in giving adequate advice for solving the problem and they are interested their advice to be followed. They want to provide the client with satisfying results and receive high client satisfaction

Stakeholders with **low power and high interest**:

- End users – they have high interest in the problem with meeting CR to be resolved but meanwhile they do not have the power to fix this.
- Subcontractors – they are the parties that are very interested in meeting CR and be able to have an access to them, meanwhile, this also depends on the designers/ consultants if they provide them with proper and relevant information

Stakeholders with **high power and low interest**:

- It does not make sense to exist a party having high power of fixing the problem, but meanwhile low interest

Stakeholders with **low power and low interest**:

- Municipality – it has low power and low interest in fixing the problem. They are only interested in solving the problem to the extent that it would not cause any harm to the surrounding environment. In addition, they have very low power because they have a limited ability to interfere and affect the overall project processes.
- Neighbors – they have low power and low interest in fixing the problem with meeting CR as long as it does not disturb them.

5.3 Problem statement

I have analyzed the current situation of the building projects in connection with client satisfaction and meeting client demands. As discussed earlier in this chapter the main problem identified is **'No link between CR and project participants during the design phase'**.

I want to answer the question why meeting CR is important for the consultants/ designers and the client, and how they could benefit from this. Furthermore, I want to propose a solution that would help to solve this issue and increase the client satisfaction.

As I have analyzed above, most of the public projects are having problems with meeting CR and the participants seem not aware of the possibilities that Building Information Management would bring to improve the communication. A proper management tool would facilitate the design process and bring positive results at the end. In case project participants do not implement one they would miss out on a number of benefits, the most significant ones are more clients and increase the profit. Proper management system would gather and communicate these CR while strengthening the relationship between client and consultant. This will increase client satisfaction and the advisory would process their work properly by providing the contractors with the right information. Furthermore, improvement in the communication would allow:

- clients to be aware why different changes are needed,
- consultants would be able to prioritize the demands correctly
- all the involved parties would track different changes and client demands
- consultants would provide the contractors with credible information
- the client would receive what he pays for

Without implementing communication management system, projects would not be successful and this could increase the costs for both the client and the consultant. Therefore, it is important for a building project to go along with by proper requirement management system. The rest of the master thesis will be based on the following problem formulation:

How a link between client requirements (CR) and project participants in the design phase can be accomplished?

The following questions are to be used to answer the problem formulation:

- What benefits can proper requirement management system bring to the client and involved parties?
- Which recommendations can be made to improve the information sharing in building projects?
- What tools and approaches can be used to support the exchange of information during the design phase?
- How would Building Information Management support the design phase and the process of meeting CR?
- How would Building Commissioning support a design phase and the process of meeting CR, and is it a proper solution for every building project?

Coming up with the main problem statement and providing research questions, create a stable base for further analyses. The following chapter is actually one of the most valuable ones since it includes possible solutions for reaching the desired objectives listed in chapter 5.2.2 Objective tree.

6 Main analyses

The following chapter discusses the role and the use of BIM during the design phases. It starts with an explanation about the needs of different design phases and after that, a review and analyses of BIM advantages and benefits are given. This chapter provides a suggestion for an evaluation system for different BIM tools and a new approach in connection to meeting CR is presented and analyzed.

Different Building Information Management tools and integrations are also analyzed in connection to design phase. Building project parties do not understand the full potential of Building Information Management and the potential value it can bring in practice by sharing information within the organization. Building Information Management enables successful information sharing between consultants, architect, engineers, manager, and subcontractors. It provides expert construction knowledge to the design team and generates constructability reports, coordinate, plan, schedule and cost estimate. Building Information Management enables integrated project delivery and encourages teams to collaborate effectively, reduce project time and cost.

6.1 BIM overview

BIM has different meanings and the two often used terms are Building Information Modeling and Building Information Management. Building Information Modeling is a new technology that allows relevant graphical and topical information related to the built environment to be stored in a relational database for access and management. On the other hand, Building Information Management consists of collection, organization, analysis, and distribution of attributed data contained within a building project. (Weygant, 2011, p. vii)

Building Information Management is a new form of collaboration in the architecture, engineering and construction industry (AEC). It is used as a platform that allows different project participants to share knowledge, due to common and updated information. Building Information Management gives new communication opportunities and allows one or more virtual models to be constructed digitally. In practice, instead of having several documentations containing architectural design, landscape, construction and installation design, all of these is on one 3D model including all this information. (Ireneusz Czmocha, Adam Pekala, 2014, p. 212)

Building Information Management intents, the integration of all phases of the building process, by integration and promotion of collaborative work by all designers involved in the design phase. The great potential of Building Information Management is also the standardization of information being supported among others. This is reached by standardization of methods to perform the design process, which is one of the issues mentioned in the problem tree (chapter 5.2.1 Problem tree) Due to this fact, the potential of improvements in preparation, coordination, revision and management of design documents of the building project might be valuable. (Lino Maia, Pedro Mêda, João G. Freitas, 2015)

BIM supports all design phases with the used of simulation options, clash detection, and quality assurance. BIM provides better, valid and correct information by digital tools and modeling programs. Building Information Management also facilitates more integrated design and construction process that results in a building with better quality, lower cost, and reduced project duration. (Chuck Eastman, Paul Teicholz, Rafael Sacks, Kathleen Liston, 2011, p. 1)

BIM models are changing the conceptual phase of the design. Analysis of the concept design and trials to find out structural design suitable for architect ideas is time-consuming and expensive when using traditional design methods. Each concept phase is examined and manually calculated with the help of simplified methods. Building Information Management simplifies the collaboration between the consultants, architects, and structural engineers. Each 3D model prepared by an architect can be easily and quickly converted to the analytical model that the engineer can use in the structural analysis. Furthermore, the architect can easily check up the cost for each conceptual design already approved by the structural designer. (Ireneusz Czmocha, Adam Pekala, 2014, p. 213)

6.1.1 Different from traditional 2D-3D CAD design method

Designer's work has changed over the last yeas dramatically, from using only sheets of paper to the use of CAD systems. (Ireneusz Czmocha, Adam Pekala, 2014, p. 211) The design of a building is a task for a large team, which consists of architects, constructors, engineers, project managers and so on. Each of them uses 2D drawings of designed building. Architects are the ones using sketches and the engineers are using plans and detailed drawings. During the classical method of design each of the specialists works on separate industry drawings with only those elements for which they are responsible.

The traditional 2D design method is focusing on own products and it is based on paper communication. All the used data is completed separately from the project, so there is no intelligent connection between the documents. Another limitation is the minimum connection between the project phases which increases the possibility of mistakes, delays, and higher costs. One of the biggest problems with 2D-based communication during the design phase is the estimated time and expense required to generate critical assessment information about the proposed design. Most of the time cost estimations, energy analysis, and structural details are made last when it is already too late to made important changes and often leads to compromises from the original design. (Chuck Eastman, Paul Teicholz, Rafael Sacks, Kathleen Liston, 2011, p. 2)

Comparing 2D-3D design with Building Information Management, the reader can understand the big difference between them. BIM is more than a drawing and communication tool. It is a data storage for building design, construction, and maintenance, and every participant has access to. All these is combined in one model which is shared with all the stakeholders. Building Information Management-based design can be effectively implemented during the design phase by experienced designers, meanwhile leading to simplification of many tasks, which saves both money and time. However, the successful implementation of this technology requires skillful design team who acts exactly in accordance with BIM system procedures.

Building Information Management is a set of processes to produce, communicate and analyze building models. These building models are characterized by (Chuck Eastman, Paul Teicholz, Rafael Sacks, Kathleen Liston, 2011):

- Building components that are represented with intelligent digital representations that 'know' what they are and can be associated with computable graphic and data attributes and parametric rules.
- Components that include data that describe how they behave, as needed for analyses and work processes, e.g. takeoff, specification and energy analysis.

6.1.2 BIM supports design stage

As mentioned above Building Information Management has lots of advantages. It is important for the reader to understand how Building Information Management supports the design stage, and what benefits it can bring to this particular part of the building project and to the project parties.

The use of Building Information Management during the design phase can maximize its impact on the project since it has the ability to influence cost. It allows the team to give ideas and solutions before actual problems cause higher costs. This is achieved through the cooperation and coordination of all parties involved in the project. This is why good communication and collaboration are very important parts between project participants. The architect and engineer can test their design ideas including energy analysis. The construction manager can provide constructability, value, and engineering reports. They can also start 3D coordination between subcontractors and vendors during early design stages. The client can see if the design is what he is looking for and if it meets his requirements. (Hergunsel, 2011, p. 13) Meanwhile, the consultants/ designers could use BIM models to extract quantities of work, so to be able to make cost estimates. The BIM model can create 3D rendering, animations, analysis, and preparation of logistic plans. The consultants can constantly update time schedule and costs. Building Information Management has many uses suitable for each party involved in the project. (Hergunsel, 2011)

Visualization

BIM model programs are great visualization tools, due to the fact that they provide a 3D representation of the project. Designers can provide renderings, walkthroughs, and sequencing of the model. Mainly the visualization provides a better understanding of what the final product would be like, which leads to right decisions on the aesthetics and the functionality of the spaces. It helps also to improve the communication and collaboration between project parties. Virtual models are cost efficient in comparison with the physical ones. (Hergunsel, 2011, p. 14)

3D coordination

Good idea is to start the collaboration between the consultants, designers, and the client in the beginning of the design phase when Building Information Management is also implemented. In case the designers provide only 2D drawings, then the engineers and managers have to convert these 2D drawings into the 3D intelligent model. 3D coordination should start after the BIM model is created, so to assure all conflicts in the model are fixed. This type of coordination helps the design mistakes to be reduced and to understand wat has to be done. (Hergunsel, 2011, pp. 14-15)

Cost estimation

Cost estimation contains quantity take-off and pricing. Quantities from the BIM model are extracted to a cost database or an excel file. Cost estimation requires the expertise to analyze the components of a material and how they are going to be installed. If the pricing for a certain activity is not available in the database, it is required a further breakdown of the element for more accurate pricing. The unit labor cost is driven by the mobilization and installation durations, and the labor wage. Meanwhile, the unit material cost is the sum of the material costs used for the activity per unit. Once the unit price is attained, the cost of the entire activity can be achieved by multiplication of the total quantity extracted from the BIM model and unit price. In the BIM model, it is significantly important designers to agree on component definitions. Overall, the Building Information Management optimize the productivity of the estimators through quantity extraction from the model especially if the project parties work collaboratively. (Hergunsel, 2011, p. 22)

Quality assurance

Design quality is important for every client. It depends on the designers as well as on defining and delivering the project for the client to receive the desired product. The client has to develop own expectations and aims for the project, which should be tested against the design throughout the process. Comparison with completed project and successful practices helps to improve processes and targets.

There are different tools used during the building process to inspect the current stage of the design process, and one of them is Autodesk Design Review. It is all digital and gives the possibility to view, mark up, print, and track changes to 2D and 3D files without having the original software. All the data is safe since the file cannot be changed and it is a great opportunity for marking up and red-lining. This leads each party to have an access to the project design by giving comments and feedback. Meanwhile, users can "track the changes" through several versions of the model. (Holmberg, 2014)

Furthermore, a client, who does not have knowledge of Revit or similar software, can use Design Review tools to follow the project, measure, comment and look at it. The DWF files are exported from Revit and all of its versions by going to the application menu. Markup tool and Callouts are advantages since they can be assigned to the DWF-file in the exchange between the different parties in the project. Earlier this method of information exchange was plotting the drawing and do the markups by hand. Afterward, the markups and callouts have to be uploaded to the digital drawing, which provided a time-consuming process with a high risk of errors, omission, and misunderstandings. Stamps are also very useful because it is a text markup that can be used to assign a sheet. This stamp can tell the reader about the status of the design phase if it is approved or rejected. These stamps cannot be deleted but it is possible to create own so they fit better for the exact building project and stage. (Holmberg, 2014)

Design Web Format (DWF) is a secure file format for efficient distribution and communication of rich design data to anyone who needs to view, review or print the files. Due to the fact that DWF files are highly compressed, they are smaller and times faster to exchange than design files. (Holmberg, 2014)

As mentioned earlier in chapter 4.4 the communication between project participants is significant for the project success. During the design phases, Building Information Management helps to link the functional components of the design so that the architect and client can easily communicate by reducing the number of paper works. This enables easily switching, navigating, and customizing the whole database by a single component. (Tessema, 2006)

When changes in the design are made, the changes are automatically updated in the entire set of drawings. Building Information Management improves design communication between architects and their clients because it deals with understanding the information associated with the cost, function, and aesthetics of a building. (Tessema, 2006)

Using Building Information Management, the proposed design solutions can be measured against the client's requirements and expected building performance. The functionalities of Building Information Management to support the design process by three-dimensional visualization and detailing, clash detection, material schedule, planning, cost estimate, production and logistic information, and as-built documents.

Building Information Management goal is to digitalize the entire project life cycle, starting from design phase to operation and maintenance phase. Clients also have demand when using BIM and according to (Lidegaard, 2013), they are in connection with the use of a proper construction classification for the exact project. The client has requirements about the use of Project web, Digital building model in 3D and requirements for digital handing over of the project including operation, maintenance, and management information.

6.1.3 Implementation challenges

Even though Building Information Modeling has lots of advantages, there are also some limitations. (InfoComm, 2011, p. 11) BIM has the ability to improve the communication and coordination between all the parties of a building project and its benefits are covering the range from simple improvements in effectiveness and coordination to greater client satisfaction. Despite all of the mentioned above advantages, the client should know that there are some considerations and current limitations that must be taken into account when implementing Building Information Modeling. Under are listed some disadvantages inspired by (InfoComm, 2011, p. 12).

Cost of Software and Hardware

There are costs of purchasing, maintaining and upgrading software licenses. The cost of BIM software is higher than CAD software. With the introduction of BIM software, the requirements on hardware have increased significantly. BIM software implementation requires computers with high-specification, due to the advanced modeling and rendering software. When starting the use of BIM software, it is essential to know exactly what parameters of the hardware improve the performance and what elements have no effect at all.

Cost of Training

Any time when implementing new software, it is needed an employee's training quickly so that the investment can be justified. It is important to remember that professionals cannot learn new BIM software so quickly without any specialized training. Building Information Management allows every member of the team to be involved in the design and modeling process, by giving them control over the end product. Investment in training for early adoption provides the participants a competitive advantage with projects that have clearly specified requirements to be documented utilizing Building Information Management.

Switching from Drafting to Modeling

When shifting from a CAD usage to a BIM software, a change in the workflow will happen. BIM software requires a higher-level skilled design drafter who understands the project and the used materials. Some companies may even be compelled to stay out of the Building Information Management world due to the time- and knowledge-intensive nature. Shifting from traditional CAD places an increased level of responsibility on the designer to ensure that all system components are coordinated with others design professionals such as architecture and engineering services and the site issues are reduced to a minimum. In any case, Building Information Management allows coordinated delivery earlier in the design process so that double supervision or redesign are avoided.

Compatibility Between Software Platforms

One of the biggest problems with early adaptors of Building Information Management is the inter-product compatibility. Every software manufacturer is doing something different with its software, so this interoperability challenge can make it difficult for projects to function if different team members own different software packages. This interoperability issue is due to BIM software development, where newer versions of programs within the same platform can have interoperability issues. One alternative is the Industry Foundation Classes (IFC) format which captures both geometry and properties of intelligent building objects and their relationships within BIM, thus facilitating the sharing of information across otherwise incompatible applications.

Innovation

The goal of Building Information Management is to assign constraints and parameters to intelligent objects to improve efficiency, therefore there is a potential to inhibit innovation which would possibly otherwise occur without the automated processes and shared knowledge that it provides. Those firms implementing Building Information Management should view the parameters and metadata constraints as a global database that allows designers to save time associated with updating and configuring product-specific data repetitively on different projects, hence increasing the amount of time spent on system design and innovation.

When Building Information Management is adopted for the first time, the users could feel a negative impact on their profitability due to the investment in new technology and the need of knowledge improvement. (Hergunsel, 2011) Some of the users may not feel changes in project profitability, which limits the Building Information Management use only to make design and visualization. Constantly use of BIM would lead to gain more benefits and the users would notice an increase in their profits. The majority of the users indicates that the use of Building Information Management reduces cost and create the strict project schedule. Overall Building Information Management implementation and its support technologies increase the investments, but meanwhile increases profits, lowers costs and schedule time.

6.1.4 It is not used the full potential of BIM

This master thesis studies different BIM activities such as visualization, 3D coordination and cost estimation. The visualization is the simplest use of a BIM and most of the designers use it for renderings and as build models. When the model is made, quality takeoffs can be extracted so to provide cost estimations for the building project. 3D coordination is used to detect and eliminate clashes and conflicts. While 4D scheduling helps to understand the construction components and schedule progress that in turn results in better construction planning. Building Information Management combines collaboration of the office staff on a centric platform.

Most of the clients, consultants, and designers do not understand and realize the full potential of Building Information Management. The top uses of Building Information Management for contractors are clash detection, visualization, and the creation of as-built models. On the fig. 12 below can be seen the industry-wide uses of Building Information Management.

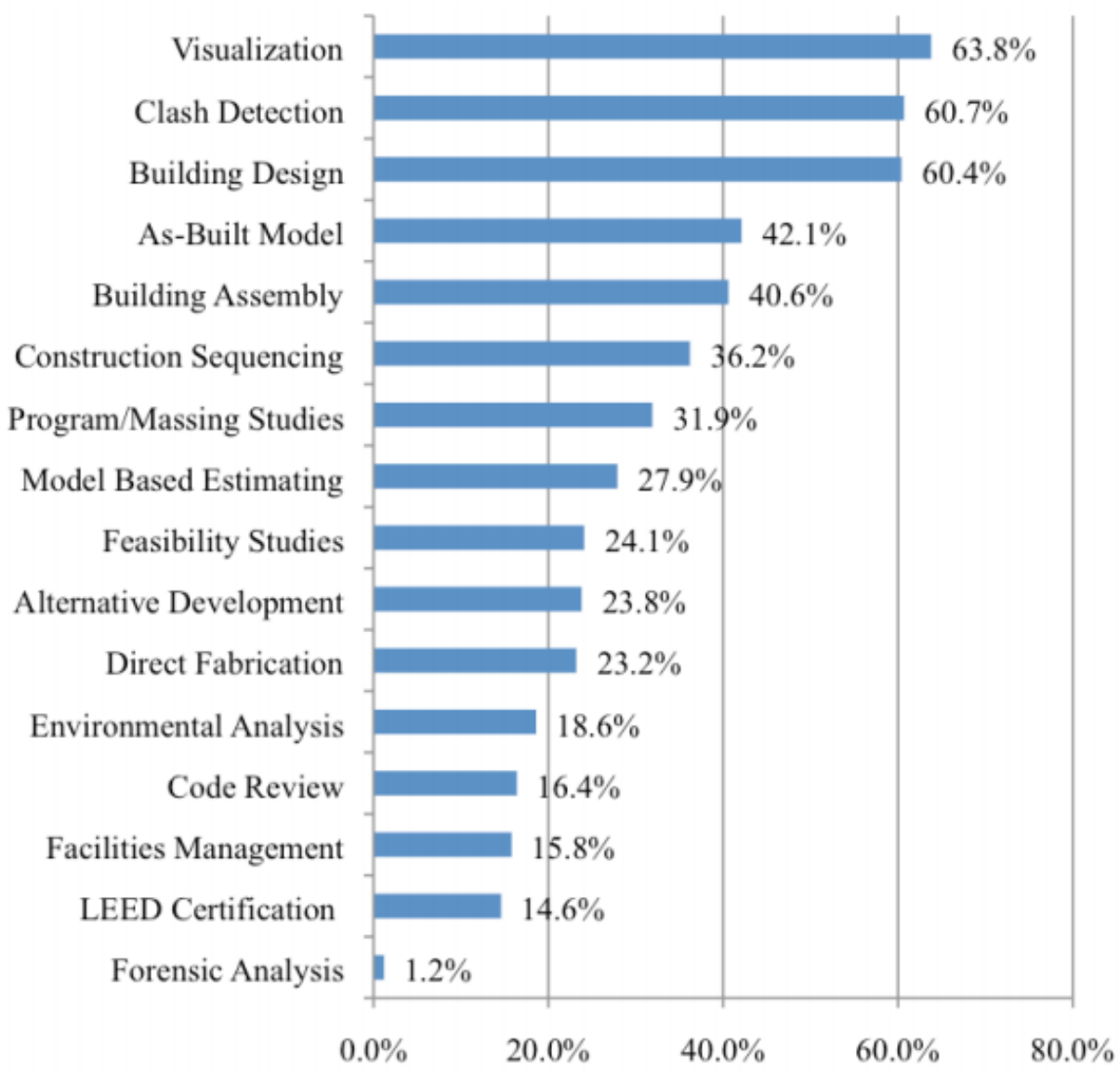

Figure 12 BIM uses (Burcin Becerik-Gerber, Samara Rice, 2010)

As seen in the figure above BIM is used mostly for visualization, clash detection, building design and as-built model. This research improves one more time that different project parties are not aware of all other Building Information Management potentials for information sharing. Therefore the next sub-chapter is mandatory by giving an overview of different Building Information Management tools and their impact on the information exchange between different project participants.

6.2 Needs for each design stage

The following sub-chapter contains a brief description about each of the design building stages, starting from Design brief and finishing with Detail Design II. Each of them includes important tasks to be done in order for the whole process to proceed successfully. The building project has several design processes, in which a constant exchange of information takes place. In each new building project, there are differences in the design team regarding different approaches, design methodologies, and the perspectives taken towards the design task. In order for the design phase of

the project to be successful, the client and the consultants have to comply with requirements for this part of the building project.

The design phase is subdivided into five different stages, each leading to the next one. Working carefully through each of them bring the success of the project and receive an approval from the local authority. One of the main things that define the project's level and extent of the design phase is the form of procurement that is used. Once it is decided the design phase can start. There are different types of procurement used in Denmark (Herforth, 2015):

- Trade by Trade
- Main contractor
- Turnkey contractor

Depending on the form of procurement the design is split into different phases and different parties are having different responsibilities. The following report is concentrated more on BIM, therefore, the focus on the legal aspects is not further investigated. No matter which type of contract is used Building Information Management can be implemented.

The consultants are the ones providing the information necessary for the design and resulting in a good proposal. The best proposal is chosen to be implemented and developed. The well-defined proposal is an important part, therefore, the consultant should spend the time to study the details for mistakes. He has to analyses in detail CR and document them - which will subsequently become "an agreed document" for the rest of the project when it is read and approved by the client. (Muller, 1997, p. 53)

Below are presented few tables related to each of the design stages, including their main goals and requirements.

Design brief

The inception's main goals:	**The main goals for the design brief:**
• The first adaption on the client's thoughts and ideas • Assessments of the idea's realization • Need for rooms • The client's project organization • Drawings related to the plot • Information about the plot • Local authority conditions/ Town planning conditions • Timeframe • Economic frame • Demands for quality • Possible client demands or wishes about the use of information technology (BIPS) • Determination of where a CAD/IT project contract is to be drawn-up	• Adoption of the inception • Client's project organization • Need for room and functional needs • Need for space • Possible rooms description • Layouts needs • Technical installation • Utility support conditions • Operation and maintenance premises and assessment • Possible room and room functions • Time frame for design and construction • Budget frame • Price index and expected regulations • Collection of information about main local authority demands • Quality assurance for design and execution. Demands to be specified

Figure 13 Advice before design process (Jens Mosegaard. Ove Bjerregaard Broch, 2008, p. 21)

Outline proposal

The main goals for the phase:	**Inclusive presentation materials:**
• Situation plan • Floor plans • Cross sections • Elevations • Specifications, proposals for materials • Technical installations- principles • Constructive principles and main systems • Scheduling • Economy estimate inch. building site	• Posters • 3D visualizations • Spatial sketches • Model
Other possible initiatives: • Info. Technology agreement • Use of project web • 3D-model types, possibly Master Model as start for the architect	**Information and communication technology** • Information Level 1 • Initial computer simulations of sound and shadow conditions • Project web

Figure 14 The outline proposal (Jens Mosegaard. Ove Bjerregaard Broch, 2008, p. 27)

Scheme Design

The goals of the phase:	**Inclusive materials for presentation:**
• Situation plan • Plans • Cross sections, main section • Elevations • Furniture plans in principle • Important details	• Posters, placards • 3D visualization • Spatial drawings • Models • Material samples, product samples • Other references, photos
• Description for constructions and materials • Technical installations and their systems' extent, mode of construction and main components and sketches in principle for routing of installations • Main constructions, main principles and estimated calculations of leads • Construction plans and cross sections including typical building components and critical details • Account for works in the terrain • Schedules (Time) • Economy	**Information, communication, and technology:** • Information level 2 • Possible computer simulations indoor climate, lighting, and furnishing • Project web

Figure 15 Scheme design proposal (Jens Mosegaard. Ove Bjerregaard Broch, 2008, p. 33)

Detail Design I

Main drawings: • Situation plan • Plans – story plans • Cross sections and part – sections • Elevations	**Other drawings:** • Important details • Installation drawings, plans and cross-sections and installation specifications • Construction drawings, plans and sections and construction specifications • Documentation for fire safety in. fire plans, in accordance with the Building regulations • Revised schedule • Revised economy
Local authority drawings and specifications: • Main drawings • Documentation for fire safety • Structural information and load-bearing constructions • Information and drawings regarding installations, regarding drainage conditions, statements for the factory inspection, health, and safety for local authority use	

Figure 16 Detail design 1 (Jens Mosegaard. Ove Bjerregaard Broch, 2008, p. 39)

Detail Design II

The main goals of the phase: • Main drawings • Summary drawings • Building component drawings • Detail drawings • Building case specifications • Work and building component specifications • Quality assurance • Constructions • Structural calculations • Water, heat and sanitary installations • Ventilation system • El- installations • Refuse system • Other systems and installations	**Other services:** • Possible supplementary materials for local authority • Supplementary materials for project management • Project follow-up • Set up demands for contractors' delivery of operation and maintenance guidelines • Prepare tender forms • Possible bill of quantities • Health and safety plan

Figure 17 Detail Design 2 (Jens Mosegaard. Ove Bjerregaard Broch, 2008, p. 45)

Having all this information is useful for the project participants since they are going to be aware of the different design phases content and would understand the Building Information Management benefits. Meanwhile, the client is clear about his responsibilities and the information he has to provide.

6.2.1 BIM tools for Design stage and information sharing

In the following subchapter, different BIM tools supporting the design stages and improving the information sharing are analyzed since this is one of the issues mentioned in the problem tree (5.2.1 Problem tree). Most of the clients and consultants do not understand the full potential of Building Information Modeling, therefore an explanation for possible tools is mandatory. Giving possible tools and their properties would provide different project parties with useful information. This information access helps clients and consultants to choose a tool which is more favorable for their purposes and will help them to provide better work. Information systems are accessible to all parties in a constructions project and they improve the efficiency and improve the flow of information within the project participants. (Hergunsel, 2011)

This written project points out the maturity of the necessary IT technology, the availability and the suitability of existing commercial products. Some of these products are analyzed and compared. An evaluation is provided based on the functions offered in the products and their utility is presented. Nowadays there are different Building Information Management tools such as MEP, structural, architectural and site work 3D modeling software. Some of them are providing information such as scheduling and cost estimation. Below are identified some of these products on the market. The client and his consultant should be clear what they want to accomplish with the given tools for a particular project. (Hergunsel, 2011) As mentioned earlier early involvement of all different project participants is important for the successful collaboration. There are different types of BIM tools for:

- 3D Detailed MEP Modeling
- 3D Detailed Structural Modeling
- 3D pipe modeling
- 3D HVAC modeling
- 3D Architectural Modeling and parametric design.
- Site development
- 3D Structural Modeling and parametric design
- 3D conceptual modeling with real-time cost estimating
- 3D fire Sprinkler Design and Modeling
- Fire piping Network Design and Modeling
- 5D modeling which can be used to generate cost and schedule data
- Construction management and scheduling tools, that support coordination
- Scheduling tools that support integration

Since the following report is concentrated on the information exchange between client and consultant, different Building Information Management tools supporting the last two points are evaluated. They are compared based on the categories shown in fig. 16 below. The collected typical weighting data and the used performance criteria in the evaluation process are inspired by (Hergunsel, 2011), (Muhammad Tariq Shafiq, Jane Matthews, Stephen R. Lockley, 2013) and all the analyses conducted until now.

Properties	Explanation / Definition
Support data model formats as DXF, IFC, DWG	DWG is the universal format in the AEC industry, used by most of the programs. DXF is similar to DWG but could be bigger. Finally, is the IFC format which is the richest one in connection to information content. (Creach, 2013)
Model synchronization	The model is constantly synchronized, so everything is up to date
User rights	Different parties can work only on the parts they are responsible for
Clash detection	Clash detection is a process that notes project conflicts while examining them until the desired level of coordination is achieved. Clash detection checks models from all disciplines (architectural, structural, mechanical, electrical, etc.) against each other for interference and integrate them into a single 3D model. This allows designers to create a more efficient design. All conflicts are detected in the computer before construction starts which reduce costs. This is used as a quality assurance check for a BIM model. (Wang Guangbin, Lei Wei, Duan Xuru, 2012)
Access to history tracking/ version management	Project participants can access and track the complete history of the project design and information. Version management shows all versions of the file and the current version on top
Model changes	Different users are able to make changes to the central model
Files changes	Different users are able to make changes to the shared documents
Export and import 2D data	The possibility to import/export 2D data into the models, such as drawings, PDFs, Excel, Word files
Enable searching for the model	The possibilities to search and select different project elements for example doors, windows…
Enable searching for the files	The possibilities to search and select different project documents and file names
Model comparison	Give project participants the possibility to compare two models/ different model versions
Notify and communicate changes	Notify and communicate all participants about any changes made in the shared model
Walkthrough and 3D navigation	Users having access to the model can navigate and view components by 3D and walkthrough
Online access, mobile support	The possibilities of different project participants to view and navigate models on mobile devices

Markup and comments	Model users/ project participants can mark up and place comments on the model components
Work reports	The users/ project participants can create time schedule reports including daily/ monthly progress
Multiple project support	The system can open more than one project while storing, saving and handling large data while keeping the data integrated and workable
Information archive	Archive information for longer period of time
Cost management	Implement standardized cost and change management practices. More effectively can be track and forecast budgets for different projects. Custom reporting, flexible designs, workflows, and data exchange with the use of accounting systems provide the capabilities needed to stay on top of costs with a system that is more easily configured to your business needs. Update budgets and cost impacts automatically with workflow activates, and ease monthly payment application reviews with built-in industry-standard calculations.
Document management	Centrally organize, manage, and track all project-related documents, contracts, and information. This helps to keep projects on track. Features such as version control, search capabilities, and file-level discussion help project teams focus on value-added tasks instead of tracking down information.
Design Review	Review of different designs, documents, and information, helping to speed approvals and promote productive collaboration across disciplines. Automatic notifications of design changes and reference file management help keep team members informed and accountable when changes affect their portions of designs.

Figure 18 Properties definition

With the use of the above-mentioned evaluation criteria the following Building Information Management tools are to be evaluated later on. Nowadays the software market is full of different options. Since the following report is focusing on communication and collaboration between client and consultant, this is why I am focusing on different Building Information Management tools providing this task. The following subchapter represents parts of them and their functionality. The listed ones are not the only option. I have used exactly these tools to be evaluated because part of them I am familiar with and I can give an opinion based on my experience and for the rest, I could find more relevant data to be used.

Project Wise (see 12.5.1 Appendix 5.1 – Project Wise)

This is a project information management and collaboration cloud service, which improves the project performance by integrating people, data, and processes during the building project. It provides an easy access through the use of mobile devices. Project participants can synchronize and manage the workflows, and exchange and share all types of work packages. The information for this product is taken from its official website (Bentley, 2016) and (Lawson, 2009). With the use of Project Wise, the project participants can work on the same document at the same time. It automatically

converts data-rich content such as renderings, models, and drawings into formats such as PDF which can be shared between different stakeholders easily. With the use of Project Wise, clients can create, track and manage their submittals and payments with color-coded indicators to keep a progress check. Users can generate the request for information (RFI) and share with the right individual for correct response to solve issues quickly. (GetApp, 2016)

Constructware (see 12.5.2 Appendix 5.2 – Constructware)

Constructware is a project management tool that connects different business operations and information in order to standardize business processes. The software monitors the work by providing communication and visibility throughout the various aspects of a construction project, such as documentation, design, and cost. The XML-based software allows the exchange of data between Constructware and other programs used by the client. This tool has the capabilities of online document collaboration, electronic tracking of file activity, and a client-defined structure with independent security settings, and automatic reference file detection. In addition, it allows users to review projects, examining information such as job costs, change orders, and contract history. (Rouse, 2008)

Constructware is designed to update the project management and design throughout the entire construction, facility and design lifecycle. It provides an on-demand business environment for collaboration and project management in the construction industry that helps in connecting people, processes, and information for completion of projects. This product allows project information to be viewed at any time through a single database and provides specialized tools for file management. It offers message tracking for all the communication in real time to provide more accountability and allows users to centralize purchase orders and manage budgets. It enables users to track missing data, view contract history, manage various change orders and review job costs. (Advice, 2006-2016)

Project Center (see 12.5.3 Appendix 5.3 – Project Center)

Project Center software is a comprehensive way to manage all forms of project information, whether in the office, from the web cloud, or from mobile devices. It strengthens the organization by improvements of collaboration within the entire project team. It includes innovations such as easy web access and continuous connectivity with other companies using this software. (Newforma, 2016, p. 1) Manage project information for more successful project delivery. Versioning makes it easy to restore overwritten files. Provides secure access to the information, including record document revisions, synchronized project folders, and action items. Real-time synchronization between servers and the cloud keeps data consistent. Meanwhile, it increases the return on the investment in the electronic document management system. It shows who is accessing different documents and makes sure the ones involved in the project work with the latest shared files. Capture and record markup sessions for a history of the design review process and electronically compare document versions to identify all changes. Refer to emails and automatically generated audit trails to avoid disputes and support invoices. Review and compare documents on-screen and stamp drawings electronically. (Newforma, 2016, p. 1)

Project Dox (see 12.5.4 Appendix 5.4 – Project Dox)

Project Dox delivers better service by reducing review time, helps accelerate economic growth, and eliminate the inefficiency of paper movement and storage. It accelerates the permitting process, making it fast and easy to submit, review documents and drawings, process corrections, while monitoring and improving the work process. It balances the needs of many stakeholders without losing sight of that primary mission. Project Dox makes it easy for review personnel to work together

with the citizen applicant during the review process. Project Dox is powering economic growth, delivering better constituent service, reducing review cycle times, increasing transparency, and enhancing collaboration. It reviews the workflow for planning and zoning enable effective collaboration and efficient process among stakeholders seeking to achieve a balanced community vision while advancing economic growth.

Project Dox promotes well-designed, functional planning, that combines strategic vision with practical approaches to today's development realities. It enables effective communication and collaboration among stakeholders. This tool provides a framework to exchange and collaborate with project drawings, documents, and other information. It manages internal projects and improves the process through better collaboration and communication tools. Project Dox provides collaboration environment for managing projects, allowing project team members to access all project data and maintain a fully versioned document history. All project data is in one central location, always current with permission access securely controlled for both internal and external team members. (AvolveSoftware, http://www.avolvesoftware.com/projectdox/, 2016)

Doc Set Manager (see 12.5.5 Appendix 5.5 – Doc Set Manager)

Doc Set Manager reduce project risk and improve productivity by quickly scanning and mapping the changes in thousands of design and construction drawings, generating document-based RFIs, and managing their status through resolution. It informs the project parties about the changes and helps them to efficiently identify, understand, and react to drawing changes in a collaborative environment. Doc Set Manager provides one central source for all the project drawings, which enables to compare thousands of drawings within minutes.

The involved parties use it to manage all the document sets (the architectural plans, the structural drawings, MEP information, construction documentation, general notes) and see what sets are current, what files are there, and most importantly, are there missing files. Users can create the project document structure in advance and benefit from immediate identification of missing documents. There are also comparison reports for printing and sharing. (VICOsoftware, 2016) and (WordPress & Green Park 2, Cordobo, 2010)

Most of the companies, like most of the world, are moving from managing all the information and work on paper by sharing it through the internet and electronically, therefore the use of digital forms is becoming more and more popular. This is why implementing a proper Building Information Management tool during design phase would be beneficial for every building project. Depending on the needs and the properties every tool can be evaluated with the use of an evaluation and comparison table. An example of one is given in the next chapter.

6.2.2 Comparison Table

Tool properties Y-yes	Building Information Management Tools				
	Project Wise	Construct were	Project Center	ProjectDox	DocSet manager
Support data model formats as DXF, IFC, DWG	Y	Y	Y	Y	Y
Model synchronization	Y		Y		
User rights	Y	Y			
Clash detection	Y				
Access to history tracking/ version management	Y	Y	Y		Y
Model changes	Y	Y	Y	Y	
Files changes	Y	Y	Y		Y
Export and import of 2D data	Y	Y			Y
Enable searching for the model	Y			Y	
Enable searching for the files	Y	Y	Y	Y	Y
Model comparison			Y		Y
Notify and communicate changes	Y	Y		Y	Y
Walkthrough and 3D navigation	Y				
Online access, mobile support	Y	Y	Y	Y	
Markup and comments	Y	Y	Y	Y	Y
Work reports	Y	Y	Y	Y	Y
Multiple project support	Y	Y	Y		Y
Information archive	Y			Y	Y
Cost management		Y	Y		
Document management	Y	Y	Y	Y	Y
Drawing review	Y	Y	Y	Y	Y

Figure 19 Table of comparison inspired by (Muhammad Tariq Shafiq, Jane Matthews, Stephen R. Lockley, 2013)

The table above is inspired by (Muhammad Tariq Shafiq, Jane Matthews, Stephen R. Lockley, 2013, p. 151)It is done as an example to help the organization to evaluate possible software solutions and choose the one meeting their requirements and support decision-making.

As it is visible on the table none of the evaluated Building Information Management tools are fulfilling all on the proposed criteria. Some are meeting certain properties, but some not. So the conclusion from this analyses is that only BIM implementation is not enough to fulfill the steps with meeting CR. It is partly solution for reaching the desired objective from the Objective tree (see chapter 5.2.2Objective tree). Therefore, further analyses are to be made to find an approach that is going to cover the gaps left from Building Information Modeling implementation.

User requirement analysis is an essential part of the technology development process and there are literally hundreds of methods used in the software industry to explore, consolidate and validate user requirements. Most commonly surveys or interviews are used to explore user requirements in a domain, by investigating the existing problems and potential needs of users in the functional context of the technology. (Muhammad Tariq Shafiq, Jane Matthews, Stephen R. Lockley, 2013)

The one that is to be further analyzed and proposed is Building Commissioning. The next chapter introduces the whole process including its advantages, benefits, and specifications.

6.3 Commissioning

Building commissioning is a quality assurance process ensuring the building and its technical systems meet the needs and requirements defined by the client. Building commissioning begins in the pre-design phase and goes through the design, construction and occupancy and operation phase used as a risk management strategy that is a part of these project phases. (Rúnar Örn Ágústsson, Per Anker Jensen, 2012, pp. 2-3)

It ensures the client gets what he pays for, while it detects and corrects problems that would lead to future issues or costlier maintenance. It is achieved by the co-operation between participants of the building process. It encourages and documents the communication between owner, designers, and contractor, which in the made above researchers (see chapter 4.4 Communication chain in the 'Client' party) turned out to be very problematic. This process documents all problems that contradict the OPR (Owner's Project requirements) and their solutions in a structural way. Commissioning is a process which with the use of test and verification ensures that the building meets the CR. Different organizations, guidelines, protocols, and certifications have been created to define and clarify this process. In chapter 12.7 Appendix 7 – Systems to be commissioned is placed a list of all different type of systems that can be commissioned and in chapter 12.6 Appendix 6 – Commissioning Definitions all different Building Commissioning definitions.

Commissioning is a multi-disciplined, collaborative effort involving owners, design professionals, construction managers, and commissioning agents to achieve optimal results from the commissioning process. (Sebesta Blomberg and Associates, 2013, p. 14)

There is two type of commissioning for new construction and for existing buildings. In the following master thesis, I am going to focus on commissioning for new buildings, since all the above-made analyses are done based on new building projects. (Michael Baechler, John Farley, 2011)

Commissioning of new construction is more detailed than existing building commissioning because it involves a review process during the design phase of the project. It needs more detailed evaluation,

testing, training and documentation during the construction, occupancy, and initial operation phases. Before construction phase starts, commissioning suggests the opportunity of including the commissioning agent and commissioning activities in the pre-design and design phase of the project. Adding the commissioning agent in the pre-design phase can reduce design problems and can enable development of the necessary documentation before the design phase begins. Commissioning ensures new equipment and systems are integrated and tested thoroughly when they are added to existing systems. It begins before the design phase and continues on past acceptance phase of the project. (Michael Baechler, John Farley, 2011)

Companies and organizations that are implementing commissioning in their projects, should be aware that this tool is not a replacement for existing quality inspection process, but an addition to that process. It is neither an isolated testing event of a single equipment nor a testing, adjusting or balancing tool. (Rúnar Örn Ágústsson, Per Anker Jensen, 2012, p. 2)

Nowadays all participants of the building project can benefit from the commissioning process, but the main direct advantages of commissioning are still mainly beneficial for the owner of the building, the O&M personnel, and the occupants of the building. This lead to the idea that the Aalborg University building would benefit a lot if they were using commissioning in an early stage, since now the occupants of the new AAU building are not satisfied with the final results. Building commissioning is a process for achieving, validating and documenting that the performance of the total building and its systems meet the design intent and CR. (General Services Administration GSA, 2005)

A few years ago the term ‘commissioning’ referred to the way how heating, ventilation, and air condition (HVAC) systems were tested in order to make sure they perform according to the stated CR. Nowadays commissioning refer to building systems performance and how it impacts the sustainability, productivity, safety, and security. (General Services Administration GSA, 2005)

6.3.1 Commissioning advantages and goals

Building commissioning has lots of benefits. According to (Rúnar Örn Ágústsson, Per Anker Jensen, 2012, p. 33), they are energy benefits and non-energy benefits. Each party in the building project can benefit from Building Commissioning, not only the owner but also the designers and the contractors. Since the following master thesis is concentrated only in the design phase, contractors’ benefits will not be identified. Building Commissioning process leads to increase in the construction time delays and cost overrun in connection to meeting CR. The following sub-chapter represents the benefits for the client and the design team because the following report is focusing on pre-design and design phases. Some of the overall commissioning benefits for a building project according to (General Services Administration GSA, 2005) are:

- Improved building occupant productivity
- Lower utility bills through energy savings
- Increased occupant and owner satisfaction
- Enhanced environmental/health conditions and occupant comfort
- Improved system and equipment function
- Improved building operation and maintenance
- Increased occupant safety
- Better building documentation
- Shortened occupancy shift period

Benefits for the client

The bigger part of the commissioning benefits is linked to the client and the end users of the building. Below are listed some of the benefits (John A. Heinz, Rick Casault, 2004):

- CR are clearly documented including a performance level and acceptance criteria for each item.
- All building systems function as described in the OPR document. This includes complex interaction between systems that often do not get tested or looked at due to the high level of complexity and little knowledge of how to optimize the interaction between the systems.
- A safe, healthy, comfortable environment is assured before the handover. The results for good indoor air quality can be seen in productivity of workers inside the building. This can be achieved because building commissioning forces problems to be discovered as early as possible and can, therefore, be corrected during design or construction phase.
- All building systems will be achieving at the minimum performance level and efficiency standard described in acceptance criteria in the OPR.
- The opportunity to monitor building performance and O&M personnel that are capable of analyzing the data and perform benchmarks.
- Increased equipment life because of less wear and tear due to optimized building systems.
- Well trained O&M personnel are capable of maintaining the efficiency and performance level of the building.
- All key information of the building is documented which can be vital for the O&M personnel to be able to maintain and operate the building and also in later years when renovation of the building is being planned the design consultant will not be forced to make assumptions regarding what thoughts were behind the design due to the extensive documentation because of the building commissioning process.

The benefits that are listed for the owner do all contribute to increased probability of the project being on schedule, within budget, the operational cost being as low as possible due to optimized operating systems and fulfilling the OPR. (Rúnar Örn Ágústsson, Per Anker Jensen, 2012, p. 35)

Benefits for the design team

Except for the client benefits, bellow are listed the design team benefits, which they can expect to experience by participating in a commissioning process (John A. Heinz, Rick Casault, 2004)

- The building commissioning team together with the design team improves the building design by bringing a construction expert to review design concepts and ideas throughout the design phase. Meanwhile, it opens a communication line between the design team and the operation engineer and the construction experts.
- Through systematic reviews, the number of design errors is reduced. With a use of a performance testing during the construction phase, the post construction callbacks for the design team are reduced drastically.
- Then the amount of time the design team spends for resolving design problems that are causing construction problems is minimized.
- By being part of the building commissioning process the design team becomes more qualified for future projects were building commissioning will be part of the project.

The benefits for the design team occur indirectly due to the building commissioning process being included in the project. Most of the time these benefits are not recognized. The reason for this is

that the client is not interested in these benefits and what the rest of the project participants can gain from the commissioning.

Commissioning goals (Sebesta Blomberg and Associates, 2013)*:*

Building Commissioning is a process for planning, delivering, and operating buildings to work as required. Commissioning starts with project planning and includes design, construction, start-up, acceptance, training and warranty phase services. The goals of the commissioning process are to:

- Define, document, and maintain a clearly stated set of measurable integrated system performance requirements throughout the design and construction of the project
- Verify and document compliance with these requirements at each completion milestone
- Establish a clear set of tasks, deliverables, and schedule milestones for every member of the commissioning team to drive building delivery to a successful conclusion
- Demonstrate and document effective integrated buildings performance through a process of system testing
- Verify that operation and maintenance personnel and occupants are properly trained
- Provide documentation, training tools, and building performance metrics to sustain the life of the building.

Even though Building Commissioning has lots of advantages, benefits, and a significant positive impact on the success of the building project, project participants are not fully trusting this new approach. The design team seems to think that the main purpose of building commissioning is to make them reliable for any future problems or errors that might happen rather than looking at the commissioning team as an extra set of eyes that can discover possible problems which can interfere the success of the project. Meanwhile, the client does not agree to pay extra for a service, he thinks is already part of the contract. Many hours are used for the design and often it is too late to make changes, more advantageous is to work with the commissioning team throughout the building process. (Sebesta Blomberg and Associates, 2013) Due to this fact, deeper analyses in this area are following.

6.3.2 SWOT analysis for a new Building Commissioning

SWOT analysis is used to identify the strength, weaknesses, opportunities and threats of Building Commissioning. With the use of this tool, it is possible to get an overview of how Building Commissioning might change the organization which is implementing it. This approach is also very useful as a basis for creating strategic options and evaluating future paths of actions. The main purpose is to identify the extent to which the Strengths and Weaknesses are capable of dealing with the changes happening in the AEC (Architecture, engineer, and construction industry) (Johnson, 2014, p. 91).

To summarize the advantages and disadvantages of building commissioning a SWOT analysis is elaborated (see fig.20). It divides advantages into either strengths or opportunities and the disadvantages into either weaknesses or threats. By doing so I want to provide the reader with a clear idea of what issues should be underlined to make the building commissioning process even better, what opportunities give the possibility of introducing building commissioning to improve the building and the building process, what weaknesses should be resolved to improve the building commissioning process and it also shows what threats should be avoided. (Ágústsson, 2010, p. 78)

Strength: (Rúnar Örn Ágústsson, Per Anker Jensen, 2012, p. 3) and (Alice Sung, Chad B. Dorgan, Lisa Gelfand, 2015) • Owner's requirements and identified and documented in the OPR. It is used a measurable acceptance criterion for each requirement. • Define the end goals • Increased the communication between all parties involved in a building project • Each individual is responsible for quality • Reduces the number of requests for information, change orders and conflicts which increase the likelihood that the construction is finished on time and within budget. • Final product meets all the requirements defined in the OPR. • It is a cost effective quality assurance process. • Reduces energy and operating costs • Ensures high-performance level and efficiency of all commissioned building systems. • Increases the likelihood the construction is finished on time due to fewer conflicts and order changes. • Reduce occupants' complaints and warranty issues. • Achieve indoor air quality the comfort, safety, and healthy environment	***Weaknesses*:** (Ágústsson, 2010, p. 79) • Require investment and owners do not like to spend more money on an already expensive project. • Commissioning has unsatisfied return on investment in some projects • Many clients don't want to pay extra for a service ensuring their requirements are met since they feel it is already included in the cost of the design team and contractors. *Lack of certified commissioning providers* • Companies providing these service but not to its full content, which leads to a bad experience with commissioning. This leads to commissioning bad reputation • Due to few companies being certified there is a lack of a standard building commissioning process which prevents that application of consistent practices.
Opportunities (Ágústsson, 2010, p. 80) • When the owner has an unclear idea regarding requirements and needs for the building. • When there are unclear requirements regarding minimum acceptance criteria for the performance level of building systems and equipment. • Used for complex and/or large building projects • When there is no functional performance testing. • Inadequate O&M manuals, training of O&M personnel and system documentation.	**Threats** (Ágústsson, 2010, p. 80) • Project economy- additional costs on top of the project cost is skipped. • Buildings with low level of complexity and small building systems • Lack of experienced and educated commissioning authorities. • Companies offering building commissioning which, that did not pass a certification process, leading to unsatisfied results • Requires the cooperation of many people at one time, which can add cost if it is not clearly defined in relevant contracts. • Time delays due to increased documentation that might take longer time than expected because of the inexperience of parties involved.

Figure 20 SWAT analysis

By the above made SWOT analyses I have stated the advantages of commissioning, which leads to the conclusion that this tool can only bring positive results. But there are some disadvantages that are holding building commissioning back. Most of the building owners do not take the cost of commissioning as an additional cost for a building project because is it not viewed as a necessary part of the building process and therefore it is skipped. Meanwhile as mentioned above in this report most of the problems identified through design phase often are discovered later in the project. Therefore the costs of fixing these problems are greater than the cost of implementing commissioning, so they are not fixed and just coped with.

The overall conclusion of the SWOT analyses is that Building Commissioning process is different for different projects, therefore there is not fix cost implementing it. In some cases, the client and the involved parties have an idea what is required from them, but in some cases, it takes time wondering around and understanding the whole concept. Meanwhile, the threats are these external disadvantages which are hard to handle. Building Commissioning is facing some threats in connection to construction delays, due to some reported cases. Very often the reason for these delays is the fact that the commissioning team is included late in the building process and therefore they are not able to find or identify problems in the very beginning. These construction delays can be avoided by including the building commissioning team from the very begging of the building process and clearly identifying and stating what is expected from the rest of the project participants through the whole process. (Agustsson, 2010) Therefore, further analyses in connection to building commissioning during different project stages are provided.

As every new approach, Building Commissioning also needs improvements which can happen with time and constant development. According to (Agustsson, 2010) the threats of inexperienced and uneducated commissioning authorities and inadequate building commissioning programs will be eliminated by standardization and certification processes both for companies and personnel which will decrease the spread of bad experience of commissioning among building owners.

6.3.3 Building commissioning during project stages

Building commissioning is used to assure CR are sufficiently defined and adequately and accurately reflected in the contract document. During project stages, the commissioning team gets the opportunity to assure the building systems and assemblies as designed are going to function according to the client expectations. Later specific test and procedures are developed and incorporated into the contract documents in order to verify the performance of the systems. (General Services Administration GSA, 2005)

The building commissioning process is connected to the overall project delivery process. Below are listed the necessary steps within the building commissioning process, without going into details. (Sebesta Blomberg and Associates, 2013) :

Pre-design

General information about the CR is gathered and reviewed. This information includes:

- program requirement (e.g. facility interior conditions)
- community context (e.g. reflectance limits on glazing)
- design standards, guidelines, and regulations
- site and climate (e.g. outdoor air design conditions)

Design Phase

The Commissioning Agent should review documents developed by the architect/engineer. These documents include the CR, the design history, and design submissions. The objectives of the review process are:

- Verify that each exterior system fulfills the CR and that the various enclosure systems are coordinated with each other and with other related systems.
- Develop commissioning process requirements for inclusion in the Construction Documents such as submittals, periodic inspections, laboratory testing, field testing, mock-ups of exterior assemblies, and documentation.
- Developing preliminary construction checklists, pre-functional checklists, and functional performance test procedures.
- Performing commissioning-focused design review to check proposed design solutions against the CR requirement

Construction Phase

During construction, the Commissioning Agent coordinates with the construction and design teams to fulfill the following objectives:

- Assist with developing construction details for elements not addressed or coordinated during the design phase.
- Observe field testing, including coordinating the need for additional field testing, alteration of installation details, and resolution of issues identified during field or laboratory testing.
- Field review aesthetic and functional mock-ups; review the interface conditions to verify that they meet the design requirements; verify that the required level of water and air tightness can be achieved; review of iterative repair submittals; and testing prior to actual construction.
- Submittal review of shop drawings, mock-ups, sample constructions, project schedules and sequencing, and building enclosure components to verify the required level of water and air tightness can be achieved.
- Review of the contractor's site-specific quality plans for the building enclosure.
- Field verification of actual construction for conformance to design and manufacturers' requirements.
- Field observation of contractor's testing.
- Assist in resolution of any issues identified during field reviews or testing

Warranty Phase

During the warranty, the Commissioning Agent specialist coordinates the Facilities Operations staff to fulfill the following objectives

- Review and comment on contractor's documentation including (a) Operations and Maintenance Manuals; (b) manufacturers' conformance records; (c) field test records; (d) record drawings; (e) exterior envelope preventive maintenance program; and (f) manufacturer's and contractors' warranties.
- Documentation of non-conforming performance levels relative to exterior closure systems
- Verification of exterior closure performance levels prior to warranty expiration.
- Coordination of corrective actions relative to exterior closure systems.
- Coordination of seasonal testing of exterior closure systems.
- Developing the re-commissioning or ongoing commissioning program

All analyses until now are based and concentrated on the design phase, therefore analyzing the Building Commissioning process will be minimized only on the design phase. Detailed analysis of building commissioning during the design phase is introduced in the next sub-chapter.

6.3.4 Commissioning during design phases

Building commissioning process gives greater importance in the design phase. Then building performance requirements are determined and implemented. Building Commissioning ensures that final product meets the performance requirements, review of constructability, maintainability, reliability and sustainability. Using early identification building commissioning provides an opportunity to resolve the issues before bidding and construction start. (Sebesta Blomberg and Associates, 2013)

The Design Stage gives the opportunity to the Building Commissioning team to assure that building systems and assemblies as designed will function according to user expectations. Further, specific tests and procedures designed to verify the performance of systems and assemblies are developed and incorporated into the contract documents. (General Services Administration GSA, 2005)

The difference between the normal design phase and the one including commissioning is not that big. Throughout the design phase with commissioning the design is regularly reviewed by the commissioning team and compared with the OPR and the design team has the OPR which defines the CR in a structured and clear way than the usual process.

One of the very first things that have to be done during the design phase is all design and construction commissioning activities to be well defined. After that, they have to be included in the architect/engineers and construction managers' contracts. According to (General Services Administration GSA, 2005). this step is going to provide the involved parties with information how building commissioning services are going to be delivered. After that, a Building Commissioning team has to be created. Below are listed the Building Commissioning team responsibilities and objectives.

Building Commissioning team objectives inspired by (ASHRAE, 2013)

The main responsibility of the Building Commissioning team during the design phase is to ensure that the construction documentations are according to and meet all CR stated in the OPR. In order for this task to be successful there are several things that have to be done during the design phase so the following objectives to be met:

- Compare the construction documents with OPR
- Analyze if the design complies with the stated requirement in OPR
- The Building Commissioning plan has to be updated and it should include both construction phase and operation and maintenance phase Building Commissioning activities
- A construction checklist has to be created with the help of the design team
- Update the scope of the system manual
- It has to be defined how the O&M personnel is to be trained including information about the material requirements
- All requirements in connection to Building Commissioning works are included in the contract

Building Commissioning team responsibilities inspired by (ASHRAE, 2013)

- Make sure the construction documents and the design are according to OPR
- Make sure all Building commissioning participants are places in the contract

- Create a scope and budget for the Building Commissioning process and each of the activities it includes
- Make sure the Building Commissioning plans is updated and includes the information of the people responsible for the commissioning activities
- Make sure the Building Commissioning schedule and the project schedule are running parallel
- Make sure the Issue Log is updated
- It is creating training requirements for O&M
- Update the OPR in case defined requirements can no longer be meet and notify all relevant personal of the changes made to the OPR
- Make sure the construction checklist is developed
- It is creating test requirements for the project to be performed during the construction and O&M phase

It should be taken into consideration that the provided list is not the only one that exists since it depends on the guideline used. Most of the guidelines are describing the steps differently, but they are basically the same.

After that, a Building Commissioning agent (CxA) has to be assigned. It is very important to understand the different between Commissioning agent and Construction manager since they have different skills and responsibilities. Construction manager provides skills including technical and administrative experience from the very beginning to the very end of the building process, so ensure that the goals relating to the time schedule, budget and quality are met. Meanwhile, the Commissioning agent (CxA) has technical background and expertise with commissioning process. He has significant building commissioning experience, including technical and management knowledge on projects with similar scope, type, size, and complexity. He has knowledge on building fire codes, water water-based extinguishing systems, detection systems, certificates as LEED and similar. (General Services Administration GSA, 2005)

Building Commissioning agent is involved in the building process from the beginning of the design phase. He can be selected by qualification or by the proposal. The process Building Commissioning agent is chosen depends on the organization and the complexity of the project. (Michael Baechler, John Farley, 2011)

The **Request for Qualifications** (RFQ) a comparison between different Building Commissioning agents and it is based on the following:

- Project background – building type, size, budget, schedule dates, certifications
- Objectives – All the objectives for commissioning
- Scope of work – Design, Construction and other stage expectations for the Commissioning agent
- Systems and Assembles – Preliminary identification of the systems and assemblies to be Commissioned. Once contracted, the CxA will further develop this matrix.
- Qualifications – includes the desired qualification of the CxA
- Proposal – includes expectations for format & content of prospective CxA's proposal
- Change in Personnel –CxA changes in personnel for the project
- Selection Criteria – includes a table indicating the selection criteria and scoring system for evaluating CxA proposals

The **Request for Proposals** (RFP) is a selection process that requires a higher level of effort by both providers and project managers. It provides both the information on qualifications that is obtained through an RFQ, plus a detailed scope of work and budget specific to the project commissioning needs. It is used mainly in large and complex projects. On the fig. 21 is presented a typical procedure for selecting a commissioning agent with the use of RFP.

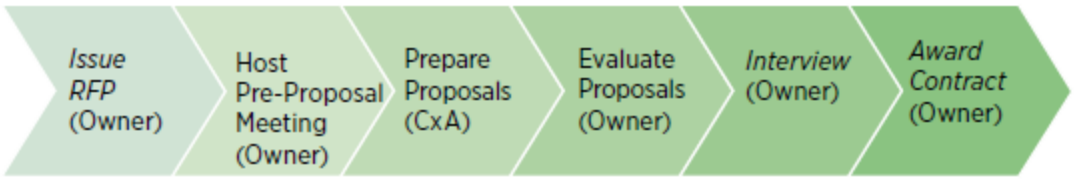

Figure 21 RFP for commissioning agent (Michael Baechler, John Farley, 2011, p. 12)

The first 2 steps give the Building Commissioning agent the information he needs, so to provide a proposal for the building project. The RFP includes the same project information provided in the RFQ, plus a list of the client expectations for the commissioning process. This in most of the cases is a list about the meetings that must be held, systems that require functional testing, the extent of sampling allowed, and documentation and training requirements. The RFP gives bidders specific guidance on the proper format for proposals and the procedure that will be used to determine the winning proposal. The standard process for selecting proper proposal is done by a team from the organization, which most of the time are project team and stakeholders. The proposal is evaluated according to relevant experience and qualifications, quality of references, and budget estimate. These criteria can be weighted as needed to fit the priorities of the building project. (Michael Baechler, John Farley, 2011, p. 12)

After assigning a Building Commissioning agent, a Basis of Design is created. It is a document created by the design team. The purpose of this document is to capture the thought and reasons behind the design that makes the construction document. It includes all assumptions during the design phase, calculations, methods, and description of the building. The basis of design is used by the project participants who are working on the construction document, so they will understand the building systems. It is very important to be made in a structured way because it is filling the gap between OPR and the construction documents. The main purpose of the construction document is to illustrate why different decisions are taken and where the basis of design comes in. The goal of Basis of Design is to give the designers a chance to explain why the design is as it is in a document. The Basis of Design is also valuable for the design team if there have to make changes to the building. Then they can track the details behind the design instead of being forced to make assumptions. (Michael Baechler, John Farley, 2011, p. 12)

Construction documents include all the building plans, drawings, specification, supporting documents and contracts used until the end of the project. They translate the needs and requirements specified in the OPR into a buildable format that can be understood throughout the construction industry. They allow the client to put the project out for bid, obtain permits from local authorities and a key purpose is it provides a comprehensive instruction to the contractor as to how the project should be constructed. It is important to include the performance level and acceptance criteria and how tests to be conducted. It should be clearly stated who is responsible for doing the test procedures. (Agustsson, 2010) and (BCA, 2016)

Except a construction documents a commissioning plan is created. All commissioning activities that are going to be performed during the construction phase are developed and scheduled. This plan has

to be updated during the design phase. Below is listed the main information that commissioning plan has to includes:

- Information about the parts of the building that are going to be tested and verified
- Commissioning schedule for the construction phase and O&M phase
- Roles and responsibilities of commissioning team members
- Communication protocols, which are updated during construction and O&M phase

Nowadays large and complex buildings and systems are collaborating, where small problems could have big effects on performance and the final result. Even though the building project to be designed carefully, if the systems or equipment and materials are not installed and operated as planned, the building might not perform the way it should. Therefore, building participants need the knowledge and resources to operate and maintain effectively the systems and component to they can work effectively and unfailingly. Building Commissioning is a way to achieve improved building performance. It meets the unique needs of the client, design team, and future occupants. When it is appropriately applied, Building Commissioning avoids inadequate solutions and addresses root causes, so to ensure that building systems operate efficiently, effectively, and reliably over time. (Tudi Haasl, Kristin Heinemeier, 2006)

6.4 Outcome of solving the problem

Every building project is a complex system, were changes lead to improvement or failure. In order to predict the direction of possible changes, Harold Leavitt (1965) created the diamond model of organization system.

According to him every change within the organization has to be analyzed and controlled, so to ensure its successful integration in the market chain. It is important to pay attention to the four major components which are: task, people, technology, and structure. Under “Task”, Leavitt refers to the production of goods or services. Under “People” are all the individuals who carry out the tasks. “Technology” refers to direct problem-solving inventions including all kind of tools, machinery, information technology/ computers. Under “Structure” is all sub- components such as workflow, decision-making authority, and systems of communication within the organization.

These four factors depend on each other, therefore changes in one component lead to an impact on the other components of the organization. It is happening this impact not to be distributed equally among the other component, therefore each component has to be analyzed in order to identify the magnitude of occurring change. (J.Leavitt, 1965, p. 1144)

On the fig. 22 below are presented the four factors and how they are interconnected. According to Leavitt “Any of these changes could likely be consciously intended, or they could occur as unforeseen and often costly outcomes of efforts of change only one or two of variables” (J.Leavitt, 1965, p. 1145)

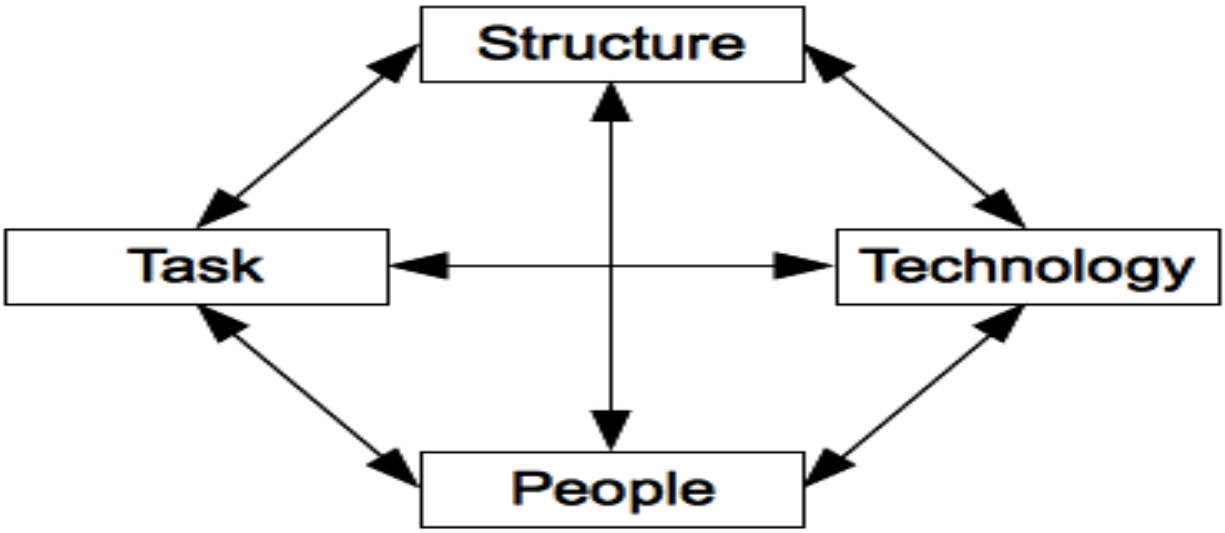

Figure 22 Leavitt Diamond

As mentioned in earlier in the report (see chapter 1Introduction and background) every client wants to receive a building that meets his requirements. This in the Leavitt Diamond is represented as 'Task', which is the desired product.

Meanwhile, Building Information Management represents the technology part of the diamond and Building Commissioning is the 'Structure'. Meeting CR is the arrow between structure and technology. Making this arrow more stable and stronger would lead to improvements in the final results, which is this case is meeting CR and increasing client satisfaction.

Improved performance is a common goal for every company or organization, therefore this project offers process changes which are affecting the whole working process, as foreseen in Leavitt diamond. Providing a new system for gathering and properly managing CR would lead to operational improvement. New technology tool like implementing Building Information Management could cause positive changes in the entire building process. Building Commissioning implementation would improve the structure of the organization and the whole building process. Meanwhile, these changes will affect the performance of work and 'Task' in a positive way.

Building Commissioning produces a big amount of data since all the systems and assemblies are tested, set to work and integrated. Meanwhile, Building Information Management simply facilitates and store all the collected information in a common platform, where all project participants have access to. Seems like a combination between Building Information Management and Building Commission could bring lots of advantages for the success of the whole building project while assuring the work is performed right and all client requirements are met.

7 Solutions and Implementation

After analyzing both Building Information Modeling and Building Commissioning the next step until the following project to be completed is to provide the reader with implementation steps for both of the things.

7.1 Steps for BIM implementation and Decision about proper BIM tool

Usually, Building Information Management implementation requires proper planning, patience and full commitment from all levels of the organization. When introducing BIM to an organization, the information provided should be structured and completed, because, with only a minimum amount of knowledge, it is possible the message not to be received. An action plan for Building Information Management has to be created. Without this plan, in place, it is easy to lose track of what information is required to be successful. The plan should consist of two major sections: analysis and implementation. This is why the following questions are important to be answered and a table as the one in chapter 6.2.2 Comparison Table can be created depending on the organization demands and different tools to be evaluated.

QUESTIONS to decide which BIM tool to use	Answers
What is the purpose of using the BIM in your project?	
What type of information is needed to provide value for different project participants?	
How many models there will be?	
Who is going to use Building Information Management tool?	
What is the role of the exact project team? Consultant/ client/ designer	
Who has to be trained about the chosen tool?	
What type of training different employees need?	
Which Building Information Management tools meets organization requirements?	

QUESTIONS	YES	NO
Do you have money to invest in different BIM tools?		
Do you have money to invest in hardware suitable for BIM?		
Do you have money to invest in BIM training?		
Do you have money to invest in Switching from Drafting to Modeling?		
Do you have a person to develop, update, and maintain BIM? Does this person have the expertise to update work?		
Is the project model going to be interoperable?		
Is it BIM a must according to the contract?		

With the use of the questions above the organization can very fast find their place in the information exchange chain. Meanwhile, these answers would provide relevant information in connection with the main question ‘Is it worth all the effort or an external company providing this services is more than enough?’

7.2 Building Commissioning implementation steps

Commissioning implementation steps that I have come up with are inspired from the analyses done until now, the conclusions I have come up with and from the work done by (Rúnar Örn Ágústsson, Per Anker Jensen, 2012):

Step 1 Identify Building Commissioning agent (Michael Baechler, John Farley, 2011)

As mentioned earlier (see chapter 6.3.4Commissioning during design phases) commissioning agent is the core person, from which it depends if the final product will meet CR or not. There are lots of building commissioning agents the organization can choose from, who are having certifications from recognized commissioning organization. Such certification identifies if the Building Commissioning agent has passed specialized commissioning course. The first time of choosing Building Commissioning agent is not an easy task, and an organization that does not have any aide how to choose one meeting their needs could face some difficulties. Therefor (Michael Baechler, John Farley, 2011) are suggesting two ways of evaluating Building Commissioning candidates.

The first one is by Request for Qualification (RFQ) and the second one by Request for Proposal (RFP).

Request for Qualification – comparing different candidates by overall submissions, qualifications and free.

Questions	Yes	No
Does the candidate have the necessary technical knowledge?		
Does the candidate have experience in similar projects?		
Does the candidate have building commissioning certification?		
Does the candidate provide a documentation/ reference for successfully completed projects?		
Does the candidate have management and leadership skill?		

Step 2 Interview with the client (Michael Baechler, John Farley, 2011)

During this interview, the Building Commissioning agent understands client expirations, needs and requirements for the project/ system.

Step 3 Acceptance criteria (Michael Baechler, John Farley, 2011)

Step 2 to be analyzed in details including acceptance criteria, performance level and level of efficiency.

Step 4 Comparison (Michael Baechler, John Farley, 2011)

All construction documents are analyzed for issued and compared if CR is met or not.

Step 5 Designers provided with documentation (Rúnar Örn Ágústsson, Per Anker Jensen, 2012)

Building Commissioning agent provides the design team with a copy of the commissioning reports, which is reviewed and comments can be added. The design team has to go through the documents and comment, in the report, on what actions will be taken on the issues. If they think that no action is needed for some of the issues they are asked to show arguments to support their decision.

Step 6 Testing (Michael Baechler, John Farley, 2011)

Develop testing paradigms together with the contractors. When the building system is installed it is tested and the information is compared to the stated CR, if the system fulfills the CR. Either the commissioning agent do the test or they trust the contractor to perform it, but he should provide a report for the work done.

Step 7 Update (Michael Baechler, John Farley, 2011)

Update the commissioning report to show present status of issues that were identified.

Step 8 Inform the client about the final results (Michael Baechler, John Farley, 2011)

Send the client a copy of the commissioning report and the test results for the building system. The commissioning report follows the building in the future and is updated at regular intervals, for example, when one-year and five-year inspections are done.

8 Conclusion

The following chapter summarizes the context of this report which has been focused on the problems identified in the very beginning. Even though the construction industry is developing different project parties are still using the traditional paper- based communication. The collaboration between parties and exchange of information still depends on 2D drawings and documents. The main problem with paper-based communication in the AEC industry is the inefficient data of the project information, where mistakes are possible to happen. Project participants providing such data do not support effectively the communication and collaboration. This communication complexity is a result due to lack of management system that can combine and track the drawings and documents used trough the design phase. Therefore, the demand for adoption of information technologies is increasing.

Building Information Management is a great solution for the exchange of information and visualization, which is replacing the traditional methods. The possibility to directly use and exchange information between stakeholders improves the communication between different project participants. Every building project requires efficient collaboration between project participants and so they can communicate in a clear way. Every communication which is open, honest and efficient is a key factor to the success of building project. Effective communication between the client and the contractor can control the time, cost and quality of the construction project. Centralized source of information creates strong communication and collaboration between different project parties thought the design phase, which simplifies the workflow towards the success of the project. Good communication and coordination with the use of a Building Information Management tools help to reduce errors, wastage, and risk by reinforcing the project participants' relationship in the collaborative design process. Even though Building Information Management tools are having a significant impact on the communication improvement through project participants, they cannot assure that the end result would meet CR. Therefore, part of the report solutions is a combination between Building Information Management tool and Building Commissioning. One improving the technical part of the project, the other one improving the organization's aspect of the project.

It is interesting to focus on what building commissioning is, how it is applied within the building process and how it improves the situation with meeting client requirements. Starting to analyze Building Commissioning, provided a huge amount of unclear information, which at some point gave the impression that this new approach would complicate the traditional building process. This is due to the amount of documentation, communication, and co-operation between project participants at the same time. As long as Building Commissioning is done proper and correct, it simplifies the building process. Lots of unclear issues can be identified and fixed on time, meanwhile, reduces change order, warranty claims and project handover is on time. Properly used Building Commissioning is cost effective and brings success for the building project and project participants. Building commissioning has lots of advantages similar to a quality assurance process. This new approach defines OPR where the client states his needs, demands, and requirements. Later this documentation followed by acceptance criteria, based on measurable values verified with the use of a test performance.

In case the project participants continue to implement traditional methods of collaboration during project design the problem with meeting client requirements will continue to exist. Unawareness of possible Building Information Management tools for improving the communication and collaboration would keep project participants in a position where they do not realize the potentials

and possible benefits. Also without Building Commissioning the effort of meeting CR would be increased. The existence of a functional BIM visualization has satisfied the desire of all parties involved in a construction project as communication becomes more meaningful and communication will not be a problem which is encountered in the construction industry. With the implementation of BIM, effective communication will increase the productivity and efficiency in the construction activities, thus enhancing project collaboration between industry stakeholders. This phenomenon calls for the need of

9 Discussion

Building Commissioning is something new that is introduced in the construction industry, therefore the information about it is limited. In Denmark, there are no building projects where it was elaborated so to be able to use it during my analyses, which limits my analyses to the point that Building Commissioning is great only on words.

During my work and if the paper is further developed it would be nice to see how the transfer of information is done by consultants and contractors. Also, It would be nice not to focus only on the design phase but also on the rest of the project phases. This is related both for the analyses, and for the Building Information Management and Building Commissioning.

I have used only the point of view of the client site of the problem, it would be interesting to see what consultant company thinks about my findings. Actually, the opinion of all stakeholders would be interesting to be analyzed.

Actual investigation of the success of a Building Commissioning is interesting to be a view, but the time needed to gather the information and evaluate is would be long.

Something else that can be improved in the following work is to analyses the effect on different contract forms over the participants' responsibilities and the way information is transferred between different project participants.

I have tried to search for a real project where Building Commissioning is implemented in Denmark without success. This is another part of the project that can be improved in the future.

Something that can turn the scope of work could be other Building Information Management tools that were not included in the report, or even different comparison criteria since the one used is not made by a professional in Building Information Management.

When I have started to write this master thesis I realized that I would like to deal with problems in connection to BIM and how building process can be improved by meeting client requirements.

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11 List of Figures and Tables

12 Appendix

12.1 Appendix 1 – Communication Chain

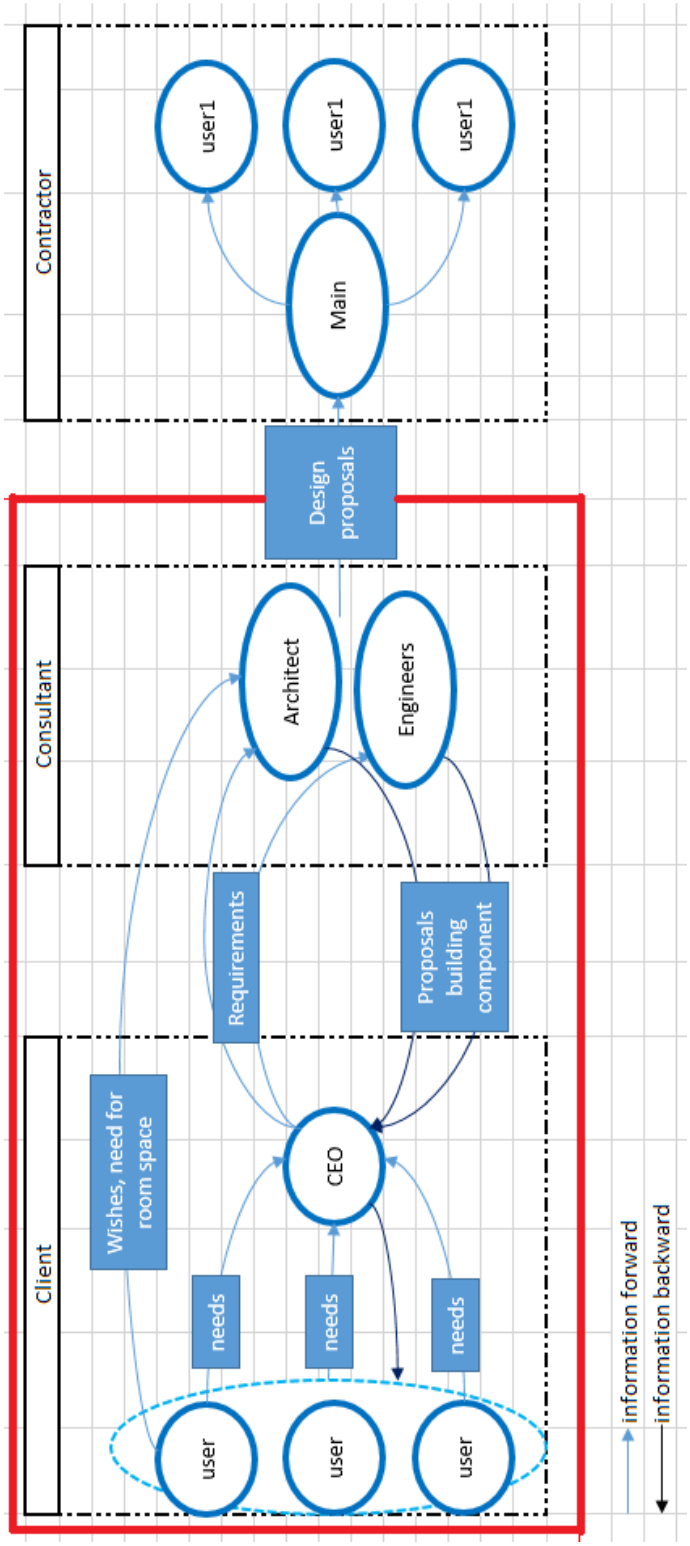

Figure 23 Communication chain

12.2Appendix 2 – Meeting with client representative #1

Antoaneta Kaneva, Aalborg University Date: 20/10-2016

QUESTIONS FOR Mai

1. How all the information about the client requirements is collected?
   There is No standard procedure. The head of department ask the head of the department in civil engineers, and architects. They 2 collect the information from the users. They made user target groups 12. Divided the groups what the entire building will cover.
   After collecting all the information, they go to the director of the faculty, so to make sure they are realistic.
   3 weeks from a question to getting an answer
   No tools, they had to invent everything themselves (intranet.byggeri.aau.dk/byggesagen
   Only in word, including yes and no
2. Who sets the requirements and when?
   There are different books for the public buildings – read a lot of books!!! Which is a lot Campus service also have a lot of requirements placed in a book. According to ventilation again there are some extra books. The faculty has requirements for the amount of space, gross and net m2. There is a mistake between bruto and netto, therefor the terms are not clear. Need for a basement- because a neighbor do not like the ventilation. Lots of people are setting the requirements. The Employees in the department Laboratory – in the beginning of the project. In the beginning is collected the information. Problem what you wish for and what you receive
3. What type of tools have you used and when?
   Word and Excel files
4. Who is collecting this information and who is responsible for it?
   Maria and Mai are collecting. The head of the department is responsible for the information to go further
5. Did you make distinguish between Direct and Indirect client requirements?
   No the architects did not thought about this, as well as the users. Informal meetings are done as well. The little talks are done, but are not written down, therefor it is very difficult to track Sink and tap are not at the sale place. There are no demands about the refrigerator. It seems logical this things not to happen but the client did not set his proper requirements.
6. In case of a problem how much time does it take you to trace back the specific client's requirements? Fx what type of laboratory is needed in connection to space, light?
   Long time takes to do it. People are changing, therefor people do not know all the information. All the information is in the paper 4 books of paper. It is very difficult to search. They use ByggeWeb, but they are not satisfied from this, because in the computer you can search, but in byggeweb you cannot actually search- they have to download all documents and search in a single paper.
7. Does someone else have access to them and how much time it takes to get access?
   Huge amount of time, everybody who has been involved in the process. The engineer decides who to have access to the information, because he is the head of the advisory group

8. How much time do you spend to search for these requirements or you continue working with own assumptions?

   Mai thinks that they do not have a problem. Not much because they have a standard and they know what they have to make. On a meeting they are doing a details (this answer is according to Mai). This question is more relevant to the consultants so it is more realistic to ask them.

9. If the client is not happy about the result, what do you do to satisfy him?

   Not happy about the result. Communication problems. Fix things according to the contract that is signed. The clients do not blame the contractors.

10. Do you realize why this problem occurs?

    There are lots of people between the end users and the advisory

11. Do you think even if we implement BIM there is still waste, and do you think that commissioning can eliminate this waste?

    3D models are fine, but not everything is there, because they might be very heavy to include everything.

12.3 Appendix 3 – Meeting with client representative #2

Antoaneta Kaneva, Aalborg University Date: 31/10-2016

QUESTIONS FOR Mai

1. **Which are the users of the Aalborg University building?**

If you mean the building for Department of Civil Engineering, then:

People in the building every day: Students at Department of Civil Engineering, Students from other departments having lectures at Department of Civil Engineering, The employees at the school, the employees at the Department, the Head of Department, cleaning staff, janitors.

People with an interest in the building: Employees at the Faculty, The Dean of the Faculty, The University Board, Employees at Campus Service, Employees at ITS

2. **How did you divide the groups? How many groups were there?**

Maria and I went through what we thought was important for a new building, and developed groups according to that. 12 topic groups. The 12 topic groups were dealing with 12 different areas of the working environment for both students and employees: 1. Offices, 2. Teaching, 3. Students, 4. Laboratories, 5. Living Lab, 6. Working environment and security, 7. IT and technology, 8. Art, 9. Moving, 10. The collecting group, 11. Façades, 12. FoodLab.

3. **Which group had strict requirements and who not?**

I am not sure of what you mean by this… The laboratories were the most concrete of what they needed.

4. **How did you prioritize these requirements?**

Within the Collecting Group and according to our budget and visions at the department.

5. **'Broken telephone', this Is a game where a word is told to person, then he has to say it to another one, and like this to go through different people. Like this different people hear different thing and at the end the final person understand completely different word- is there some approach analyzing the wrong transfer of information? Did this happen when you were collecting client requirements?**

I do not understand the question…

12.4 Appendix 4 – Requirements for Digital Construction

Below is the translated version of the requirements to Digital construction taken from the official website **www.retsinformation.dk**

7 requirements to Digital Construction (Lidegaard, 2013)

1. ICT coordination - § 3. The developer must ensure that throughout the entire project is coordination of the overall ICT use between all parties involved.
2. Managing digital building objects - § 4. The client must require that digital construction objects throughout the entire project are structured, classified, named, coded and identified uniform for a certain level of detail. The developer must in this regard require building the objects provided with the information and features that are relevant for the subsequent management, operation, and maintenance.
   PCS. 2. The developer must ensure that established guidelines for the handling of digital construction objects throughout the construction proceedings.
3. Digital communication and project web etc. - § 5. The developer must require the use of a system for digital communication and archive of all relevant information to substantiate the proceedings.
   PCS. 2. The developer must ensure:
   - preparation of a plan for which parties must make the information available in the system and at what times,
   - the information can be retrieved from the system and transferred to other systems, and that it is part of the plan drawn up, which transfers required during the project and upon completion, see. § 10,
   - the system is provided with access control, notification, and log,
   - that it determined which file formats to be used, and
   - that define the metadata to be attached to each file types.
4. The use of digital building models - § 6. In contests developer in the competition, the program requires that the proposals include digital, object-based building models and visualizations performed on the basis of these. Building models and visualizations to document the proposals architectural, functional and technical aspects of a certain level of information.
   PCS. 2. The developer must ensure:
   - that in the competition program required for building models structure and information content, see. § 4, from the competition's size and complexity,
   - to visualize ringers number and location determined by the competition's size and complexity, and
   - to object-based building models delivered in IFC format.

   § 7. During the design and execution, the developer must require the use of object-based building modeling.
   PCS. 2. The developer must ensure:
   - that any agreement on the subject and common models that are produced
   - to each of the model responsible parties shall prepare the necessary discipline models, whose content and use specified in proportion to each party's performance,
   - to discipline models are coordinated through one or more common models to simulation, collision check, drawings, and specifications, and

- that the building models are available for the IFC format.

5. Digital supply and Deals - § 8. The client must require that by the supply of construction work using digital supply and offer the use of a digital system. The tender documents shall be prepared so that the appropriate use of digital bidders for bid submission, and thus to offer structured by the structure also used in the construction proceedings provided. § 4th § 9. To the extent offered by volumes, the developer must ensure:
    - the amounts contained in the tender documents offers lists
    - the contract documents for each contract includes both offer lists as appropriate, digital, object-based building models, which amounts can be read,
    - the digital building models made available to the bidder in IFC format, and
    - that the tender documents stated the basis on which the amounts are calculated, including the gauging and/or measurement methods used.
6. Digital delivery by building inspection - § 10. The developer must, in consultation with the operator require digital delivery of the information considered relevant for:
    - documentation of the building,
    - documentation of the construction project,
    - operation and maintenance, and
    - the prospective property management

    PCS. 2. The developer must ensure:
    - the digital delivery of building inspection in agreements with consultants, contractors, and suppliers,
    - the agreements cover to dispose of magnitude, structure, classification, identification, and formats, and
    - to the object-based building, models delivered in IFC format.
7. Digital lack information - § 11. The developer must ensure the use of digital deficiency lists that describe the data is missing according to the project defined structure, see. § 4th

12.5 Appendix 5 – BIM tools

12.5.1 Appendix 5.1 – Project Wise

Improve your project performance by integrating people, data, and processes throughout the project lifecycle. Share project information with secure information mobility. Using PCs, tablets, or mobile devices, your project participants will collaborate effectively to keep the project moving forward. Give your project stakeholders visibility into project performance to mitigate risk. You will win more work and develop repeatable best practices to improve your ROI.

First released in 1998, Project Wise has always been the workhorse for design coordination based on organizational and project workflows, or industry standards such as BS1192. With the CONNECT Edition, Project Wise extends beyond design coordination to comprehensive work sharing, empowering the project team to collaborate throughout the entire project delivery lifecycle.

Collaborative, interoperability to connect global project teams where information and deliverables are available on-demand for improved performance and increased project transparency for comprehensive project delivery. A gold standard for engineering design integration and collaboration for multi-discipline geographically dispersed teams. Cooperating teams or organizations can now synchronize distinct Project Wise instances with managed workflows for the exchange and sharing of all types of work packages. Supply chain collaboration to manage the exchange of transmittals, submittals and to solve problems with RFIs and issues resolution, bridging the divide between engineering work-in-progress and the extended supply chain. Complete your capital projects faster with construction and contract management, financial performance and risk monitoring, and an automated electronic construction record. Unparalleled information mobility and federated information access that helps project-intensive companies avoid risk and stay competitive with comprehensive project delivery. Advantages:

- **A Common Data Environment:** Improve the accuracy, reuse, and auditing of design and construction documents and data to start projects faster, eliminate redesigns and reduce the risk of rework.
- **Reduced Delivery Risk:** Unify design and construction teams with managed workflows with the entire supply chain throughout the project delivery lifecycle.
- **Virtualized Talent:** Enhance performance by leveraging best skill sets of in-house resources regardless of location and open access to new sources of talent from Value Engineering Centers providing more cost-effective project execution models.
- **Managed Project Outcomes:** By acting on insights revealed through key performance indicators (KPIs) on activity, progress, documentation status and other project metrics, organizations will increase accountability and improve responsiveness to minimize delays and keep the project moving forward.
- **Faster Time to Value:** Project teams now have hybrid cloud services providing enhanced agility to respond to varying project requirements, improved operational readiness resulting in improved ROI on the project and at the organizational level. (Bentley, 2016)

12.5.2 Appendix 5.2 – Constructware (Autodesk, 2010)

Autodesk®

Autodesk® Constructware®

Manage efficiently, deliver consistently.

Perform Consistently, Deliver Predictably

Improve construction project results by better managing operations, information, and costs.

Hoag Memorial Hospital Presbyterian
Since 1952, Hoag Memorial Hospital Presbyterian (Hoag) has grown from a one-building community hospital into a state-of-the-art health care facility. As Hoag grew, however, the lack of a centralized project management system continually strained the facilities design and construction department.

By adopting Autodesk Constructware and configuring it to meet the hospital's needs, Hoag's project teams were able to revamp the processes of all 140 existing projects and then centralize their management into a single, automated system. "It was clear that Constructware was our best option because it could adapt to the way we did business," said Jennifer Rayner, manager of operations for facilities design and construction at Hoag.

Across the board, Hoag has recognized gains in their construction project management process. Rayner estimated that using Autodesk Constructware has increased operational efficiency in her department by at least 50 percent. Constructware also helped Hoag simplify cost management, providing automated reports to better track budgets, apply released budget dollars, track purchase orders, and monitor project cost to complete.

"Once people get up and running, there is no going back," offered Rayner. "They appreciate how collaborative Constructware is and how easy it is to use."

Construction projects have become more complicated to manage. Relying on traditional project management processes makes it difficult to stay on top of activities and to communicate with internal and external project stakeholders. And with rising pressures to deliver projects faster and more cost effectively, it is becoming increasingly important to identify new ways to help optimize project performance in order to minimize avoidable costs and delays.

The Autodesk® Constructware® web-based project management solution helps standardize and streamline business processes to deliver projects more efficiently and cost effectively. With an easy-to-use, web-based environment for project management and collaboration, Constructware helps establish and maintain best practices, streamline project management, and reduce reliance on your IT infrastructure.

Establish Standard Practices and Automate Business Processes

In today's competitive environment, there is little margin for error in the design, construction, development, or operation of facilities. With the right construction project management tools and business processes in place, you can more easily maintain efficient practices to help keep projects moving forward. Autodesk Constructware helps provide transparency and accountability across projects and programs in a more secure, permission-based environment. Automated workflows, approvals, and reporting can help teams work more consistently and predictably throughout all stages of project execution. In turn, your project delivery schedules can benefit from the ability to more proactively and collaboratively address change.

Streamline Project Management and Data Exchange

Conventional methods of project management and data sharing to keep all teams on the same page with the most up-to-date information are often inadequate.

Autodesk Constructware helps streamline operations and optimize execution in the field to promote time and cost savings. Centralize project drawings, documents, schedules, and cost management processes to connect people, processes, and information in real time. Configurable to support leading methodologies such as integrated project delivery (IPD) and lean construction, Constructware helps you move to a best-practices approach as you plan, construct, and operate your facilities. Project data can be exchanged with ERP and accounting systems, helping your staff to spend less time on data entry and more time working on the project.

Leverage More Secure, On-Demand Project Management

Autodesk Constructware minimizes the need to maintain a costly and complex IT infrastructure by providing software as a service (SaaS) technology for your construction project management needs. Using Autodesk Constructware, you can store your project information in a more secure, professionally managed, web-based environment. More efficiently share project information internally and externally, without worrying about managing necessary IT resources or compromising your corporate network.

Standardize, Optimize, and Control

Connect project teams to help drive efficiency and consistency during every stage of the project lifecycle.

Autodesk Constructware enables you to adopt more consistent processes with minimal disruption to your business. Best of all, it supports each stage of the building lifecycle so you can better standardize, optimize, and control your construction projects.

Document Management
Centrally organize, manage, and track all project-related documents, contracts, and information to help keep projects on track. Features such as version control, search capabilities, and file-level discussion help project teams focus on value-added tasks instead of tracking down information.

Design Review
Better manage the review of conceptual and schematic designs, documents, and information, helping to speed approvals and promote productive collaboration across disciplines. Automatic notifications of design changes and reference file management help keep team members informed and accountable when changes affect their portions of designs.

Bid Management
Coordinate the preparation, distribution, and award of bids to help improve efficiency and control construction costs. Disseminate bid documents in a fraction of the time it takes with traditional methods, evaluate competing bids more quickly and efficiently, and accept winning bids by easily converting to contracts or purchase orders.

Cost Management
Implement standardized cost and change management practices so you can more effectively track and forecast budgets and expenditures for individual projects and across multiproject programs. Custom reporting, flexible ledger designs and workflows, and data exchange with accounting systems provide the capabilities you need to help stay on top of costs with a system that is more easily configured to your business needs. Update budgets and cost impacts automatically with workflow triggers, and ease monthly payment application reviews with built-in industry-standard calculations.

Construction Management
Help accelerate construction management processes and communications by automating routine functions, such as RFIs, transmittals, meeting minutes, change orders, and reporting. Automatic notifications, smoother exception reporting, histories, and project management dashboards help you minimize delays and expensive surprises. Automated connectivity between processes helps you more easily understand the origin of change.

12.5.3 Appendix 5.3 – Project Center (ProjectCenter, 2016)

Benefits

Enjoy the benefits of improved communication, effective collaboration and operational efficiency without the burden of hardware and system administration costs.

Here's what makes ProjectCenter the best tool available for project collaboration:

It's Easy To Use

Because ProjectCenter is a **Software as a Service** application, no hardware or software investment is required. All you need is a computer, a Web browser and an Internet connection. And since training takes less than an hour, team members will be up and running in no time.

It's Focused on the AEC Industry

ProjectCenter includes configurable **workflows** especially designed for **engineers**, **architects**, **contractors** and **building owners**. They work the way you and the industry work

It's Secure, Reliable and Fast

Our secure hosting and state-of-the-art encryption technology ensure that your data is protected, backed up and **available 24 hours a day** so you have peace of mind. Broadband connection ensures that you can access information instantly.

It's Customizable and Flexible

ProjectCenter is designed to allow companies the freedom to organize documents, folders and information without having to adhere to unforgiving templates. Organizations that use ProjectCenter have the flexibility to create and modify forms to meet specific business requirements, and to organize documents, folders and information in the ways that are most useful to their operations. Users can store, manage and administer data in ways that are most familiar to them, helping team members gain immediate efficiency.

It's a Proven Money-Saver

ProjectCenter clients report savings of as much as 50 percent on printing, copying and shipping, as well as savings of 20 percent or more on travel. In addition, our clients consistently tell us that they see reductions in the need for administrative support, along with increases in quality and revenue.

12.5.4 Appendix 5.4 – Project Dox

Project Dox is an Electronic Plan Review (ePlan) solution that has an electronic plan review for permit application review, which projects success. (AvolveSoftware, http://www.avolvesoftware.com/projectdox/, 2016)

- **Plan Review for Permitting -** This tool delivers better service by reducing review time, helps accelerate economic growth, and eliminate the inefficiency of paper movement and storage. Project Dox plan review accelerates the permitting process, making it fast and easy to submit, review documents and drawings, process corrections, while monitoring and improving the work process. It balances the needs of many stakeholders without losing sight of that primary mission. Project Dox makes it easy for review personnel to work together with the citizen applicant during the review process. Project Dox is powering economic growth, delivering better constituent service, reducing review cycle times, increasing transparency, and enhancing collaboration. (AvolveSoftware, http://www.avolvesoftware.com/solutions/building-departments/, 2016)
- **Planning and Zoning** - It reviews the workflow for planning and zoning enable effective collaboration and efficient process among stakeholders seeking to achieve a balanced community vision while advancing economic growth. Project Dox promotes well-designed, functional planning, that combines strategic vision with practical approaches to today's development realities. It strives to build consensus on short and long range plans. It enables effective communication and collaboration among stakeholders. (AvolveSoftware, http://www.avolvesoftware.com/solutions/planning-departments/, 2016) Project Dox automates and manages planning operations, including:
    - Land planning
    - Development applications
    - Entitlements
    - Long range planning
    - Includes project templates, checklists, eForms, reports, and process steps needed to automate the planning process in Project Dox
- **Public Works and Capital Projects –** public projects require a wide variety of planning, collaboration, review and approval and ongoing operations functions. This tool provides a framework to exchange and collaborate with project drawings, documents, and other information. It manages internal projects and improves the process through better collaboration and communication tools. Project Dox provides collaboration environment for managing projects, allowing project team members to access all project data and maintain a fully versioned document history. All project data is in one central location, always current with permission access securely controlled for both internal and external team members. All project data is now linked to the GIS system for quick reference access and maintenance, further expanding the electronic built environment for future economic growth and development. (AvolveSoftware, http://www.avolvesoftware.com/solutions/public-works-and-capital-projects/, 2016)
- **Public Safety Planning**- Fire and emergency response personnel need accurate, timely access to building environment information to meet citizens' needs. Project Dox allows remote plan access from field-deployed units and the command center simultaneously; allowing responding units to be on the same page. It allows Emergency response agencies to electronically access, view, and markup building plans for any building. Plans can be accessed from field-deployed units and the command center simultaneously. (AvolveSoftware, http://www.avolvesoftware.com/solutions/pre-fire-safety-review/, 2016)
    - Pre-plan emergency response with the aid of full marked-up drawings

- Identify and highlight key items such as Gas and Electric Shut-offs, Stand Pipes, Master Elevator Controls, Security Controls, and all Access Points
- Mark and log the location of all stored hazardous materials
- Coordinate response to centralizing information and accessing plans wirelessly
- Instant, automated status notifications can be triggered from the field when drawings are accessed

When emergencies arise, having an action plan is essential. This plan can be shared between multiple response teams. The command center is more coordinated and efficient and increases the capability to save valuable property and human life. Project Dox protects valuable Built Environment information for use in critical situations.

12.5.5 Appendix 5.5 – Doc Set Manager

Doc Set Manager is used to reduce project risk and improve productivity by quickly scanning and mapping the changes in thousands of design and construction drawings, generating document-based RFIs, and managing their status through resolution. It informs the project parties about the changes and helps them to efficiently identify, understand, and react to drawing changes in a collaborative environment. Doc Set Manager provides one central source for all the project drawings, which enables to compare thousands of drawings within minutes.

The involved parties use it to manage all the document sets (the architectural plans, the structural drawings, MEP information, construction documentation, general notes) and see what sets are current, what files are there, and most importantly, are there missing files. Users can create the project document structure in advance and benefit from immediate identification of missing documents. There are also comparison reports for printing and sharing. There is an option that allows GCs to invite their subs to participate in the collaborative review, assignments, and resolution. (VICOsoftware, 2016)

Doc Set Manager also provides automatic mapping and a quick comparison between large drawing sets. All users can log into the drawing sets at the same time so as to resolve issues collaboratively. They can also define the DWG or PDF drawings for review and select the preferred comparison mode. The color-coded table of PDFs and DWGs enables to see a list of documents, their versions, compare their changes and then to investigate. Side by side it presents the previous documents version next to the view with the changes. Once these changes are identified, all involved parties can closely inspect the drawings, cloud the area, and assign tasks to another team member.

All identified changes can be clouded and RFI documents generated. Clouds with Pending RFIs are automatically transferred to any new versions so the involved parties can't lose track of any changes. These RFIs (request for information) can be prioritized for determination and linked so no change is ever lost and historical data for changes can be easily retrieved.

Advantages:

- Compare thousands of drawings in minutes
- Analyze DWG and PDF formats
- Accelerate change tracking with unique visualization tools
- Store history of changes
- Easy to learn and use
- Review Document set Versions Changes - Create the project document structure, import document version sets, and review changes.
- Define Comparison Rules - Refine your comparison settings to make sure you track only significant changes.
- Compare Document Versions - Click the Run Comparison button and let Vico Doc Set Manager do the work for you.
- Analyze and Track Changes - Compare color-coded documents using the most suitable view mode. Use the cloud tool to easily define, and assign new tasks to team members.
- Define and Assign - Easily review the list of changes, set priorities and assign tasks to team members.
- Take Charge - Review assigned tasks and their status. Reassign, add comments and browse history to ensure that changes are tracked and actioned.

Other benefits of DocSet manager are (VICO, 2016):

- Vico Doc Set Manager™ reduces risk and improves productivity by automating the process of checking for drawing revisions across construction drawing sets.
- **Enhanced Performance**-Vico Doc Set Manager accelerates your change management process by using TechSoft3D Hoops - the industry leading graphics engine - as the graphics workhorse. This new engine, together with the drawing registration function, accelerates the process and saves you precious time.
- **RealDWG™ Support**-With Vico Doc Set Manager you have 100% compatibility with Autodesk DWG™. Using RealDWG 2009 you are assured of compatibility with AutoCAD DWG design files; including support for the AutoCAD R14, 2000, 2000i, 2002, 2004, 2005, 2006, 2007, 2008, and 2009 software releases
- **Single Document Viewer**-To ease your sorting and matching processes, Doc Set Manger provides a single document viewer. The zooming and panning function are supported, as well as support for multi-page PDF files, DWG Xref and AutoCAD DWG Model and Layout views.
- **DWG Comparison**-Vico Doc Set Manager supports the newest DWG™ file formats. Compare full drawing sets or individual files. Refine your comparison using the Layout/Model space modes and graphic filtering options.
- **PDF Comparison**-The improved PDF comparison tool supports geometric comparison and text comparison; including support for multiple-page PDF files.
- **Graphic Viewing Modes**- Simply switch between the three graphic comparison modes to best suit your needs:
  Side-by-side mode - Presents the previous document version side by side with the new version using color codes for changed, deleted and new entities.
  Slider mode - Drag a slider bar across the screen to reveal each of the two overlay drawings
  Highlight Mode - Presents the two overlay drawings using color codes to identify new and old geometry
- **Manage Team Assignments**- Review each team member's assignments and check assignment status. Reassign tasks and add notes.
- **Document Register**- The new Document Register allows full control over large documentation sets, improves workflow, and increases efficiency. Using this feature, you benefit from- The ability to simultaneously manage multiple drawing sets. Full control over the directory structure and document organization. Automation of the drawing matching process. RFI management tools
- **Task History-** Gain full control over project changes. Doc Set Manager provides historical data throughout the whole of the project. Trackback every assignment and action made during the project
- **Clouding Changes and RFI Linking-** Improve your RFI management process by linking RFI to clouded changes. Using Vico Doc Set Manager, users can create RFIs based on a document template and efficiently track and manage the RFI process.
- **Copy Forward Clouds for Non-Answered RFIs-** Copy Forward support the tracking of RFIs across document versions, ensuring that you will not lose track of your RFIs. With this new feature, any clouds associated with the previous version of a document that has an RFI set to Pending will be copied forward to the new document. Additionally, any cloud linked to a document(s) that answer an RFI will be copied forward.

12.6 Appendix 6 – Commissioning Definitions (General Services Administration GSA, 2005)

Basis of Design (BOD): The documentation by the design team of the primary thought processes and assumptions behind design decisions that are made to meet the Owner's Project Requirements. The BOD describes the assumptions used for sizing and selection of systems (i.e. codes, standards, operating conditions, design conditions, weather data, interior environmental criteria, other pertinent design assumptions, etc.).

Commissioning (Cx): The National Conference on Building Commissioning has established an official definition of 'Total Building Commissioning' as follows:

> **"Systematic process of assuring by verification and documentation, from the design stage to a minimum of one year after construction, that all facility systems perform interactively in accordance with the design documentation and intent, and in accordance with the owner's operational needs, including preparation of operation personnel"**

Commissioning Agent (CxA): The qualified person, company or agency that plans, coordinates and oversees the entire commissioning process.

Commissioning Plan: The document prepared for each project that describes all aspects of the commissioning process including schedules, responsibilities, documentation requirements and communication structures.

Commissioning Record: The complete set of commissioning documentation for the project which is turned over to GSA at the end of the construction phase.

Construction Checklist: A checklist to ensure that the specified equipment has been provided, is properly installed and initially started and checked out adequately in preparation for full operation and functional testing.

Functional Tests: Tests that evaluate the dynamic function and operation of equipment and systems using direct observation or other monitoring methods. Functional testing is the assessment of the system's (rather than just component's) ability to perform within the parameters set up within the Owner's Project Requirements and Basis of Design. Functional tests are performed after construction checklists are complete.

Indoor Environmental Quality (IEQ): The artificial environment that exists in a building that includes the factors of thermal comfort, illumination, noise, ventilation and level of indoor air pollutants.

Issues Log: A formal and ongoing record of problems or concerns, as well as associated priorities, implications and resolutions.

Owner's Project Requirements: The documentation that provides the Owner's vision for the planned facility, functional performance requirements and expectations for how it will be used and operated. It also provides benchmarks and criteria for performance.

Recommissioning: The process of commissioning a facility beyond project development and warranty phases. The purpose of recommissioning is to assure the facility performs as expected over its useful life.

12.7 Appendix 7 – Systems to be commissioned (Sebesta Blomberg and Associates, 2013, pp. 23-27)

System	Description
Building Exterior Closure	
Foundations	Standard, special, slab-on-grade, vapor barriers, air barriers
Basements	Basement walls, crawl spaces, waterproofing, drainage
Superstructure	Floor construction, roof construction, sunshades, connections to adjacent structures
Exterior Closure	Exterior walls, exterior windows, exterior doors, louvers, grilles and sunscreens
Roofing	Roof system and roof openings
Note:	The emphasis on commissioning the above building envelope systems is on control of air flow, heat flow, noise, infrared, ultraviolet, rain penetration, moisture, durability, security, reliability, constructability, maintainability, and sustainability.
Specialties	
Patient Bed Service Walls	Medical gas certification and cross check, electrical connections
Equipment	
Parking Control Equipment	Barriers
Laboratory Fume Hoods	Laboratory Fume Hoods
Biological Safety Cabinets	Cabinet Certification
Packaged Incinerators	Combustion Testing, Cycle Certification
Conveying Equipment	
Electric Dumbwaiters	Interface with other systems
Elevators	Interface with other systems
Escalators	Interface with other systems
Material Delivery Systems	Interface with other systems
Pneumatic Tube Systems	Interface with other systems
Fire Suppression	
Fire Pump	Fire Pump, jockey pump, fire pump controller/ATS
Fire Sprinkler Systems	Wet pipe system, dry pipe system, pre-action system, special agent systems
Plumbing	
Domestic Water Distribution	Booster pumps, backflow preventers, water softeners, potable water storage tanks
Domestic Hot Water Systems	Water heaters heat exchangers, circulation pumps, point-of-use water heaters
Sewerage Pump Systems	Sewage ejectors
Wastewater Pump Systems	Sump pumps
Sanitary Waste Interceptors	Grease interceptors, acid neutralizers
General Service Air Systems	Packaged compressor systems, air dryers, filtration
Medical Air Systems	Packaged medical air compressor units. Outlet certification, cross-connection verification
Medical Vacuum Systems	Packaged medical vacuum units, outlet certification, cross-connection verification

Dental Air Systems	Packaged dental air compressor units, outlet certification, cross-connect verification
Chemical Waste Systems	Chemical storage tanks, neutralization systems, ventilation, process control
HVAC	
Noise and Vibration Control	[Noise and vibration levels for critical equipment such as Air Handlers, Chillers, Cooling Towers, Boilers, Generators, etc. will be commissioned as part of the system commissioning]
Direct Digital Control System	Operator Interface Computer, Operator Work Station (including graphics, point mapping, trends, alarms), Network Communications Modules and Wiring, Integration Panels. [DDC Control panels will be commissioned with the systems controlled by the panel]
Chilled Water System	Chillers (centrifugal, rotary screw, air-cooled), pumps (primary, secondary, variable primary), VFDs associated with chilled water system components, DDC Control Panels (including integration with Building Control System)
Condenser Water System	Cooling Towers, Fluid Coolers, heat exchangers/economizers, pumps, VFDs associated with condenser water system components, DDC control panels
Steam/Heating Hot Water System	Boilers, boiler feed water system, economizers/heat recovery equipment, condensate recovery, water treatment, boiler fuel system, controls, interface with facility DDC system.
HVAC Air Handling Systems	Air handling Units, packaged rooftop AHU, Outdoor Air conditioning units, humidifiers, DDC control panels
HVAC Ventilation/Exhaust Systems	General exhaust, toilet exhaust, laboratory exhaust, isolation exhaust, room pressurization control systems
HVAC Energy Recovery Systems	Heat Wheels, Heat Recovery Loops, AHU Integrated Heat Recovery
HVAC Terminal Unit Systems	VAV Terminal Units, CAV terminal units, fan coil units, fin-tube radiation, unit heaters
Decentralized Unitary HVAC Systems	Split-system HVAC systems, controls, interface with facility DDC
Unitary Heat Pump Systems	Water-source heat pumps, controls, interface with facility DDC
Humidity Control Systems	Humidifiers, dehumidifiers, controls, interface with facility DDC
Hydronic Distribution Systems	Pumps, DDC control panels, heat exchangers
Facility Fuel Systems	Boiler fuel system, generator fuel system
Geothermal Energy Direct Use Heating	Geothermal well, ground heat exchanger, geothermal pumps, heat exchanger, valves, instrumentation
Solar Energy Heating Systems	Solar collectors, heat exchangers, storage tanks, solar-boosted domestic hot water heater, pumps, valves, instrumentation
Facility Fuel Gas Systems	Witness Natural gas piping pressure testing, natural gas compressors, and storage, propane storage
Smoke	Atrium smoke evacuation, other smoke evacuation and smoke management systems, controls, interface with other systems (fire alarm), emergency operation.
Electrical	
Medium-Voltage Electrical Distribution Systems	Medium-Voltage Switchgear, Medium-Voltage Switches, Underground duct bank and distribution, Pad-Mount Transformers, Medium-Voltage Load Interrupter Switches,

Grounding & Bonding Systems	Witness 3rd party testing, review reports
Electric Power Monitoring Systems	Metering, sub-metering, power monitoring systems, PLC control systems
Electrical System Protective Device Study	Review reports, verify field settings consistent with Study
Secondary Unit Substations	Medium-voltage components, transformers, low-voltage distribution, verify breaker testing results
Low-Voltage Distribution System	Normal power distribution system, Life-safety power distribution system, critical power distribution system, equipment power distribution system, switchboards, distribution panels, panel boards, verify breaker testing results
Emergency Power Generation Systems	Generators, Generator paralleling switchgear, automatic transfer switches, PLC and other control systems
Lighting & Lighting Control Systems	Emergency lighting, occupancy sensors, lighting control systems, architectural dimming systems, theatrical dimming systems, exterior lighting and controls
Cathodic Protection Systems	Review 3rd party testing results
Lightning Protection System	Witness 3rd party testing, review reports
Communications	
Grounding & Bonding System	Witness 3rd party testing, review reports
Structured Cabling System	Witness 3rd party testing, review reports
Master Antenna Television System	Witness 3rd party testing, review reports
Public Address & Mass Notification S	Witness 3rd party testing, review reports
Intercom & Program Systems	Witness 3rd party testing, review reports
Nurse Call & Code Blue Systems	Witness 3rd party testing, review reports
Security Emergency Call Systems	Witness 3rd party testing, review reports
Duress Alarm Systems	Witness 3rd party testing, review reports
Electronic Safety and Security	
Grounding & Bonding	Witness 3rd party testing, review reports
Physical Access Control Systems	Witness 3rd party testing, review reports
Access Control Systems	Witness 3rd party testing, review reports
Security Access Detection Systems	Witness 3rd party testing, review reports
Video Surveillance System	Witness 3rd party testing, review reports
Electronic Personal Protection System	Witness 3rd party testing, review reports
Fire Detection and Alarm System	Witness 3rd party testing, review reports
Renewable Energy Sources	
Geothermal Energy Electrical Generation Systems	Geothermal well, DC-AC Inverters, storage batteries, turbine generator modules, switchgear, combiner boxes, instrumentation, monitoring and control systems
Solar Energy Electrical Power Generation Systems	Solar collector modules, DC-AC inverter, storage batteries, combiners, Switchgear, instrumentation, monitoring and control systems

Wind Energy Electrical Power Generation Systems	Wind Turbines, DC-AC inverter, storage batteries, combiners, switchgear, instrumentation, monitoring and control systems
Site Utilities	
Water Utilities	City Water Service Entrance, Backflow Prevention, Pressure Control, Booster Pumps, Irrigation Systems
Sanitary Sewerage Utilities	City Sanitary Connection, Waste Treatment Systems
Storm Drainage Utilities	City Storm Water Connection, Site Storm Water Distribution
Energy Distribution Utilities	Connection to Third Party Energy (Steam, High Temp Hot Water, Chilled Water) Supply Systems, Metering, Pressure Control
Transportation	
Active Traffic Barrier Systems	Witness 3rd party testing, review reports
Integrated Systems Tests	
Loss of Power Response	Loss of power to building, loss of power to campus, restoration of power to building, restoration of power to campus
Fire Alarm Response	Integrated System Response to Fire Alarm Condition and Return to Normal

Figure 24 Systems to be commissioned (Sebesta Blomberg and Associates, 2013)

12.8 Appendix 8 – Building Commissioning Agent responsibilities (General Services Administration GSA, 2005)

Certification Facilitation	Review contract documents to facilitate project certification goals (i.e. does design meet Energy Star requirements; does Cx meet LEED criteria, etc.)
Commissioning Facilitation	Review contract documents to facilitate effective commissioning (sufficient accessibility, test ports, monitoring points, etc.)
Commissioning Specifications	Verify that bid documents adequately specify building commissioning, including testing requirements by equipment type.
Control System & Control Strategies	Review HVAC, lighting, fire control, emergency power, security control system, strategies and sequences of operation for adequacy and efficiency.
Electrical	Review the electrical concepts/systems for enhancements.
Energy Efficiency	Review for adequacy of the effectiveness of building layout and efficiency of system types and components for building shell, HVAC systems and lighting systems.
Envelope	Review envelope design and assemblies for thermal and water integrity, moisture vapor control and assembly life, including impacts of interior surface finishes and impacts and interactions with HVAC systems (blast, hurricane, water penetration).
Fire Protection & Life Safety*	Review contract documents to facilitate effective Cx of fire protection & life safety systems and to aid Fire Protection Engineer in system testing to obtain the GSA Occupancy Permit
GSA Design Guidelines & Standards	Verify that the design complies with GSA design guidelines and standards (i.e. GSA P-100, Court Design Guide, Border Station Guide and Federal Facility Council requirements).
Functionality	Ensure the design maximizes the functional needs of the occupants.
Indoor Environmental Quality (IEQ)	Review to ensure that systems relating to thermal, visual acoustical, air quality comfort, air distribution maximize comfort and are in accordance with Owner's Project Requirements.
Life Cycle Costs	Review a life cycle assessment of the primary competing mechanical systems relative to energy efficiency, O&M, IEQ, functionality, sustainability.
Mechanical	Review for owner requirements that provide flexible and efficient operation as required in the P-100, including off peak chiller heating/cooling AHU operations, and size and zoning of AHUs and thermostated areas
Operations and Maintenance (O&M)	Review for effects of specified systems and layout toward facilitating O&M (equipment accessibility, system control, etc.).

O&M Documentation	Verify adequate building O&M documentation requirements.
Owner's Project Requirements	Verify that contract documents are in keeping with and will meet the Owner's Project Requirements.
Structural	Review the structural concepts/design for enhancements (i.e. blast & progressive collapse).
Sustainability	Review to ensure that the building materials, landscaping, water & waste management create less of an impact on the environment, contribute to creating a healthful & productive workspace, & are in accordance with Owner's Project Requirements. See also P-100 LEED requirements.
Training	Verify adequate operator training requirements.

12.9 Appendix 9 – Commissioning Team roles and Responsibilities (Michael Baechler, John Farley, 2011)

Team Member	Roles and Responsibilities
Owner	Identifies commissioning as a requirement for the project and includes a statement regarding design professional commissioning responsibilities and scope in the request for design services. Develop and commit to the Owner's Project Requirements. Selects the commissioning authority – 3rd party provider recommended. Ensures availability of operating staff for all scheduled instruction and demonstration sessions. Ensures appropriate involvement of the team members, including Electrical Engineer, Architect, and any other consultants as required, during the commissioning process.
Mechanical Engineer	Participate and assist in the development of the Owner's Project Requirements (OPR). Attend the Pre-Design and Design Phase coordination and review meetings. Review the Commissioning Plan and participate as appropriate in on-site commissioning meetings. Review and incorporate as appropriate the commissioning authority's comments from submittal reviews. During the acceptance phase of the commissioning process, be on site to review commissioning documentation, to witness functional performance tests, and to analyze the installation and its performance.
Mechanical Contractor	Cooperate with the commissioning authority and other team members to facilitate completion of the commissioning process. Attend commissioning meetings, foster communication between mechanical subs, and follow through on all action items. Provide estimate of cost to participate in the commissioning process. Ensure the controls contractor performs their commissioning activities. Provide instruction on equipment operation. Facilitate cooperation and participation of sub-contractors. Facilitate participation of major equipment manufacturers in start-up, testing, and training. Ensure correct and complete installation of all equipment and systems to ensure safe start-up. Prepare equipment for FPT's. Carry out the FPT's with the commissioning authority oversight. Correct deficiencies as necessary. Submit O&M manuals and conduct training. Generate As-Built drawings.
Controls Contractor	Include cost for commissioning in quoted price. Thoroughly review specifications to ensure compatibility with FPTs. Ensure proper sizing and functionality of equipment safety features, actuators, sensors, control sequences, valves and dampers. Attend commissioning meetings. Provide submittals and manuals to the commissioning authority. Demonstrate system performance to the commissioning authority. Provide thorough training to operating personnel. Participate in system verification and functional performance testing. Support TAB Agency as necessary.

TAB Agency	Provide cost of commissioning in bid documents. Attend commissioning meetings Submit proposed TAB procedures to commissioning authority and mechanical engineer for review and acceptance. Submit the final TAB report to the construction team. Participate in verification of the TAB report by the commissioning authority by re-testing 10% to 20% of the TAB measurements. Participate in O&M personnel training sessions.
General Contractor	Ensure the overall completion of the work. Participate as required in the HVAC commissioning process. Ensure the Mechanical Contractor performs all assigned HVAC commissioning responsibilities. Ensure the Electrical Contractor performs all assigned HVAC commissioning responsibilities. Ensure the cooperation and participation in the HVAC commissioning process of all other sub-contractors. Assign a representative to the commissioning team to attend meetings, ensure all action items are followed through on, and facilitate communication between team members.

5

Commissioning Authority	Plan, organize, and implement the commissioning process as specified. Prepare the commissioning plan, and ensure its distribution for review and comment. Revise the commission plan as required during construction. Chair commissioning meetings and prepare and distribute minutes to all commissioning team members. Coordinate commissioning activities among all contractors, subs, and suppliers. Develop and maintain an Issues Log. Monitor system verification checks and ensure the results are documented. Monitor controls point to point checks done by the controls contractor, and ensure the results documented. Observe all start-ups and initial system operations tests and checks. Direct the contractors to operate equipment and systems as required to ensure that all required functional performance tests are carried out for verifications purposes. Witness all functional performance tests and document results. Prepare and submit a Commissioning Report which documents all checks and tests done throughout the commissioning process, and the results obtained from each. Ensure all required O&M manuals, instructions and demonstrations are provided to the owner's designated operating staff.
Owner's O&M Staff	Review designs for maintainability Participate in periodic site walk-throughs Participate in commissioning process meetings Observe functional testing Participate in training sessions.