Master's thesis

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The Internal Perspective of Uncertainty Management in Multiconsult

Master's thesis in Project Management
Supervisor: Agnar Johansen
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Preface

This master thesis is written in subject “TBA4910- Project Management, Master Thesis” for the Department of Civil and Environmental Engineering, with the specialization in Project Management at Norwegian University of Science and Technology (NTNU) in Trondheim, Norway.

The purpose of this research is to examine the internal perspective of uncertainty management in a consulting company within the industry of construction, Multiconsult. This research will provide knowledge of the theory behind uncertainty, uncertainty management and how it implies to the consulting actors in the construction industry. The goal is to provide a model that recommends for a better internal uncertainty management practice in Multiconsult Trondheim.

I want to thank my supervisor from Multiconsult, Kjell Kristiansen, for being a supportive actor and helpful in time of need. Further, I want to thank Ragnar Scheide and all the informants at Multiconsult giving their time and providing valuable knowledge for this research. At last, I want to thank my supervisor at NTNU, Agnar Johansen, for guidance, constructive discussions, and support.

Trondheim, 12.06.2020

Mariya Hayday

Summary

This master thesis focuses on the internal uncertainty management practice of Multiconsult Trondheim. The research is conducted in a mixed method methodology with two parts. The first part contains a quantitative screening process, and the second part includes four separate case studies, document study, and a literature review. The purposed outcome of this thesis is to develop a model for a better internal uncertainty management practice.

Project management became a highly focused aspect in Norwegian construction projects after the discovery of oil on the Norwegian continental shelf. With the development of technology, projects tend to increase in their level of complexity. This typically leads to a higher demand for expertise in the management of uncertain aspects. Uncertainties can be defined as the lack of knowledge and is *"the difference between the amount of information required to perform a task and the amount of information already possessed by the organization"* (Chapman & Ward, 2007). They are present in aspects as cost, time, and quality, and are important to manage when obtaining successful outcomes. Uncertainties do not always need to be referred to in a negative matter. The positive aspects, also called opportunities, allows a more proactive management and can in some cases turn failure into success. It all depends on how uncertainties are identified, structured and managed.

This thesis has a goal of recommending a better uncertainty management practice for Multiconsult Trondheim. A mapping of the current state of uncertainty management practice was therefore done. The results introduce five elements describing the internal uncertainty management of Multiconsult Trondheim:

1. Checklists (for uncertainty evaluation and quality assurance)
2. Reporting and follow-up of uncertainties
3. Meetings regarding uncertainties
4. Roles and capacity
5. Internal economic system

These elements have been divided in two groups, depending on their impact on the uncertainty management practice. Element 1-3 affect the uncertainty management directly, while element 4-5 affect the uncertainty management indirectly. The reason for this division, is that the direct impacts are supported by uncertainty management theory, while the indirect impacts are not. These impacts are findings that have an influence on how projects are managed, which again reflects upon the internal uncertainty management.

After examination through the selected methods, the results show that uncertainty management in Multiconsult Trondheim has room for improvement. Uncertainties are usually left behind in the early phase of the project, which impairs proactive uncertainty management. The most important recommendations for improving the internal practice are therefore to:

- Implement a qualitative uncertainty analysis that can be used in different stages or phases of the project process
- Develop an action plan as a result of the uncertainty analysis
- Develop a process for management, follow-up and reporting of uncertainties
- Develop a process that proactive uncertainty management can be a part of

These measures will help keeping the management of uncertainties continuous and bring more awareness and focus to the threats and opportunities that can appear through a project course.

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1. Why manage uncertainties

The first chapter presents the background information and the purpose of the research. Further, the problem statement, research questions, limitations and the structure of the thesis are addressed.

The construction industry is currently facing challenges as urbanization, climate adaption and future transportation systems. This requires innovative solutions, competition on a local and a global scale as well as cooperation (Byggenæringens Landsforening , n.d.). Construction projects are growing larger by the year and getting more complex than ever, resulting in a higher demand for uncertainty management.

One of the key performance indicators in a construction project is the management of uncertainty (Project Management Institute, 2000). Uncertainty management has been a part of Norwegian project management history, as the discovery of oil on the Norwegian continental shelf led to the need of new ways to manage complex projects (Johansen, 2015). Many national programs have been initiated through the years, with the purpose to shed a light upon the tools and methods within uncertainty management that can improve the success-rate of projects (Torp, Johansen & Karlsen, 2008). The practices that have been developed, have all one thing in common; their focus is mainly on the project owner- and the construction contractor perspective.

The essence of this thesis is the design engineering perspective on uncertainty management. A literature review conducted for this purpose revealed that most of the theory found is written from the project owner point of view (Torp, et al., 2008), (Johansen, Olsson, George & Roslatdås, 2019). The intention is therefore to create a larger focus on uncertainty management in the design engineering sector.

Since 1908, Multiconsult has been one of the leading companies of consulting engineers and designers in Norway (Christensen, u.d.). Today, they are a world-wide firm and offer a full range of services such as consulting, designing, project engineering and -management and several supervision services for various types of projects.

Through the summer of 2019, I had a summer job at Multiconsult in Trondheim, in the department of Design Project Management. Here, I got to develop my interest for the subject whereas the head of department enlightened me upon their needs and wishes. I was told that

there was an interest for a further research on how the office is managing uncertainty in design projects, and which processes, procedures and actions have potential for improvement.

To explain the background for these needs, one must go back two years in history. In 2018, Multiconsult introduced a new corporate strategy, called 3-2-1 GO. GO stands for "Gain" and "Operation", which addresses the profitability challenge the company was facing at that time. Furthermore, this strategy showed seven main steps that, in total, would ensure the firm's ability to consolidate their position within the selected areas of great strategic importance to the corporation:

1. Regain a normalized level of profitability as foundation for further development
2. Take on a leading position in large and profitable projects, in collaboration with construction contractors and project owners
3. Take on a leading position and achieve higher profitability within the transport sector
4. Achieve higher profitability and selective growth within the energy sector in Norway as well as internationally
5. Further develop the leading position within health buildings in Scandinavia
6. Enable digital innovation and develop new business models with clients and collaborators
7. Develop flexible and profitable solutions for staffing, right expertise, and capacity

The operation-part of the strategy refers to the development of a more commercial internal culture focused on value making and profitability, as well as strengthened expertise and capacity of design project management (Multiconsult ASA, 2018).

This master thesis builds on my previous work in the subject TBA 4530 Specialization Project in Project Management and Construction Engineering at NTNU. The research elaborated upon uncertainty management, the triangle of project owner – construction contractor-consultant, how Multiconsult, the consulting company in focus, manage uncertainty and their detected challenges. This work has given an insight in the general internal management in Multiconsult Trondheim and attributed with information that was used in the screening process.

1.1 Problem statement and research questions

The basis for objectives of the thesis is the problem statement. The problem statement is a starting point for the research, and provides demarcation to the scope of the research (Larsen, 2012). As mentioned in Chapter 1, the needs were addressed according to the corporate

strategy, 3-2-1 GO. This strategy focuses on achieving the presented steps, whereas one of these is to develop flexible staffing solutions and ensure the right expertise and capacity. The "O" in the strategy, operation, focuses upon the internal expertise and design project management. When adding the strategy to the needs expressed by the head of department for Design Project Management, a problem statement defines:

How can Multiconsult improve their uncertainty management in order to achieve internal and external goals?

To achieve the objectives and answer the problem statement, two research questions have been defined:

The research questions are:

1. What elements characterize the internal uncertainty management in Multiconsult Trondheim, and how are these in line with current industry practices?
2. What parts of Multiconsult Trondheim's uncertainty management practice is good and can or should be developed further, as well as what parts are weak and need to be strengthened or developed?

1.2 Objectives of the research

In reference to the problem statement and the research questions, the objective of this thesis is to identify the characteristic elements of today's uncertainty management practice in Multiconsult Trondheim and suggest a model that improves the elements found. From a personal point of view, an objective is also to learn more about uncertainty management and how the identified project owner- methods can be implemented for consultants. To achieve these objectives, there is a need for:

- A research of uncertainty and uncertainty management theory
- A research of the designer's role in a construction projects, and the most common uncertainties
- Mapping of today's uncertainty management practice in Multiconsult Trondheim
- A detailed research including 4-6 case studies, that can provide an in-depth knowledge
- An external search for how similar actors to Multiconsult manage internal uncertainties

These needs will be developed into methods that will answer the problem statement and research questions. The methods are presented in Chapter 2.1.

1.3 Report outline

This master thesis consists of six chapters, in addition to the respected references and appendixes. The first chapter includes the basic information needed to understand the nature of the thesis, relevance of the research, scope, objectives, and the limitations.

The second chapter is dedicated for methodology used in the thesis and an evaluation of it. Here, the research strategy is presented, and the choices of methods for ensuring the fulfillment of the objectives are justified.

The theoretical framework of this thesis is presented in Chapter 3. Definitions of uncertainty and uncertainty management will be presented, followed by a theoretical view of how uncertainty management can improve project management. Several models and uncertainty analysis methods will be described in this subchapter. Further, an elaboration of why construction projects contain uncertainties and the most used project models and design agreements. Lastly, the most common uncertainties of design projects will be explained.

In the fourth chapter, the results of the research will be presented and discussed. This part will first consider the current uncertainty management practice of five different design engineering firms in the construction industry in Norway today. The next part will provide a description of the internal organization and the procedures related to each level in Multiconsult Trondheim. Further, the results from the screening process and the case studies are presented. The last part of this chapter introduces a model with complimentary recommendations for a better internal uncertainty management in Multiconsult.

Chapter 5 will discuss the results presented in Chapter 4 against the presented theory from Chapter 3 and evaluate the benefits and disadvantages regarding the findings.

Chapter 6 presents the conclusion for the thesis. This chapter will also evaluate the research from a holistic point of view. In addition, this chapter presents recommendation for further work, including research and development that will ensure a higher level of uncertainty management than this thesis considers.

The last section of this document contains the references and appendixes. List of appendixes follows:

Table 1 List of appendixes

Appendix 1	Questionnaire-results for screening
Appendix 2	Interview guide design project managers
Appendix 3	Interview guide design project directors
Appendix 4	Interview guide project owner/construction contractor
Appendix 5	Summary interviews design project managers
Appendix 6	Summary interviews design project directors
Appendix 7	Summary interviews project owner/construction contractor

1.4 Limitations of research

Multiconsult is the firm in focus of this thesis, and there are several constraints that had to be made in order to keep the scope at a manageable level. It was decided to focus only on the uncertainty management in Multiconsult Trondheim. This limitation implies that only a segment of the firm will be representative in this research, and the addressed case studies will not necessarily show how uncertainties are managed in design projects on a general Multiconsult- basis. Even though the head office of Multiconsult is in Oslo, the organizational system is consistent throughout the different offices. This means that the document study of internal procedures presented in this thesis will in theory apply to all offices. Since the Trondheim office is considerably smaller than the head office, the organizational structure and use of procedures are adjusted to the practice and client portfolio. This applies also to the management of uncertainty. In Oslo, the project management- department is significantly larger than it is Trondheim, leading to a larger focus and a better integrated uncertainty management than can be expected in the Trondheim office with approximately ¼ of head office size.

The latter limitation carried both benefits and disadvantages. A benefit was that the research will be able to go deeper into specifics and be less complex to manage, whilst the disadvantage was that the research will not cover projects executed by different leadership styles. This inhibited the opportunity to compare different offices against each other.

Another restriction was the list of relevant design projects for the screening process. These selected design projects were extracted from a list of all design projects executed by the Trondheim office, with profits and losses from 2018-2019. The list of screening candidates

was then limited to the 35 highest profits and losses. Repercussions of this limitation was first the fact that several of these design projects were active before 2018. This leads to uncertainties regarding the accuracy of the provided facts and their level of detail. Another uncertainty was that the results might not be representative for all projects of Multiconsult Trondheim, or Multiconsult Norway.

2. Research design and method

This chapter elaborates upon the methodology and research design used.

According to Larsen (2012), there are two main types of methods within social science: *qualitative* and *quantitative* methods.

The qualitative method is about the qualitative characteristics of a research object. Information obtained by this method can be through unstructured and semi-structured interviews, literature studies and observation. Results of such research are often referred to as *soft data.* Qualitative methods are often used in cases where the central problem is not specific, or to gain generic knowledge of a topic (Larsen, 2012).

The quantitative method has a more hypothetically deductive approach to obtaining information, meaning that the goal of the result is clear, and the central problem is specifically defined. In this method, tools as surveys, data gathering, standardized and structured interviews, give results called *hard data* (Larsen, 2012).

In addition, method triangulation or mixed method is often used. Triangulation of methods refers to use of different methods within the respected research, combining both qualitative and quantitative (Larsen, 2012). Mixed methods research design is usually divided into two phases. The first phase considers quantitative methods, where data is collected through surveys or questionnaires. According to Creswell (2014), the second part uses qualitative methodology to make a in depth research and to explain the hard data more detailed, which results in *an explanatory sequential mixed methods design.* Another approach is to make the qualitative research in the first phase, and then supplement this research with quantitative methods. This is called *exploratory sequential mixed method* (Creswell, 2014).

When conducting a research, the decision is not only made by selecting qualitative-, quantitative method or method triangulation (mixed method). A decision upon a type of study within these three options must also be made. In addition to the mentioned approaches, the alternative research designs are following:

Table 2 Types of quantitative, qualitative, and mixed method research designs

Quantitative	Qualitative	Mixed methods
Experimental designs	Narrative research	Convergent
	Phenomenology	Explanatory sequential
Nonexperimental designs	Grounded theory	Exploratory sequential
	Ethnographies	Transformative
	Case studies	

When choosing a research design, Creswell (2014) states that there are three main factors the decision must be based on. Firstly, is the nature of the problem statement and question(s). The second is the personal experiences of the author and the third, the audience. This means that prior to the selection of methodology and research design, it is important to establish the intention of the research and what is expected to convey.

2.1 Choice of methods and research design

To ensure that the research answers both the research questions and problem statement, a design model with the best suited methods was made. The research questions that are to be answered through these methods are:

1. *"What elements characterize the internal uncertainty management in Multiconsult Trondheim, and how are these in line with current industry practices?"*
2. *"What parts of Multiconsult Trondheim's uncertainty management practice is good and can or should be developed further, as well as what parts are weak and need to be strengthened or developed?"*.

The data collected in this research has both quantitative and qualitative nature. Quantitative method used in this research, shows a representative selection of respondents and their replies to the questionnaire. These results answer the first research question. Further, the data that was needed to answer the remaining question was of a more elaborative nature. Identifying how Multiconsult Trondheim's uncertainty management differentiates from other actors in the industry, was done through a document study. This method was also used for internal purpose. To understand why some aspects of the internal uncertainty management is good or weak, and how it is shown in internal management, elaborations from several points of view

were needed. This was not only to ensure objectivity of the research, but also to maintain diversity of opinions.

With the need of both qualitative and quantitative information to achieve the intended results, the best suited approach is to use *explanatory sequential mixed method design.* This design method allows to identify factors that make the foundation for a selection of case studies by obtaining quantitative results from a questionnaire, and then following up with purposefully selected design projects to explore the results in more depth through qualitative case study analysis.

Figure 1 highlights the research design of this thesis. The model shows the mixed method design- structure used in this research, including the quantitative and qualitative approaches used to answer the problem statement and research questions established in Chapter 1.1.

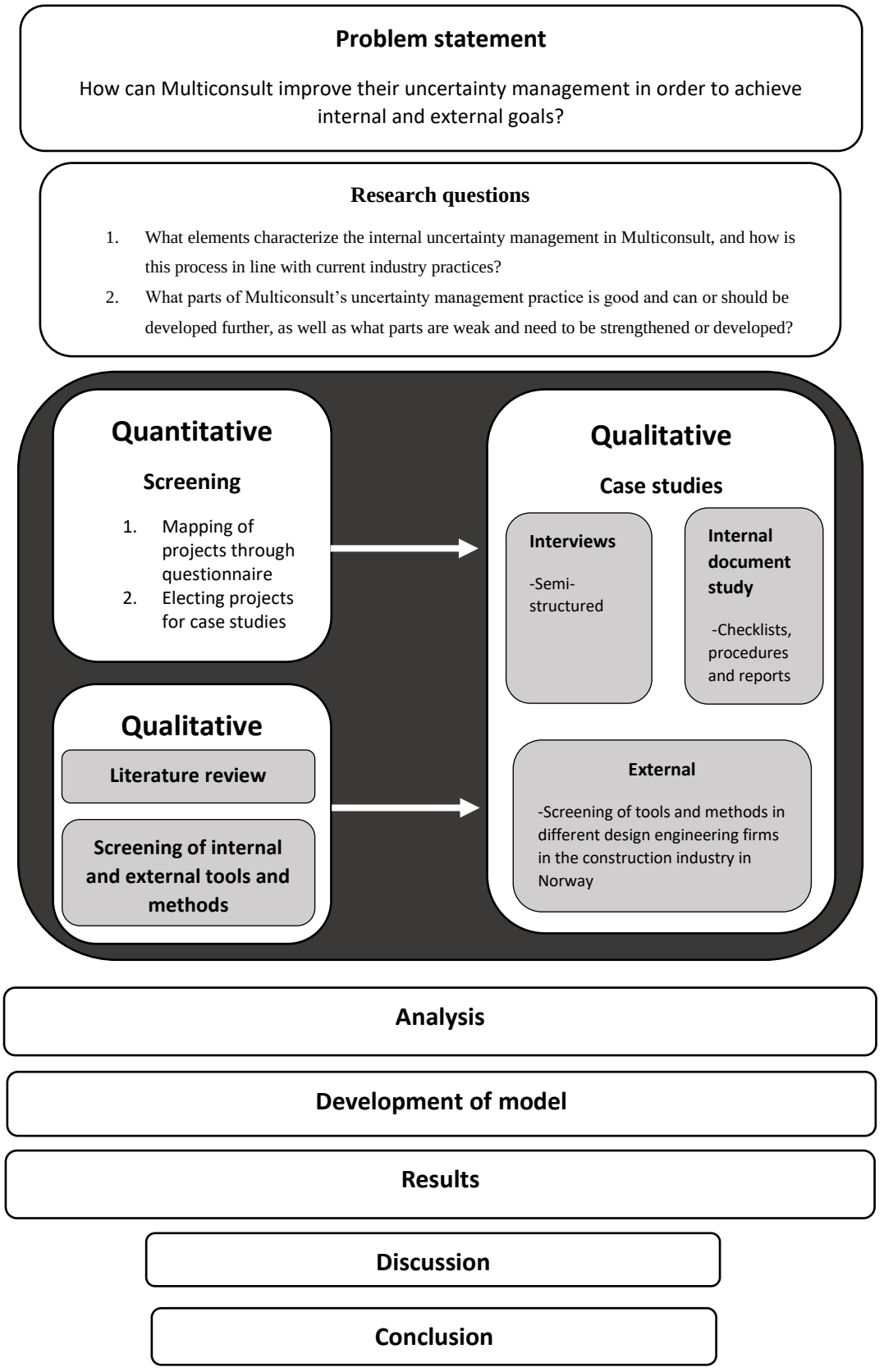


Figure 1 Research method design

The first part of the master thesis consists of a screening process mapping the 35 most and least profitable projects in Multiconsult Trondheim within the period of 2018-2019. This process was led by a systematic principle resulting into election of four cases which met all criteria presented in Chapter 2.2. The second part, the case studies, provided in-depth knowledge about the uncertainty management process in Multiconsult Trondheim, through semi-structured interviews and document study.

A literature review was conducted with the purpose to make a foundation of theory for the research. The search for external tools and methods among design engineering firms in the construction industry was done through a document study. This method was also used for acquiring internal documents that gave additional information about Multiconsult's uncertainty management process and verified information obtained by interviews.

The results from these methods, made a basis for a model with recommendations. This model focuses on the internal organization and the division of levels in Multiconsult Trondheim. Recommendations made, point to elements that needs to be strengthened and elements that should be preserved in future. The aim of the recommendations is to provide Multiconsult Trondheim awareness of their own practice and how management of uncertainties can participate in improvement of the internal uncertainty management as well as internal achievement of goals.

The data acquired through the research can be divided into *primary*- and *secondary data* (Larsen, 2012). Primary data is defined as data the researcher acquires through different data collection methods, while secondary data is found in research that has already been conducted. The data sources of this research are:

Table 3 Primary and secondary data used in this thesis

Primary data	**Details**
Questionnaire	Screening process
Interviews	Semi structured
Secondary data	
Internal documents of Multiconsult	Checklists, Templates for procedures Contracts Plans Tenders Meeting minutes
Articles	Norwegian and English
Books	Norwegian and English
Job announcements	Norwegian Within the five selected firms for document study
Doctoral thesis	Norwegian
Webpages	Of the selected five firms for document study
Reports	Norwegian and English

2.2 Quantitative screening process

The screening consists of a questionnaire with 46 questions, divided in five parts with separate focuses. The questionnaire is structured in a way provides the respondents a new question based on the answer at the previous. As the recipients of the questionnaire have Norwegian as their mother language, the whole form was written in Norwegian. This was also done to avoid misunderstandings of questions. See Appendix 1.

Part one: General

The first part of the questionnaire intended to map the general information of the selected design projects. Information as the title of the design project, whether the design project is characterized as simplified, standard, or custom control level of complexity, what contract form the design project followed, and if the design projects was terminated. The following questions were dedicated to map the economic situation of the design project. Whether the design project led to profit or economic loss, and the reasons for it.

Part two: Uncertainty in design projects

This part was designed to look closer into uncertainties in design projects, if they were identified, communicated, or documented. The aim was to map how many of the design project managers/-directors acknowledged that they detected uncertainties and what methods they used to communicate and manage them.

Part three: Uncertainty in projects

With the aim to uncover which detected uncertainties of the consultant's work affect the overall project, part three maps the design projects where this was relevant. The questions aim also to find the methods that were used to communicate these uncertainties to project owner/construction contractor.

Part four: Tools and procedures for internal uncertainty management in design projects

This part addressed the available internal tools and methods for uncertainty management in Multiconsult. Also, this part mapped how many design projects used change orders and why such changes occurred.

Part five: Uncertainty management

The last part of the questionnaire was about uncertainty management in general and which tools available offered more or less value to design project management in the respected company. This parts also opened for writing longer answers about what they felt is satisfying or should be improved regarding internal uncertainty management.

Elimination process to select case studies

In order to assess the suitability of the design projects to the research, several criteria were established prior the launch of the questionnaire. These criteria would make guidelines for what design projects could provide most value to the research and be selected for case studies.

Table 4 Criteria for elimination process of case studies

Criteria for election of case studies	Criteria for responses in screening for election
Minimum of one design project with standard management level	Avoid electing design projects where responses do not provide valuable information (such as "aa", "-" or ".")
Minimum of two design projects with design-build project models	
Minimum of two design projects with economic loss	
Both uncertainty evaluation- and quality assurance procedures must be completed	Avoid selecting design projects that are below 100 hours of work
Minimum of two design projects where uncertainties were identified	
Select design projects that have a contact person in the Trondheim office	

These criteria ensured diversity to the elected cases and facilitates a research that covers characteristic design projects as well as design projects with different challenges. Design projects that were categorized as "too narrow", would not give adequate information for the research and were therefore not recommended to select.

2.3 Literature review

The first qualitative approach to answer the research questions was a literature review. According to Creswell (2014), a literature review provides a framework for establishment of importance of the study at hand. The aim of the literature review was to show orientation of the research field, as well as establishing that the topic for the thesis are in literature limited, so that recurrence of previous research does not happen (Everett & Furseth, 2012).

The literature that has been obtained in this thesis, enlightens upon these aspects:

- Uncertainty and uncertainty management
- Methods and tools for uncertainty management
- Project models and contracts used in construction projects
- Uncertainties related to design phase and construction projects as a whole
- The role of designers in a construction project
- Theory of conducting research

Acquirement of literature

In addition to the literature found for this thesis, some literature has been collected from the specialization project report, mentioned in Chapter 1.1. The collected literature is mainly found in Chapter 3.1 and 3.4.
To ensure quality in acquired literature, several measures has been initiated. One of these was to use the online database of NTNU, called Oria. This database gives search results for both online articles and book that are available in the campus-library. In addition, Oria has a function in its software that shows whether a document is peer-reviewed. Another database that has been used, is Google Scholar. The approach to the found documents through this database has been to only use publications from large magazines or sites that are known for their quality and known uncertainty theory authors. All sources have also been evaluated according to the TONE-principal, explained in Chapter 2.7.
There has also been a focus during the literature review, to use various document forms such as master/doctorial theses, governmental project reports, parts of books and articles. This was to ensure diversity of points of view and angulation.
It has been decided to not focus on the age of the articles/books used as sources in this literature review. This is because most of the literature of uncertainty management, builds on each other. This means that in order to verify the source, the original source is used.

2.4 Case studies

According to Yin (2014), a case study is done in order to understand a real-world case and assume that this understanding is most likely to involve a contextual value for the research. The features of such a method are that a case study:

i. Copes with the technically distinctive situation in which there will be many more variables of interest than data points, and as one result
ii. Relies on multiple sources of evidence, with data needing to converge in a triangulation fashion, and as another result
iii. Benefits from the prior development of theoretical propositions to guide data collection and analysis

Four case studies have been elected though the screening process. In these case studies, semi-structured interviews and a document study have been conducted. These methods support the case studies by triangulating the information obtained and ensuring validity.

The information of the case studies made the basis of development of an internal model for a better practice and were compared to theory on the specific topic. The four elected cases are:

- **Case one: Geotechnical detail design at Lilleby- Fabrikkløkka**
    - A fixed price contracted project and a part of a design-build project model. Multiconsult's role was to consult and develop geotechnical design for residential buildings.
- **Case two: Regional mapping of quick clay in Molde and Rauma Municipality**
    - Fixed price contract as a framework agreement. Multiconsult's role was to map areas of quick clay avalanches.
- **Case three: State analysis of buildings of purpose in Trondheim Municipality**
    - Hourly commissioned contract as a framework agreement. Multiconsult's role was to provide state analysis of governmental buildings.
- **Case four: Technical solutions for a new building at NTNU Valgrinda, stage 2**
    - Fixed price contract as a part of a design-build project model. Multiconsult's role was to develop a technical design for a school building.

All case studies have been carried out in the aftermath of their main deliveries.

2.5 Interviews

An important aspect of qualitative methodology is that the researched aspect is more intangible and seeks for a subjective opinion (Larsen, 2012). Interviews were conducted in order to supply different points of views for each case and to provide experiences that are not documented and individual.

There have been conducted, in total, 11 interviews with design project managers, design project directors and project owners/construction contractors in the four case studies. Worth to notice is that in case four, the client was not interviewed due to the fact that this person is no longer working for the client. See Table 5.

All interviews conducted in this thesis were semi-structured. In semi-structured interviews, a series of questions are prepared in an interview-guide up front. These questions made a foundation that covers the problem statement of the thesis and the aspects that were included. The questions were asked in the same order to all informants, with prepared follow-up questions depending on the need. The advantage of having this structure was the focus on relevant information for the research and made it easier to compare answers post interviews.

When conducting semi-structured interviews, one can speak more freely about the aspects in the interview, and it opens for follow-up questions that benefit the researcher. These questions might also shed a light upon the experiences and undocumented details which can be valuable for further analysis.

Table 5 Specifics of interviews

	Case	Role	Duration of interview
Informant 1	Case 1	Project manager	45 min
Informant 2	Case 1	Project responsible	64 min
Informant 3	Case 1	Client	45 min
Informant 4	Case 2	Project manager	71 min
Informant 5	Case 2	Project responsible	60 min
Informant 6	Case 2	Client	40 min
Informant 7	Case 3	Project manager	39 min
Informant 8	Case 3	Project responsible	51 min
Informant 9	Case 3	Client	36 min
Informant 10	Case 4	Project manager	48 min
Informant 11	Case 4	Project responsible	59 min

The interviews were recorded after approval from the informants and transcribed so that citations could be easily used. The interview-guides were customized for the level of authorization of the informant, which means that there was an individual interview-guide template for the design project directors, design project managers and project owners/construction contractors. Such customization had a purpose of getting the right information that complied to the level of the informant's authorization. Prior to the interviews, the interview guides were tested on the supervisors of this thesis, both from NTNU and Multiconsult. The interview guides are presented in Appendix 2,3 and 4.

Also, there has been developed a structured summary of all 11 interviews, this can be found in Appendix 5, 6 and 7.

2.6 Document studies

To add knowledge and information to the case studies, regarding either the specifics of the design project or the procedures that are documented, a document study has been conducted. According to Bowen (2009), a document study is similar to other analytical methods in

qualitative research by requiring data to be examined and interpreted in order to gain understanding and develop empirical knowledge. Document analysis is particular applicable for case studies within qualitative methodology. This method is often used in combination with other qualitative methods, as a researcher is expected to draw upon several sources of evidence in order to gain convergence and verification of the information. This kind of method triangulation helps guarding against the side effects of having a research based on a single method or a single investigator's bias (Patton, 1990).

In this thesis, the document study has been conducted to uncover several aspects of information. Internally, the document study has been conducted through the internal database and covered analysis of documents shown in Table 6. Externally, a document study has been used to research other actors in the industry and how they are managing uncertainties, which tools they use, and what organizational structure they have for this kind of management. The external document study has been conducted through web-search and limited to design engineering firms within the construction industry in Norway.

Table 6 Analyzed documents

Internal document analysis	External document analysis
Contracts	Newspaper-articles
Correspondence, such as e-mails	Official websites of the companies
Documents of change	Job-announcements
Meeting notes	

2.7 Ensuring quality of methods and literature- an evaluation

To ensure good quality of the methods used, an evaluation of how these methods answer the problem statement and the research questions is provided in this chapter.

Validity and *reliability* are two terms that are central when addressing quality of methods and literature.

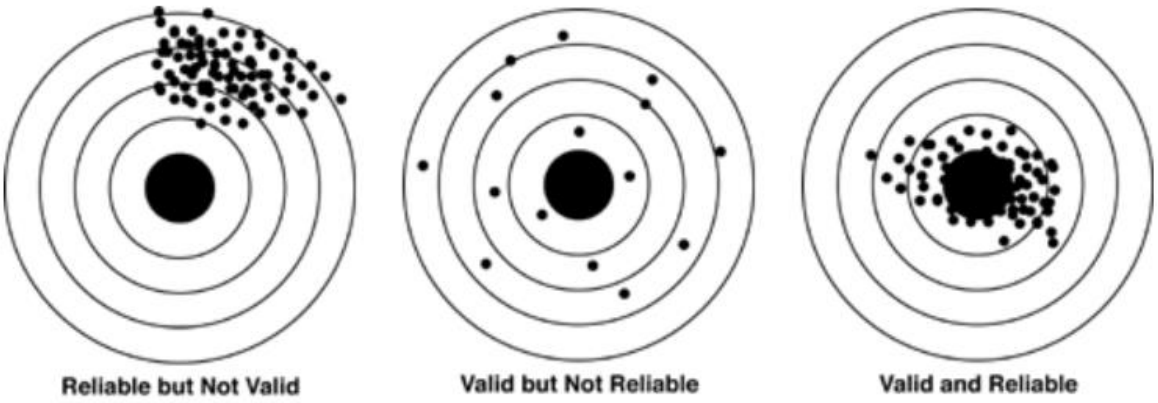


Figure 2 Illustration of validity and reliability. Derived from (Columbia CNMTL, n.d.)

According to Creswell (2014), validity is one of the strengths of qualitative research and is based on determining if the information in the literature is precise from the standpoint of the current research. When discussing validity, other terms that need to be considered appears. NDLA calls the terms to evaluate sources the TONE-principle (Overland, 2018):

Troverdighet- credibility

Objektivitet- objectivity

Nøyaktighet- authenticity/accuracy

Egnet- fit to purpose/suitability

Authenticity refers to the originality of the literature, whether the author has written the literature in his/her own words with correct language and grammar. If the literature contains many grammatical mistakes or illogical language, this will affect the credibility of the literature. In addition, the accuracy of the literature includes the detail level of the work.

Credibility refers to the trustworthiness of the literature. Questions as if the author is well-known, is the name of the author published, and if the literature is based on secure information. Peer-reviews are often a tool for ensuring this, where the literature is check for misinformation or irregularities.

Objectivity refers to the neutrality of the work, and whether is influenced by bias. Another aspect of objectivity is the purpose of the literature, whether the intention is to inform or convince the reader.

The TONE-principle also addresses *suitability* in literature. This aspect takes upon the research the literature is used for. Questions as if the literature suits the purpose of the current research and fits to the audience of the report.

Reliability as a term points to the consistent approach across researchers and methods. By anchoring the allegations with several sources, the work will be more reliable. This is also included in the TONE- principle under the credibility-aspect.

A literature review is seen as an important method in any kind of research. The reason for this is the foundation or background the literature builds on in a research. With proper knowledge of the subject in the research, the validity and reliability will be strengthened. The literature review is also a method for mapping the published knowledge of the area. If there is limited literature available of the theme, it can also become a limitation to the research. On the other hand, if there is a lot of literature published, it opens up for a possibility to compare and use elements from various research to tailor literature for the research at hand (Creswell, 2014).

Screening process

The screening was the first part in the research design, and made a groundwork for the further work, the case studies. Screening as a method, is considered in this thesis to be extensive. This is because a screening process in this context makes the mapping of design projects more efficient. The questionnaire was sent to 23 design project managers which were responsible for the 35 most and least profitable design projects in Multiconsult Trondheim in the period of 2018-2019. 19 out of 23 design project managers answered the questionnaire, which gives a response rate of 82,6%. 25 out of 35 design projects was responded to in the questionnaire as several design project managers were responsible for more than one design project that were selected for screening. After the results were collected, a weakness of the questionnaire-structure was detected. One is that in several questions, the respondents chose to answer alternative “other” to comment on why they answer “yes” or “no”. This results into a discrepancy between the actual number of “yes” and “no”- responses.

The challenge of conducting such a study, is the sincerity of the respondents. Personal experience is that recipients are often negatively set to questionnaires that might seem to take up a lot of time. Therefore, recipients may reply superficially to some of the questions, postpone responding or maybe type answers that are not informative.

Another challenge is the size of the population participating in the screening process. Even though the response rate was higher that 80%, the number of recipients is only 23. This means that if the results were to be used in hypothesis testing, the number of recipients would be too low to be representative. In this research however, the purpose was to use the screening process to statistically show the status of the most and least profitable design projects and use these results to proceed with a more in-depth research. If the number of recipients were larger, the obtaining of the questionnaire would possibly take more time and could lead to delay of the elimination process, which is not preferable.

Case studies

Case studies as a method is well suited for qualitative designs, where the it opens up for a more in-depth research (Creswell, 2014). When evaluating this method, the advantages are the coverage of the case studies. A possibility would be to choose one design project and do in-depth research to uncover all details regarding uncertainty management. Instead, there were four case studies conducted, covering a diversity of design projects. This approach made it easier to enlighten the positive aspects in the profitable design projects and the negative aspects in the unprofitable design projects. It can be argued if a larger number of case studies would make the research results more credible, for instance with six or eight cases. This decision will then be at expense of the time frame in this master thesis and would make it challenging to examine the case studies at the desired level of detail.

A challenge of this method in general is the personal bias that might arise. The researcher can be influenced by e.g. informants and develop a bias that might influence the outcome of the research. Therefore, it is very important to keep neutrality and analyze the information attained in an objective way.

Semi-structured interviews

A central part of the case studies was to conduct semi-structured interviews. This method is helpful for extracting points of views from various informants when asking identical questions. The advantage of having semi-structured interviews was that it supplied the research with experiences and personal opinions, above statistics, and results.

The largest challenge was tied to the quality of the answers obtained. Short answers, for instance, could indicate that the interview questions were poorly formulated, lack of knowledge or interest from the informant’s side. Another challenge of this method is bias,

whereas the informant could be giving answers that made their opinion/design project look good, focus on wrong aspects of the question or focus directed on only one aspect (Larsen, 2012).

Throughout the period of interviews, there has been a focus on minimizing the factors that affect the research negatively. The measure taken into action, was to make an interview guide with question that allow the informant answer freely, with additional follow-up questions. However, it must be stated that this research may be to a certain level affected by the challenges above.

Document studies

In addition to interviews, document study is a well supporting method in qualitative research (Creswell, 2014). In this research, the document studies have been used for attaining more information in each design project and cover the aspects that are not covered by interviews, e.g. details of design project and illustrations. The internal document study has also been used to verify the information obtained by interviews and ensure valid results.

This method has been helpful for the internal research, but for the external, it can be discussed if another method would have a better result. External document study had an aim to research how other similar companies as Multiconsult manage their uncertainties. The results showed only generic information that did not give any intel on how the internal processes are structured. This is an unfortunate result, that only gives a comparison of what services the different companies offer to clients.

To sum up

These methods have been chosen on the basis that they are applicable to answer the research questions. The literature review made a theoretical background for answering both research questions as it provided information on the topics that are important for the research. By using a screening, the main elements that characterize the internal uncertainty management were enlightened, whereas the case studies verified and added more in-depth information. The case studies enlightened upon what elements have showed to be valuable and should be strengthened, as well as what uncertainties were not managed or what cases led to economical loss. The document studies enable more information on the details behind the elected case studies as well as the information of five similar companies to Multiconsult in the industry, although the value of the external document study can be discussed.

3. Uncertainties, construction projects and the designer– a theoretical overview

This chapter presents the theoretical framework for the research. The chapter consists of six parts. Chapter 3.1and 3.2 addresses uncertainty, uncertainty management and how they are used to improve project management. Chapter 3.3 and 3.4 explain the most common project models, contracts, and uncertainties in construction projects. Chapter 3.5 and 3.6 show the designer's role in construction projects and uncertainties tied to the design phase.

3.1 What is uncertainty and uncertainty management?

Uncertainty is a term with many definitions. It all depends on in which context uncertainty is a part of, and from what point of view it is seen from. According to Chapman and Ward (2007), the generic definition of uncertainty is "lack of certainty" referring to lack of clarity, data, details and structure among others. Uncertainty is often connected to decision making, where certainty increases as decisions are made in projects. Torp et al.'s (2008) report is *"uncertainty is the difference between the information needed for a decision and the information available at the time of the decision"*, and is used as a reference to uncertainty in this thesis.

Uncertainty has two outcomes: *threats* and *opportunities*. A threat is defined as a negative uncertainty that is given by the probability for and the consequence of an unwanted situation (Torp, et al., 2008). An opportunity is on the other hand defined as a positive uncertainty and can affect a situation in a beneficial way.

According to Rolstadås and Johansen (2008), there are three main types of uncertainty: *contextual*, *strategic*, and *operational uncertainty*.

Contextual uncertainty refers to the external environment the project is a part off. These uncertainties can be tied to the market fluctuations, economic conditions, governmental and legislative changes.

Strategic uncertainty refers to the impacts on income or capital as a result of adverse business decisions. These uncertainties are beyond the project team's control but can be tied to the project owner or the stakeholders.

Operational uncertainty is connected to the internal circumstances that affect the project. Such uncertainties are tied to the time, cost, income, productivity, resource variation and technical solutions of a project. Operational uncertainty is the most common uncertainty-type that is discussed in projects. For this thesis, the operational uncertainties that are tied to the time and cost aspect are mostly emphasized on.

A term that often makes confusions when discussing uncertainty, is the term *risk*. (Achrol, 1988) states that *"risk is said to exist in situations where each outcome has a known probability of occurrence, whereas uncertainty arises where the probability of the outcome of events is unknown"*. The definition of the term led to an understanding that risk focuses on the negative outcomes that are known to happen, while uncertainty can deal with both negative and positive aspects since the outcome is unknown. In 2000, the Project Management Institute (PMI) stated in the Project Management Body of Knowledge (PMBOK) that risk was defined *as "an uncertain event or condition that if it occurs, has a positive or negative effect on a project objective"* (Project Management Institute, 2000). This means that risk also covers the positive aspects of uncertainty. Such an extension has led to discussion of differentiation of the terms among academics. The major concern was that practitioners still look at risk as a negative term and fail to exploit opportunities in projects that have potential (Kolltveit, Karlsen & Grønhaug, 2004). Figure 3, show the relationship between risk and uncertainty, illustrated by Rolstadås, Hetland, Jergeas & Westney (2011).

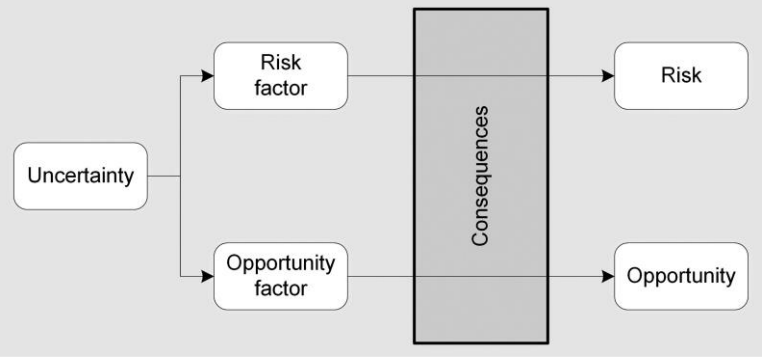


Figure 3 Relationship between uncertainty and risk (Rolstadås, et al., 2011)

A literature review, conducted by Kolltveit et al. (2004) showed that time has led to a interchangeable use of the terms, and academics as Torp et al. (2008) as well as Hillson (2009) still point out that risk should focus on the negative "hazards". Uncertainty is therefore an umbrella- term that includes risk as the negative outcomes and opportunities as the positive outcomes, and emphasizes that the outcome cannot be fully predicted (Johansen, et al., 2019).

Uncertainty Management

According to Chapman and Ward (2001), uncertainty management is about *identifying*, *analyzing* and *managing* uncertainties that leads to consequences as threats or opportunities. This means that uncertainty management includes to explore and understand the source of uncertainty before managing them in a structured manner. In Torp, Karlsen and Johansen's report (2008), representatives from their case study, point out that uncertainty management is a continuous process where uncertainties that might have a positive impact on the project are followed up and analyzed. The process of uncertainty management is therefore described as a continuous process for systematic identification, analyses, management and supervision of uncertainties through the life cycle of a product or a service (Torp, et al., 2008). The uncertainties that are identified, analyzed, and managed are all tied to the cost, income, and time aspect of a project.

The uniqueness of a project makes it challenging for the uncertainty management process to be a "one size fits all"-concept. According to Austeng , Torp, Midtbø, Helland & Jordanger (2005), the process needs to be adjusted according to the goals of the project.

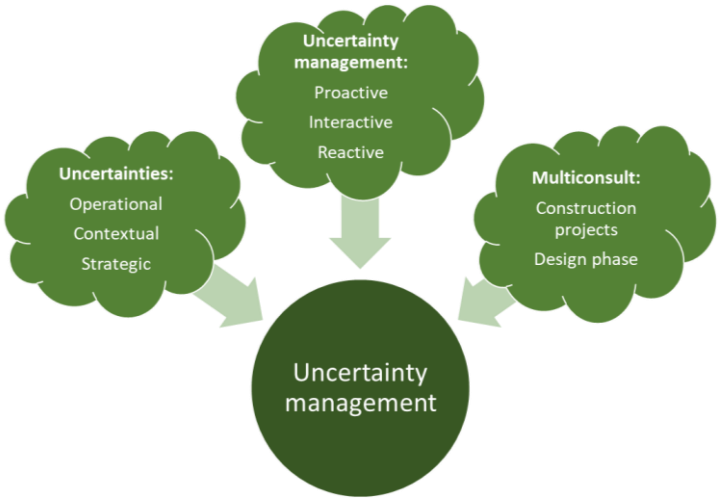


Figure 4 Illustration of the focus areas in this research.

In line with the concept of uncertainty, the concept of uncertainty management has several aspects. According to Torp, Bølviken, Aslesen, Fritzsønn, Haagensen, Lombardo & Saltveit (2018), uncertainty management includes three different ways of thinking; *proactive*, *interactive* and *reactive*. Proactive uncertainty management is about the analysis of uncertainty up front, in order to make actions before certain scenarios play out. Interactive uncertainty management is about being able to manage these scenarios as they happen, while

reactive uncertainty management is about the understanding of scenarios that have happened and is about repairing, exploiting opportunities and lessons learned.

The focus of this thesis is stated to be primarily on the design phase of a construction project and how uncertainties are managed seen from a design firm's perspective, Multiconsult Trondheim. The aspects of proactive, interactive, and reactive uncertainty management will therefore be key indicators when recommending measures for a better internal practice later in this thesis.

3.2 How can uncertainty management improve project management?

Uncertainty management can be considered as a small part of project management, yet it has a significant influence on the project's ability to achieve its goals (Klakegg, Torp, Swärd, Jordanger & Langeland, 2018). It has also been a focus in the Norwegian approach for project management for several decades. Research programs such as PS 2000, Concept and the PUS (Practical Uncertainty Management in a Project Owner Perspective) - project have all enlightened upon uncertainty management (Torp, et al., 2008). PS 2000 was a research program initiated in 1994 with the goal to develop competitiveness of Norwegian industry through methods for identification, evaluation, planning and execution of projects. Concept was a research program initiated in 2000 with the aim to develop quality assurance scheme to prevent underestimation of costs in early phase of projects. PUS was a research program initiated in 2006 with the aim to develop knowledge and insights of how uncertainty management processes should be done in project execution phase. The aim was to explore how to take advantage of opportunities and manage all threats in an appropriate manner (Johansen, 2015). These programs share a goal of strengthening the uncertainty management processes in the project owner organization.

There are many models that explain the process of uncertainty management. Several of the methods in these models share similarities, while others have their own distinctive character. Some methods are comprehensive and include both qualitative and quantitative processes, while others focus mainly on one of these (Austeng, et al., 2005). An example of such models, is the model for uncertainty management develop by the PUS-project:

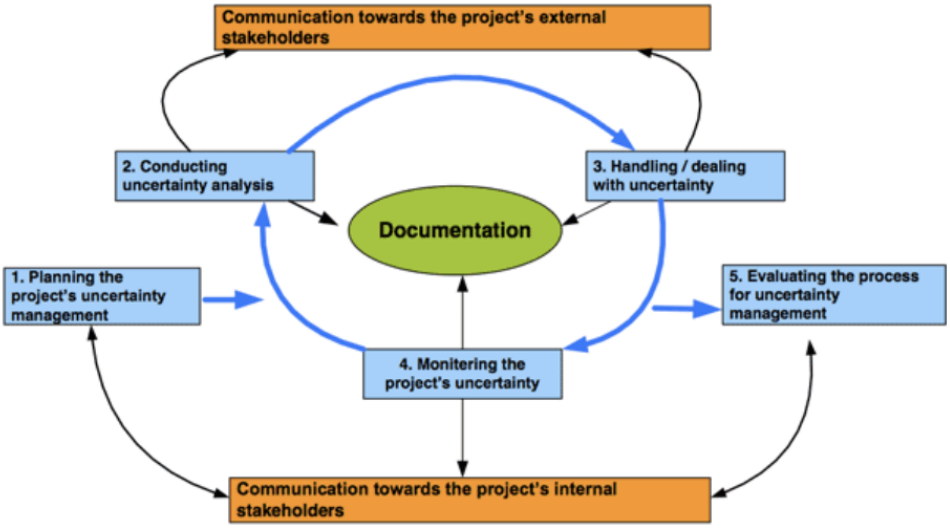


Figure 5 PUS' uncertainty management model. Derived from the official website of PUS.

This model shows that the steps of managing uncertainties works as a loop. First, the planning of the project uncertainty management is done, thereafter the uncertainty analyses are executed, and the uncertainties are followed up and managed. Monitoring of uncertainties follows the actions upon uncertainties and lastly the process of uncertainty management is evaluated before the process returns to step one.

When uncertainty analyses and the actions/follow-ups of uncertainties are ongoing, this model emphasizes on communication towards stakeholders/project owner. While the planning of uncertainty management, monitoring of uncertainties and evaluation of the process emphasizes on communicating to internal stakeholders of the project. These steps are periodically or continuously repeated, depending on the need of revising. Regardless of the steps and actions, this model shows that an important aspect is to document the process of uncertainty management. It can in be through uncertainty registers, monthly reports or revising of plans (Torp, et al., 2008).

The basis for development of the uncertainty management model in Figure 5, was three internationally recognized models by PMI, ISO 16085 and Chapman and Ward's SHAMPU (Shape, Harness, Analyze and Manage Project Uncertainty)-process (Torp, et al., 2008). ISO 16085 however, focuses on risk management in IT-projects, and will therefore not be a part of the further elaboration.

PMI's six step model for uncertainty management and uncertainty evaluation shows the chronological process of uncertainty management in a project from planning to follow-up and

management. This model is a generic framework that emphasizes on the qualitative and quantitative uncertainty evaluations and explains that the results from qualitative uncertainty analysis can be used as a basis for quantitative analysis.

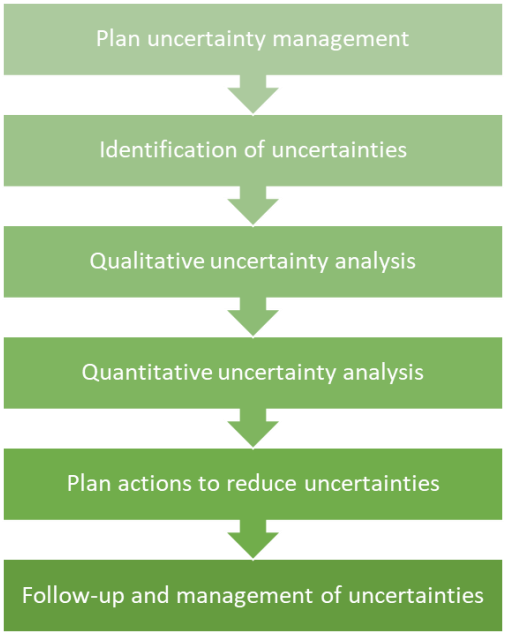


Figure 6 Illustration of PMI's six step model for analysis and management of uncertainties

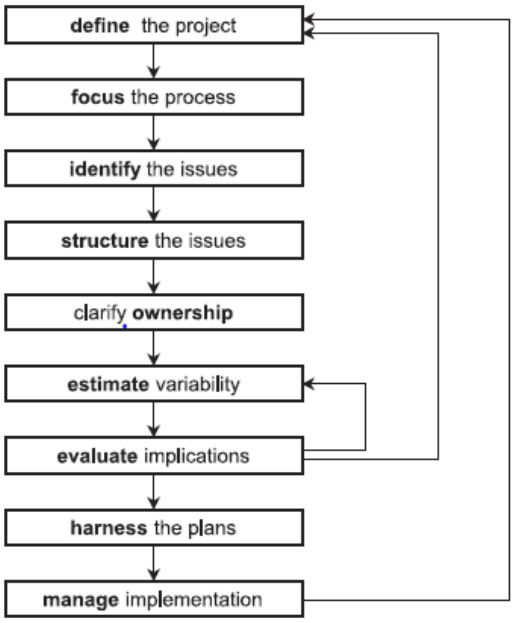


Figure 7 SHAMPU-process (Chapman & Ward, 1997)

Chapman and Ward's (2007) SHAMPU- process, consist of nine steps, whereas step 3 to 7 focus on uncertainty analyses and step 1, 2, 8 and 9 focus on management of uncertainties. This process starts off with shaping the project strategy for uncertainties and follows up with harnessing the plans, which involves developing uncertainty management plans on a tactical level. The next step focuses on analyzing the uncertainties through qualitative and quantitative analysis and managing the implementations for uncertainties.

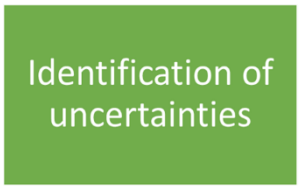
A common factor for the PUS-model, PMI's model, and the SHAMPU-process, is that they are developed for the project owner perspective. This means that the elements of these models need to be evaluated in order to implement for an uncertainty management model from a design actor-point of view. The relevant elements and a suitable model based on the stated theory will be presented in Chapter 4.1.

The phases/steps of the models addressed, share a common line of actions. They all address planning of uncertainty management, identifying the uncertainties and do analysis based on

the identifications. Thereafter, they suggest planning actions for the uncertainties from analysis results, follow-up and manage these uncertainties. Another important aspect which is only visualized by the PUS-model, is the evaluation of the uncertainty management process that have been conducted. This step helps attaining lessons learned and is an impact that attributes to uncertainty management improvement.

To gain a deeper understanding of the content of the different steps in an uncertainty management process, an elaboration of the common steps presented by the models in this chapter follows. The steps consider PMI's six steps for uncertainty management and analysis and PUS-models step of evaluating the uncertainty management process. These steps will also make a theoretical foundation for development of a model for a better uncertainty management practice in Multiconsult Trondheim.

Step one is to plan the uncertainty management. Here, a project uncertainty infrastructure is established, along with a project specific uncertainty management plan. The plans include establishments of the terminology used throughout the project, the roles and responsibilities, the work breakdown structure and the ground rules for what types of uncertainties should or should not be included further on. The method that is used in this phase is planning meetings with the project key members (Pritchard, 2015)



The next step is to identify the uncertainties. The contract, the defined scope and the work breakdown structure must be determined and available in order to identify uncertainties. Identification is usually done by describing the events that may have an impact on the project, either negatively or positively. The impacts are also described for each uncertainty. The tools used in this phase is usually brainstorming, checklists, SWOT-analysis, assumptions analysis and documentation reviews (Pritchard, 2015).

The third step is to do a qualitative uncertainty analysis. This step is done in a non-numerical matter, and prioritizes uncertainties based on their possible impact on the project (Project Management Institute,

2000). Various types of uncertainty matrixes focusing on cost and consequence are representative for this step. The analysis is described in Table 7.

Quantitative uncertainty analysis

Fourth step is to conduct a quantitative uncertainty analysis where the most significant risks or the project as a whole according to the numerical impact and probability (Pritchard, 2015). The analysis is further explained in Chapter 3.2.1.

Plan actions to manage uncertainties

The fifth step is to plan actions to manage uncertainties. In this phase, the actions for management of the uncertainties is determined, evaluated, and communicated to all responsible parties (Pritchard, 2015). The planning of actions needs to be adjusted to the altitude of the consequence, realistic to preform within the framework of the project and be cost-effective. The strategies used in this phase are to either avoid, transfer, inhibit or accept uncertainties (Project Management Institute, 2000).

Follow-up and management of uncertainties

The fifth step is to follow up and manage the uncertainties that are planned for. This phase focuses on management of the identified uncertainties, monitoring residual uncertainty, identification of new uncertainties and evaluation of the implemented measures to control uncertainties. This process is ongoing through the entire project, and is affected by the change, maturity, identification, or elimination of uncertainties. The tools used in this phase are revision of uncertainty measures, earned value analysis, measurement of technical performance, uncertainty databases and uncertainty matrixes (Project Management Institute, 2000).

Evaluate uncertainty management process

The last step is to evaluate the process of uncertainty management. Evaluating has an aim of giving feedback of the uncertainty management quality to the stakeholders, both external and internal. This includes information of the uncertainties, their causes, the actions to manage them and the results of management. Such feedback will help improving

future uncertainty management procedures and generate more knowledge of uncertainties (Torp, et al., 2008).

3.2.1 Performing uncertainty analysis

PMI's uncertainty management-model mentions two different types of uncertainty analyses: *quantitative* and *qualitative* uncertainty analyses.

The quantitative uncertainty analysis is a numerical analysis of the probability of each uncertainty and the consequence of it. These consequences are thereafter measured against the goals of the project and the total scope of uncertainties in the project. This analysis uses methods as Monte Carlo simulations and three-point estimation to determine the probability of achieving a specific project goal, quantify how vulnerable the project is for uncertainty and decide the cost and time reserves that can cover eventualities (Project Management Institute, 2000). Quantitative uncertainty analysis is usually a service many companies provide for project owners. For these actors it is more important to know how much the uncertainty will cost if the outcome will become a reality and the probability of this outcome.

The qualitative uncertainty analysis focuses on prioritization of uncertainties and analyze the possible impact of them. This is done to decide the importance and indicate for actions to ensure further uncertainty management. Evaluation of the quality of available information is also an important part of this method. This is to specify the assessment of different uncertainties. PMI (2000) also states that this analysis should be repeated throughout the project life cycle in order to keep the uncertainty situation updated.

In this thesis, it is decided to look closer into qualitative uncertainty analysis. The reason for this is that the quantitative part of the uncertainties is less relevant for the internal uncertainty management of Multiconsult Trondheim. The focus is to bring more awareness to the qualitative part of the uncertainties, and to evaluate the impact the uncertainties will foremost have on the internal project.

The identified uncertainties are in qualitative uncertainty analysis evaluated by four steps:

Table 7 Qualitative Uncertainty Analysis, derived from (Project Management Institute, 2000)

Steps	How	Why
1.Evaluate the probability and impact of the uncertainties	Using terms as "high impact" "moderate impact" and "low impact" and or percentage against cost or time aspect	To identify the uncertainties that require large actions and close follow-ups
2.Implement the uncertainties into a probability/consequence matrix with ranking of the uncertainties	Validate the uncertainties based on a combination of the scales of uncertainty and consequences, using either the terms (as shown above), numbers (0.1, 0.2, 0.3 etc.), colors or percentage	Systematization of uncertainties and ranking with respect to the importance of an action
3.Testing of consequences towards project assumptions	Testing against two criteria: 1. The assumption's stability 2. The consequences for project if the assumption is incorrect	To map the effect of the consequences to the project
4.Ranking by data precision	Ranking each uncertainty by four requirements: 1.The understanding of the uncertainty 2.Available data about the uncertainty 3.The quality of the data 4.Reliability and integrity of the data	Qualitative uncertainty analysis requires correct and balanced data to increase its value to the project management

The qualitative analysis should be done either monthly or every second month, while the quantitative uncertainty analysis should be based on the qualitative and be repeated every half year of the project (Johansen, et al., 2019). Many firms specialize in quantitative uncertainty analysis, and doing the calculations requires both expertise and training.

3.3 Why do construction projects contain uncertainties?

"A project life cycle is a series of phases that represent the evolution of a product, from concept to delivery, maturity and to retirement" (Project Management Institute , 2013). To keep a better control of large and complex projects, a common approach is to split the project into phases.

The phases of a project have nearly the same structure as the projects itself, with main parts as an early phase, an execution phase, and a termination phase. Usually, these phases are structured in a sequential matter, meaning that one phase usually ends before the next starts (Project Management Institute , 2013) Some models divide a project into three phases, while other divide projects in to both five and eight phases (Bygg 21's phase norm "Next Step") , depending on the detail level that is required to explain the project, see Figure 8.

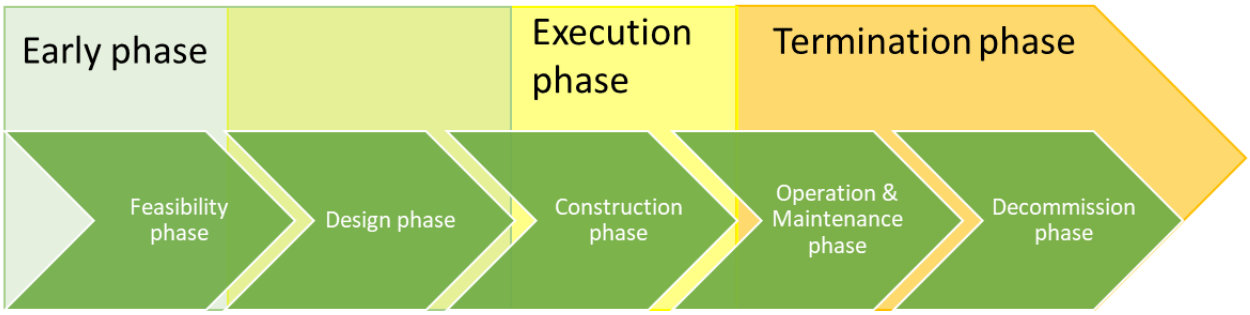


Figure 8 Illustration of project phases

Figure 8 is inspired by Farooq and Bubshait's (2001)'s article focusing on design offices' working practice together with owners and contractor. The model is a generic setup for construction projects and is highly relatable for Norwegian construction projects.

According to Eikeland (2001), the level of uncertainty in construction projects are usually at its highest in the feasibility phase, and decreases until the construction phase, where the uncertainty should be relatively low. In order to understand the uncertainties in any phase of a construction project, one must understand the cause of the uncertainties. Uncertainties takes on various forms, depending on the type of project.

As construction projects are in focus of this thesis, uncertainties in relation to these projects are addressed. The common factors that lead to these scenarios are many, but according to Hillson (2009), the most characteristic are:

- **Complexity:** In projects with higher complexity, there are also a higher number of uncertain factors of events that might have several outcomes. The variables of a construction project will control the uncertainty-level.
- **Uniqueness:** Every project has some elements that have not been before or that are unique for the specific project. Such elements are naturally associated with uncertainty.

- **Assumptions and constraints:** When scoping a project, many guesses about the details that are not clarified must be made. Assumptions are the scenarios that one believes may or may not occur, while constraints are the actions one is told to do or not to do. Therefore, uncertainty is tied to the outcomes of assumptions and constraints.
- **Human nature:** As projects are manage by humans, they are a factor tied to uncertainty. Humans may in times be irrational, which can cause a source for uncertainty on a larger scale.
- **Stakeholders:** Stakeholders can be both causes of risk and solution to uncertainties. The expectations they may have, can contradict other expectations, leading to a higher uncertainty of the outcome.
- **Changes:** A natural part of any construction project is changes, either they are internal or external. These changes are often not foreseen, which leads to a higher uncertainty in the project.

Many academics have established different listings with categorical uncertainties in projects (Wideman, 1992) (Rolstadås & Johansen, 2008). Another example is Johansen et al.'s (2019) risk and opportunity categories. Here, uncertainties are divided into several levels: first-, second- and third order consequences and opportunities. The first order uncertainties are detected in the execution and delivery phase, while second and third order uncertainties arise in the operational phase and apply to the business goals of the project owner and society goals. The first order uncertainties are therefore more relevant for this study.

Table 8 First order consequences- opportunities in the execution of the project (Johansen, et al., 2019)

Factors		From project start-up to project completion
External factors	Market	New actors in the market: lower price in the bids than expected
	Resources	More and better resources • unexpected access to skilled personnel 58 +: company's retired/older staff members
	Strategic alliance	Access to new methods or technology
	Technology	New product with better performance New technology in the market
Internal factors	Owner priority	More resources Easier access to key resources
	Resources	A big project ends in the mother organization
	Management	Better management performance (than usual) • good planning process/decision-making • good execution More or better resources than planned or expected
	Team performance	Better team performance • more work done in less time • higher productivity than planned
	Design	More robust design that fits with other solutions the company has chosen
	Technology	New product with better performance New technology in the market
	Schedule	Less rework Faster execution than planned (better performance than expected) Faster delivery of products than planned Faster delivery of services
	Cost	More money than expected from the owner Lower prices from the bidders Cheaper material: price of the material goes down Currency: cheaper than expected Inflation and taxation: more favorable than expected
	Quality	Fewer mistakes (than usual) Less rework Fewer change orders (than usual)

Johansen et al.'s (2019) listing of the uncertainties shows a contrast in uncertainty categorization theory. Most academics tend to focus on the negative aspect of uncertainty, covering the risks and their consequences. Johansen argues that the opportunity-aspect of

uncertainties is under communicated and that opportunities should have a larger focus in uncertainty management.

3.4 Project models and design agreements

Multiconsult Trondheim are usually included in two types of project models: *design-build* and *design-bid-build*.

In design-build contracts, the contractor undertakes to carry out both the design and execution of the contract. The right of responsibility can underlie the contractor or be distributed among other subcontractors for design and execution. The project owner transfers all responsibility to the contractor, which means that all communication towards the project owner goes through the contractor (Direktoratet for Byggkvalitet, 2008). Figure 11 shows that in such project models, the consultants are controlled by the entrepreneur. The project model is legislated by NS8407, which gives guidelines for all parties involved.

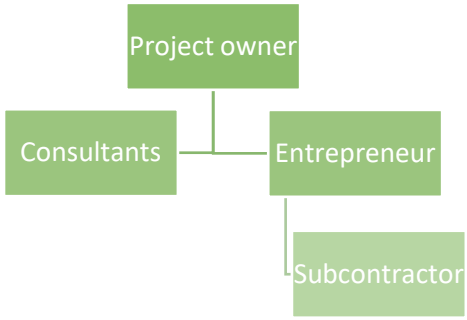


Figure 9 Illustration of design-bid-build organization

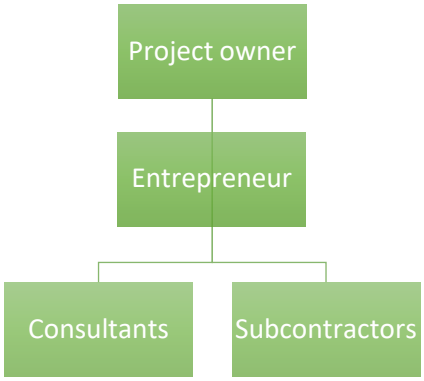


Figure 10 Illustration of design-build project model

In design-bid-build contracts, the project owner is responsible for all or parts of the design phase. The project owner usually contracts architects or consultant for this phase but can also carry out the design independently (Direktoratet for Byggkvalitet, 2008). After the design phase a contractor is hired by e.g. competitive bidding with several candidates. The contractor that is chosen by the project owner based on standardized criteria and has more flexibility to hire subcontractors if it is needed.

When contracting consultants in these project models, there are mainly two types of agreements that are frequently used: *partnership agreements* and *total design agreement* (Lædre, 2006). Partnership agreements are structured in a way where different actors join forces in order to complement each other's expertise. In total design agreements (usually

called framework agreements), the contractor is handed all of the responsibility of the design phase, and has the option to hire sub-contractors within this agreement and project (Lædre, 2006). The Norwegian Standards that apply for design services are NS 8401 and NS 8402. NS 8401 *"General conditions of contract for design commissions"* is a standard for fixed price design contracts, while NS 8402 *"General conditions of contract for consultancy commission projects with remuneration on the basis of actual time taken"* is a standard for hourly commission projected contracts.

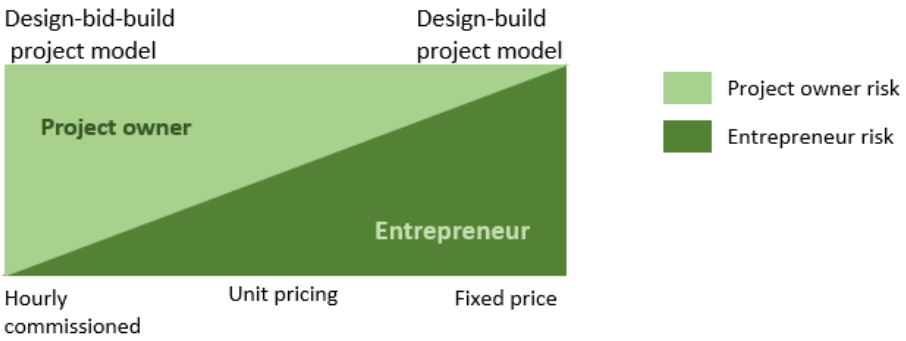


Figure 11 Illustration of project owner/construction contractor risk in projects (Vegdirektoratet, 2017)

For design engineers, both contract form and project model will affect the risk they are taking on, as well as the risk the project owner/construction contractor is taking on. Figure 11 shows the risk the design engineers take on when being contracted with hourly commission project or fixed price. The figure shows that the lowest risk lies in hourly commission projects. This is because design engineers make an estimate for how many hours the work will require, and if the more hours are needed, they may request change orders. In fixed price projects, design engineers must establish the scope of work and the number of hours that will be used. The risk is greater in this type of contract agreements since the design engineering firm loose part of the profit if they exceed this framework and make profit if they complete the work within the frame.

3.5 The role of design engineers in construction projects

When looking at the different roles in a construction project, it is also natural to explain the role of the design engineers in more detail.

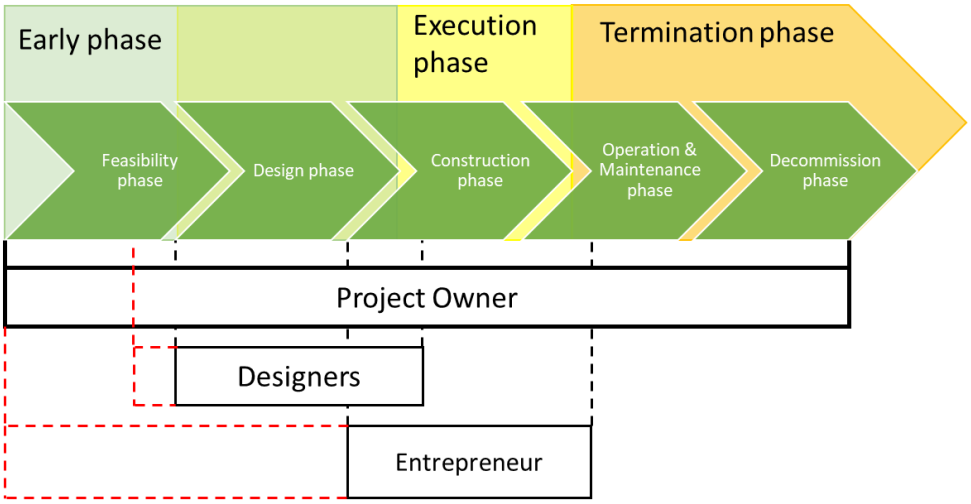


Figure 12 Illustration of contracting in projects

When the different parties in a construction project enters it, depends on the chosen contract form. In a design-build the contractor is hired in the early phase (shown in red in Figure 12) while in design-bid-build contract, the contractor is hired for the execution phase. Also, the designers can be hired at an earlier point than the design phase. Where consultants are needed to form the tender, they are hired for the early phase (Lædre, 2009).

The main roles of consultants are according to Eikeland (2001):

- Develop a decision basis for the project, including models and descriptions for project owner and building authorities
- Develop a basis for the execution phase
- Develop a basis for contracting

The reason for calling designers consultants is the consultancy they provide for the client (project owner or contractor) in addition to the solutions they design. The designer poses the available expertise at the client's disposal, to consult upon both desired and possible solutions. In such situations the designers also evaluation of the consequences of the solutions they purpose. The processes are often influenced by uncertainties that need to be mapped and reacted upon in order to give an evaluation that will help the client make reasonable decisions.

The designers are also often appointed as design managers. This role includes management and coordination of expertise when it comes to designing, as well as the progress of the design phase (Eikeland, 2001).

3.6 Design phase uncertainties in construction projects

The design phase in construction projects carry uncertainties tied to both the owner of the project and the construction contractor which is to carry out the design in the construction phase. In the design phase the uncertainties need to be managed in alliance with the other parties, depending on the project model, to minimize the consequences that might have repercussions bearing larger costs for the future phases.

According to DODGE Data and Analytics (2018), the seven major sources of uncertainty in building design and construction projects are:

1. **Owner-driven changes**: Since construction projects are completed over a long period of time, it is not unusual that requirements change between phases. In some cases, the project owner's expectations are unclear leading to uncertainties and higher possibility of alterations in future
2. **Design errors and communication gaps:** In projects where many subcontractors are hired, the communication between them is important. In the design phase, the engineers might include calculations or elements that they consider as important, while in further phases the next contractor does not take these elements into account. Also, there are many components that are not fully describes in the engineer's work product, which means that communication will help minimize uncertainties.
3. **Construction coordination:** A unique design will in most cases require some modifications or rework during construction. Some important elements can be overlooked in the tendering process and not included in the initial contract, which makes a preconstruction planning of a critical importance.
4. **Unknown site or building conditions:** When design engineers make a detailed design in a project, some unexpected site conditions may appear in the construction phase. These uncertainties are important to minimize, because their consequences may be fatal, but they can also be hard to identify if site information is not available or unknown.

5. **Design or documentation mistakes:** Usually a design made by design engineers or architects are not 100% perfect. Small errors can appear in calculations or inconsistencies in documents.
6. **Accelerated design schedules:** As the demand for shorter design schedules is becoming a competitive advantage, both with respect to time and cost, the consequences can result into more mistakes, coordination issues and miscalculation of costs.
7. **Delays in procurement, fabrication, or assembly:** These factors affect all the included parties in a construction project and lead to disruption of the project owner's business operations.

When it comes to management of these uncertainties, the practices may vary. A common practice is to involve the clients as much as possible, so that the uncertainties are at least known and managed in a transparent way (Farooq & Bubshait, 2001). Many design companies offer uncertainty analyses for the project owner and have implemented their own practice based on experienced from a long period of time. The findings of uncertainty management in five Norwegian firms are explained in Chapter 4.2.

4. Uncertainty management in the design engineering industry

This chapter presents the results of the research. The first part explains the organizational structure of Multiconsult Trondheim, and what procedures considering management of uncertainties are required. Further, this chapter addresses the findings from document study of external tools and processes, with a focus on five different design engineering actors in the Norwegian industry. The third part presents the results from the screening process and continues to the fourth part that elaborates upon the case studies. This chapter concludes with an introduction to a model for a better uncertainty management practice in Multiconsult Trondheim.

4.1 The organization of Multiconsult seen from an uncertainty management point-of-view

Each office of Multiconsult follows the generic organizational system, called "Styringssystemet". This system shows the structure of the authorities and the process of design projects, from tendering to termination, in addition to all governing documents. The organizational structure of Multiconsult is structured in a hierarchical way, shown in Figure 13.

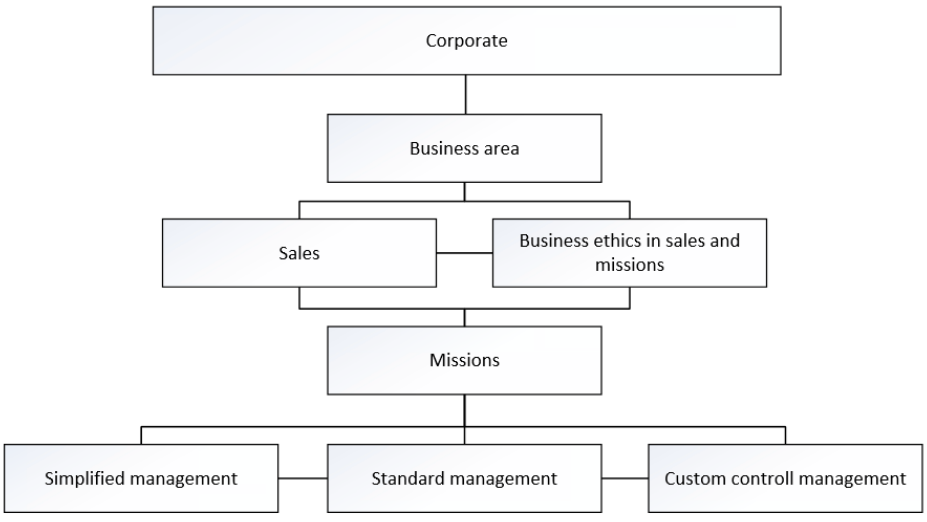


Figure 13 The organizational structure of Styringssystemet

When a design project is initiated in Multiconsult, it is first registered in the financial software, Deltek Maconomy. This software is used for project finance and time registration. A

supporting tool for reporting with inputs from Maconomy, is the software BizView. Design projects are thereafter categorized by the cost-frame, complexity, and involvement of resources, and further applied to either simplified-, standard- and custom control management.

The registration of a design project is usually done by the *design project manager* (oppdragsleder). Along with the design project manager, a *design project director* (oppdragsansvarlig) is appointed. This usually happens in the tendering of the design project. A design project manager has a daily manager role of the design project and is also a part of the design team. The design project responsible on the other hand, has a more superior role in the design project and is responsible for the achievement of the project goals. The design project accountable- role is usually filled by the head of departments, which also gives this role an opportunity to be a mentor for the design project managers.

When a design project is initiated, several procedures and checklists that are required to be done. The main checklists that needs to be filled out, are the uncertainty evaluation- and the quality assurance checklist. The purpose of these checklists is to identify uncertainties and evaluate plan of execution. Usually, these checklists are done prior or in the kick-off meeting with team members.

In addition, other procedures and checklists regarding safety, health, and work environment, as well as sustainability in design projects are filled out in design projects, they are applicable for.

The findings presented in Figure 14, show that the procedures and the checklists for all project complexity levels are the same. The content of the checklists is adjusted to the complexity level, but the activities done are identical. The uncertainty evaluation checklist focuses on the uncertainties tied to the contract, client, organization of design project and deliveries. The quality assurance checklist requires that the uncertainty evaluation checklist is completed and focuses further on assuring that aspects as budget is decided upon, that the governmental requirements are met and that the necessary risk assessments have been done.

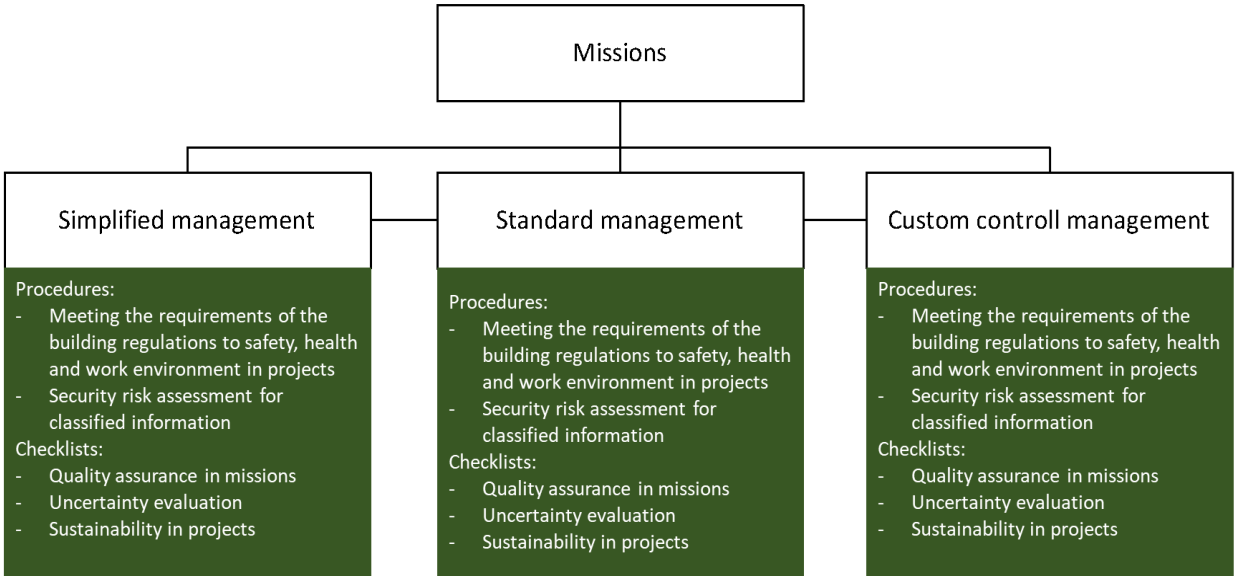


Figure 14 Procedures and checklists in design projects

When looking at the required procedures and checklist in the context of uncertainty management process, the findings show that the checklists are covering only step one and two of the common uncertainty management process steps presented in Chapter 3.2. Today's practice of uncertainty management in Multiconsult Trondheim, covers the planning for uncertainties and the identification of them:

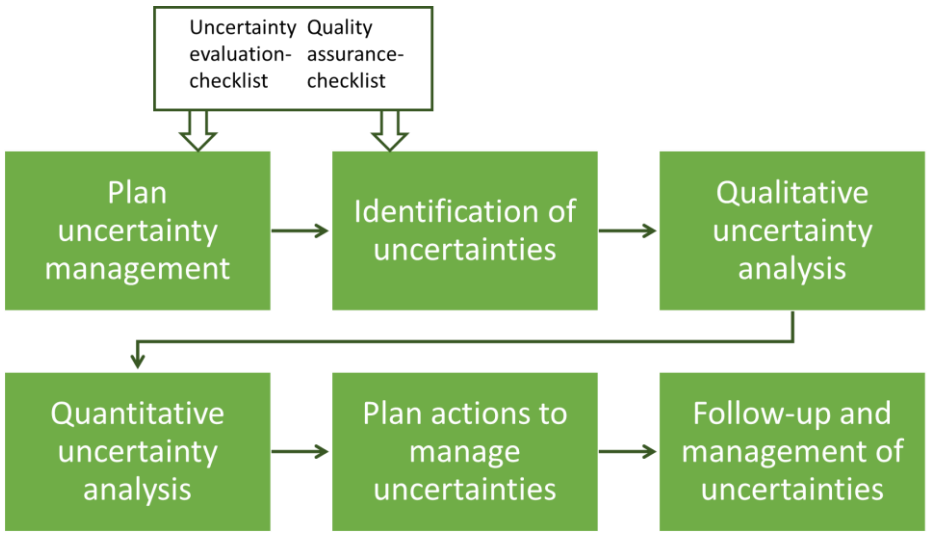


Figure 15 Illustration of the internal procedures against the common steps of uncertainty management process

It can be argued that the status of internal uncertainty management process is not ideal. As the procedures used in projects, cover less than half of the process that is described by theory, the following steps after the identification of uncertainties are missing. The recommendations for bringing the remaining four steps into the internal uncertainty management process of Multiconsult Trondheim elaborated in Chapter 4.5.

4.2 Uncertainty tools and practice in the construction industry

To examine how other actors in the same industry manage uncertainties and what tools they use, a document study has been conducted. The results show five design engineering firms within the construction industry and how they manage uncertainties. There are several firms that are specialized in project management services with methods for uncertainty management and uncertainty analysis and offer these services for project owners (Austeng, et al., 2005). Examples of such firms are Metier Scandinavia, HR Project, OPAK, WSP and Dovre. These are not included because they provide services for uncertainty management for project owner and not for engineering firms, leading to the lack of consultant's perspective.

The results of the document study focusing on external tools and methods for uncertainty management has shown that there is limited information on internal practice available. Companies that have been in focus show only what they offer for clients and to not reveal their internal procedures. Therefore, this chapter will provide generic information of what services companies similar to Multiconsult offer when it comes to uncertainty management.

Insenti

In 2014 the Norwegian, Oslo-based consulting company, Insenti, established uncertainty management as a business area within their internal organization (Saltnes, 2014). Insenti is an upcoming competitor in the industry and believes that uncertainty management in projects will have a positive effect on the results. The uncertainty management focus in the business area will mostly be on commercial risk, but it can also be applied for time, reputation, and external environment.

As the company already is at a professional level of project management, their approach to implementing uncertainty management in projects is to use methods and tools to illustrate uncertainty and discuss possibilities with client. The vision is to use uncertainty management to reduce project cost and time usage. As a result, Insenti offers risk- and uncertainty analysis, as well as advisement in all project phases (Insenti, n.d.).

COWI

COWI is a Danish- based consulting company, that is also one of the top five largest companies in the industry in Norway. No official online record state that they have a dedicated department or focused business area that works only with uncertainty management. They have on the other hand used the project management- department for management of uncertainty in the individual projects. In some projects only uncertainty analyses have been

necessary, while in others larger measures has been initiated to ensure sufficient management of the uncertainties (COWI, n.d.). All though, one can see from the job announcements the Project Controller-role in COWI includes being responsible for *"compilation and follow-up of the project's uncertainty management and -register, including risk assessment, costs and general follow-up of measures throughout the duration of project."* (COWI, 2019)

Rambøll

Rambøll is a Norwegian consulting company that offers a wide range of services in the constructing industry. In difference to the other companies listed above, Rambøll has their own training program for project- and design project management. Within this program, one of the aspects that are in focus is uncertainty management, change management and contract management. The goals with this program are to provide understanding of the entirety of project management and give insight to different processes of the project as well as understanding of success factors of projects (Rambøll, n.d.). Implicit, this will mean that the uncertainty management in Rambøll is a subarea of the project management division. In similarity to COWI, Rambøll clarifies in job announcements that for Project Controllers, one of the main areas of work is development and maintenance of uncertainty management in projects (Rambøll, n.d.).

Norconsult

Norconsult is also one of the largest consulting companies in the industry in Norway. One of their focus areas is the subsidiary Norconsult Information Systems. Here, Norconsult has developed a series of software that is used for among others project management and uncertainty management, such as ISY Prosjekt Plan and ISY ByggOffice (Norconsult, n.d.). Many companies use this software daily, for instance Multiconsult.

In addition, Norconsult has a department of project administration that handles uncertainty analyses, design- and project management and risk analyses (Norconsult, n.d.). One of the more focused aspects in Norconsult is the risk analysis. Norconsult's method to analyze risk is first to identify potential hazards and definition of relevant scenarios and their consequences. This information is then used to calculate environmental risk and individual risk, which gives results to be used in specified software to analyze consequences for the identifies scenarios (Norconsult, n.d.).

WSP

WSP is a Canadian consulting company that merged with the Norwegian firm FAVEO in 2015. FAVEO was the largest actor withing project management in Scandinavia and was known for development of uncertainty management processes for Norwegian projects.

This company offers consultants for projects and companies where uncertainty management is needed. The aspect of uncertainty management is in WSP a piece of a total project management package that is offered for large projects. The package includes a step-by step assistance that follows the phases of a project.

The aspect of uncertainty management includes a wide range of services as uncertainty consultants, custom made uncertainty analyses, sensitivity analyses and integration of uncertainty management into the management regime of the project (WSP, n.d.). According to WSP, the goal of uncertainty management is to reduce the exposure of risk and increase the chances for achievement of possibilities (WSP, n.d.). This company attaches a great importance to uncertainty analyses and uses tools customized for the project at hand. In this process, a proactive management is key. For clients, the uncertainty analysis is performed according to the standardized 9-step method.

What does the results of the study say?

This study has showed that there are two ways of conducting uncertainty management: externally and internally. The external management of uncertainties can be viewed as a product or a service companies provide for their project owners. These services are advertised and directed for clients that might need such support in their projects. The internal uncertainty management is about the actions done to identify, analyze and monitor uncertainties tied to the internal execution of a project introduced as the operational uncertainties in Chapter 3.1. The information of the internal uncertainty management of the five respected firms was not obtained, which means that this study has showed uncertainty management as a product, not an internal process. Such products can also be found in Multiconsult Oslo, where the diversity of services is larger than in the Trondheim office. A further discussion of the results is found in Chapter 5.4.

4.3 Findings from screening process in Multiconsult Trondheim

The screening process includes a questionnaire that was issued on February the 24th. 6th of March, the results were final with a response rate of 82,6%. This means that 19 of 23 project managers divided at 25 out of 35 chosen design projects responded to the questionnaire.

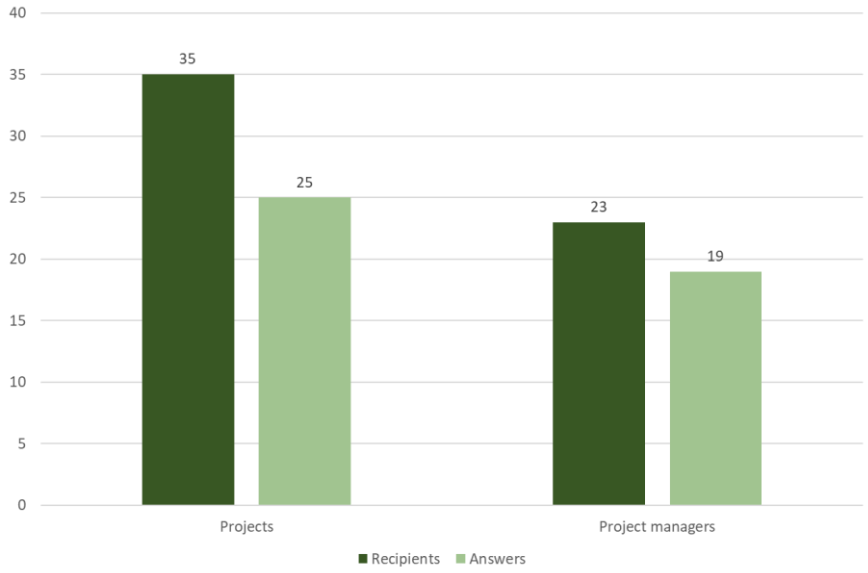


Figure 16 Illustration of responses in screening

Before elaborating upon the results from further responses it is important to clarify that:

- Not all questions from the questionnaire have been included in this chapter, but it is emphasized on highlighting the most relevant questions and responses.
- Some respondents chose to elaborate upon their responses, some of these elaborations are included in this chapter, while others who are found not that relevant are excluded. Full results with answers are found in Appendix 1.

General

The first part of the questionnaire focused on the general aspect of the design projects in focus.

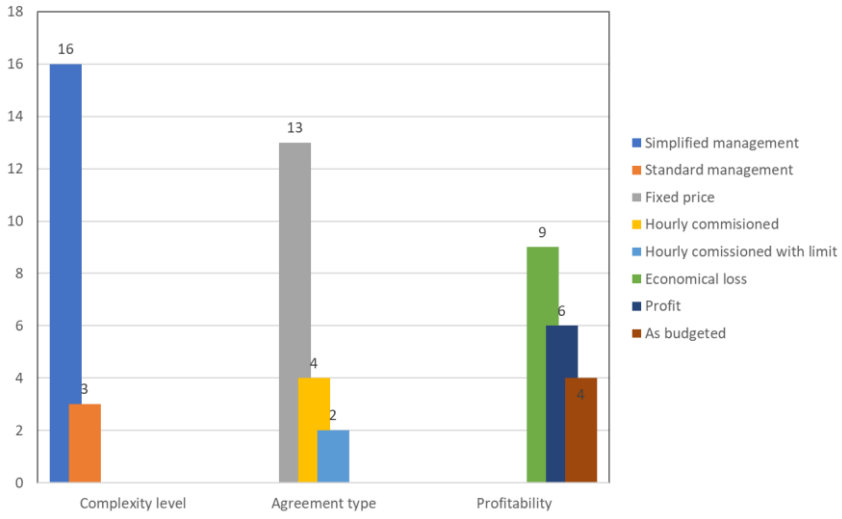


Figure 17 Illustration of responses regarding complexity level, agreement type and profitability

Results show that the majority of the design projects were characterized as simplified management and commissioned projected by NS 8401- fixed price. Figure 17 also shows that most of the design projects ended in financial loss. The top three ranked reasons for these losses were:

1. Inadequate management of resources
2. The design project was more comprehensive than assumed
3. Replacement of personnel

Complexity of the design project is often hard to predict. When the expectation clarification between project owner and Multiconsult is not fully agreed upon in the early phase, this can turn out as an operational uncertainty. The losses might therefore indicate inadequate uncertainty management.

Uncertainty in design projects

The results show that in most of the design projects, uncertainties were discovered in the early phase. Four respondents answered that they did not identify any uncertainties, and one commented that this was due to the standardized nature of the design project. Another comment was that the design project-team evaluated the design project in early phase and concluded that there were no uncertainties. The remaining no-responses did not have any

complementary comments (see Figure 18). One project manager responded that he/she did not know if there were any uncertainties. This was substantiated by the fact that there has been a change of design project manager, and this design project manager entered the design project in a later phase.

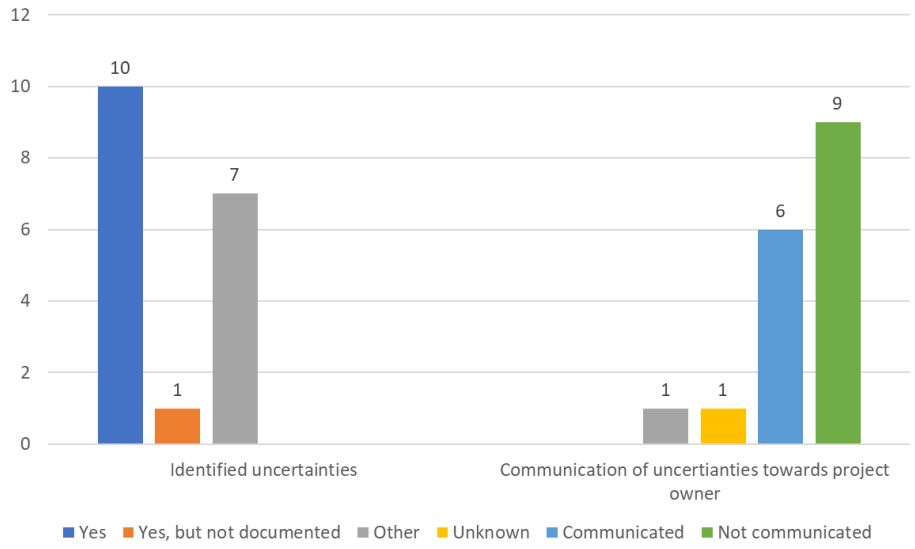


Figure 18 Illustration of identified and communicated uncertainties in design projects

Figure 18 also shows one response saying that the uncertainties were identified, but not documented (marked in orange). The design project manager's comment stated that in fixed price contracts there are far too often uncertainties regarding economics and deliveries, that are not worth documenting. Respondents who communicated uncertainties to project owner, state that the most common way the uncertainties were communicated, were through meetings (in 5 out of 6 design projects) and through e-mails (in 4 out of 6 design projects).

The respondents stating that they did not communicate uncertainties to project owner, replied that this process would be easier if it was clarified what uncertainties the project owner is responsible for. Another comment stated that a better description in tender documents would help, as well as fixed status meetings.

On a scale from 1 to 6, the respondents feel that communication of uncertainties to project owner only had a value of 3 for the design project. The communication of uncertainties has influenced the design projects by more focus on good communication and increased awareness of uncertainties.

Uncertainties on a construction project level

Figure 19 show that in 11 of the design projects, uncertainties regarding the construction project were identified, and in all cases these uncertainties were communicated to client. Here, the most used methods of communication were meetings (in 7 out of 8 design projects) and e-mail (in 7 out of 8 design projects).

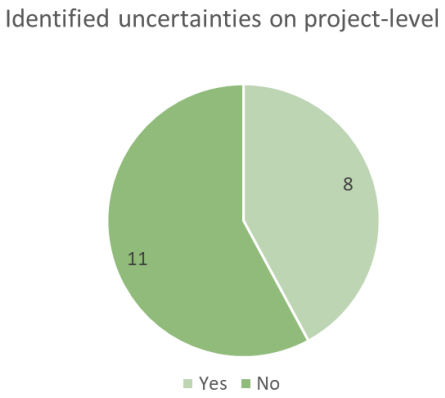


Figure 19 Illustration of identified uncertainties on project-level

The measures initiated to reduce negative uncertainties were depending on the nature of the design project. In geotechnical design projects, the measures were to do a larger number of assessments, as well as developing several alternatives for project owner to choose between. Other respondents state that brainstorming, written communication, and more follow-up during construction project execution phase were measures to reduce overall risk.

In 4 design projects, these measures resulted in more accurate tender documents, ensuring a better evaluation of decisions on an ongoing basis. In 3 other design projects the results were rather negative, resulting in poor customer satisfaction and project owner choosing a cheaper solution above the solution with lowest risk.

Tools for internal uncertainty management in design projects

This section asked the respondents about the available checklists, procedures and tools for uncertainty management and the use of them.

Figure 20 show that 15 of the design projects filled out both uncertainty evaluation- and quality assurance checklist, in the early phase of the design project.

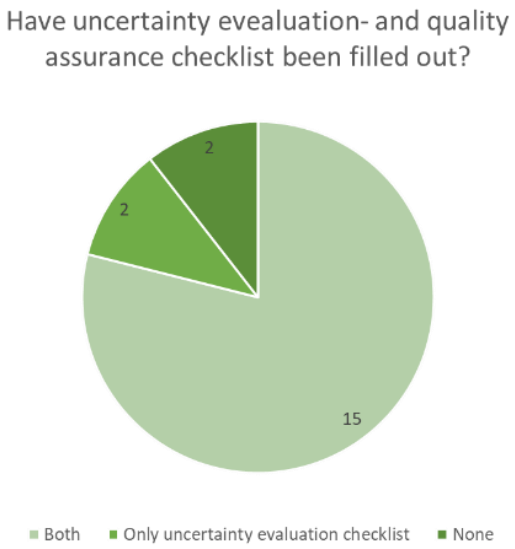


Figure 20 Illustration of filled out checklists in design projects

Responses stating that they did not fill out any checklists, explained that they did not do this due to no need or that misunderstandings led to neglect. Additional comments state they wish to be showed why these checklists are important to uncertainty management in design projects and that the checklists should be shorter and more precise.

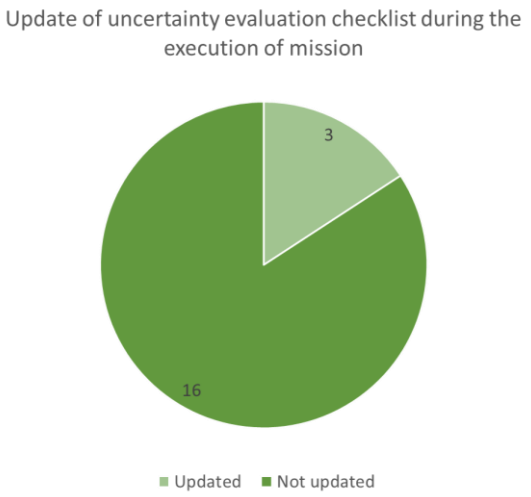


Figure 22 Illustration of update of checklists

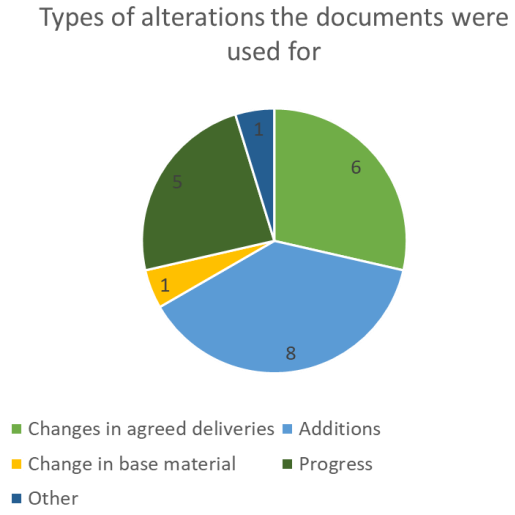


Figure 21 Illustration of changes in design

Figure 22 show that in only 3 out of 19 design projects, the uncertainty evaluation checklist was updated during the execution of the design project. This means if new uncertainties were identified during the execution, they were not documented through this checklist, nor evaluated.

The other supporting documents used in the design projects were the change orders. 10 out of 19 respondents answered that these orders were used. A majority of design projects used these orders for changes as additions to the agreed deliveries.

The 10 respondents stating that they used change orders were asked if they felt that the documents were easy to find in “Styringssystemet”. See Figure 23.

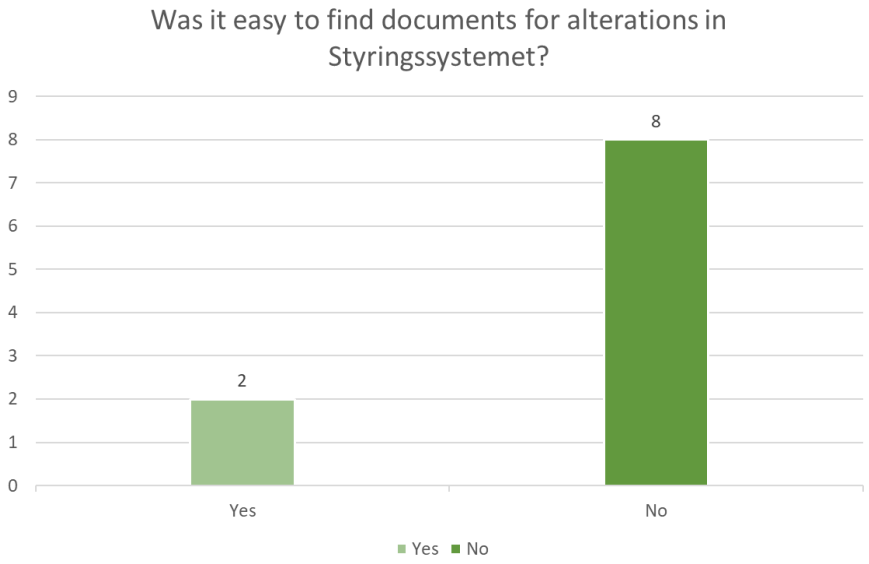


Figure 23 Illustration of finding documents for change in Styringssystemet

When seeking for a reason for the answering “no”, the responses state that “the search monitor is not good” and “the structure of Styringssystemet is not logic”.

The last part of this section focused on the available tools for design project management and the value of them for the respected project. See Figure 24.

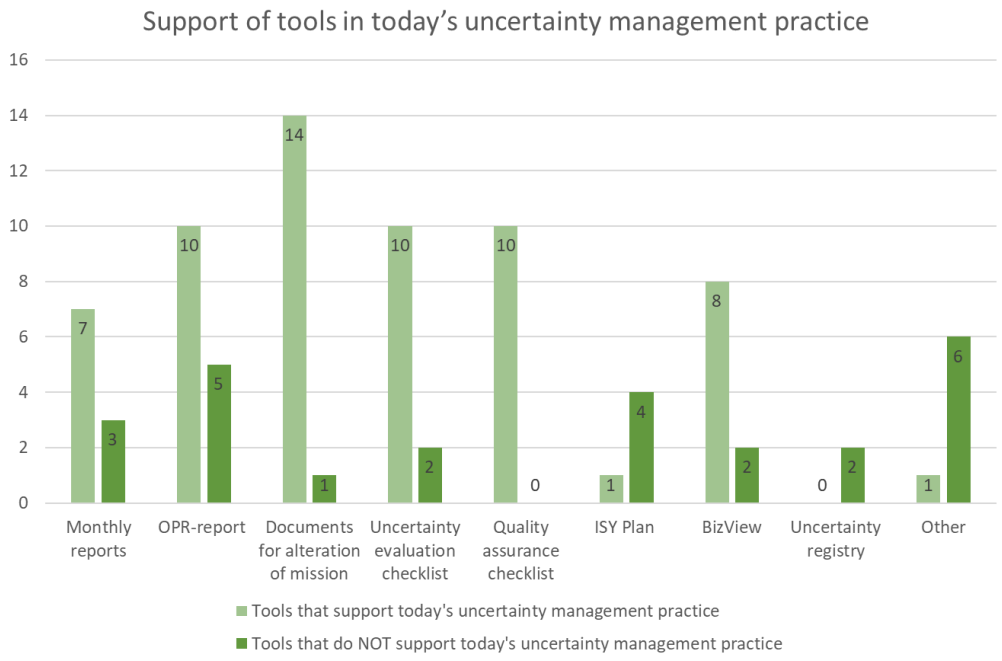


Figure 24 Illustration of the value of available tools in today's uncertainty management practice in Multiconsult Trondheim

The comments submitted regarding the available tools state that there is a need for tools that ensure sufficient quality in tenders, a database with lessons learned and a better tool than Maconomy for control of budget and time usage. The respondents also state that there should be more follow-up of design projects after the kick-off meeting, and a focus on streamlining the tools and routines to gain a higher quality of uncertainty management.

4.4 Case studies – internal uncertainty management practices

After conducting a screening process, an elimination process was initiated in order to elect 4 to 6 case studies that would fit to the research. The goal was to have a variety of design projects regarding complexity-level and economic outcome, as well as design projects that could share experiences from different fields within the construction industry. 4 design projects were elected for case study, covering different management levels, area of expertise and result. See Table 9.

Table 9 Case studies

Case name	Management level	Contract form/project model	Result
Geotechnical detail design at Lilleby-Fabrikkløkka	Simplified management	NS 8401 Fixed price Design-Build project model	Financial gain
Regional mapping of quick clay in Molde and Rauma Municipality	Standard management	NS 8401 Fixed price	Financial loss
State analysis of buildings of purpose in Trondheim Municipality	Standard management	NS 8402 Hourly commissioned	Financial loss
NTNU Valgrinda, stage 2	Simplified management	NS 8401 Fixed price Design- Build project model	Financial loss

Case 1- Geotechnical detail design at Lilleby-Fabrikkløkka

In May 2017 Veidekke Entrepreneur AS, contacted Multiconsult regarding an ongoing construction project at Lilleby in Trondheim. The original project has a design-build project model, where the project owner is Lilleby Eiendom represented by Veidekke. The project included about 450 residentials divided in eight apartment buildings and six rows of terraced houses. Multiconsult was requested by Veidekke to develop a geotechnical detail design for building stage six, seven and eight (see Figure 25). These building stages consisted of 15 terrace houses and two separate apartment buildings, with a total of 97 apartments.

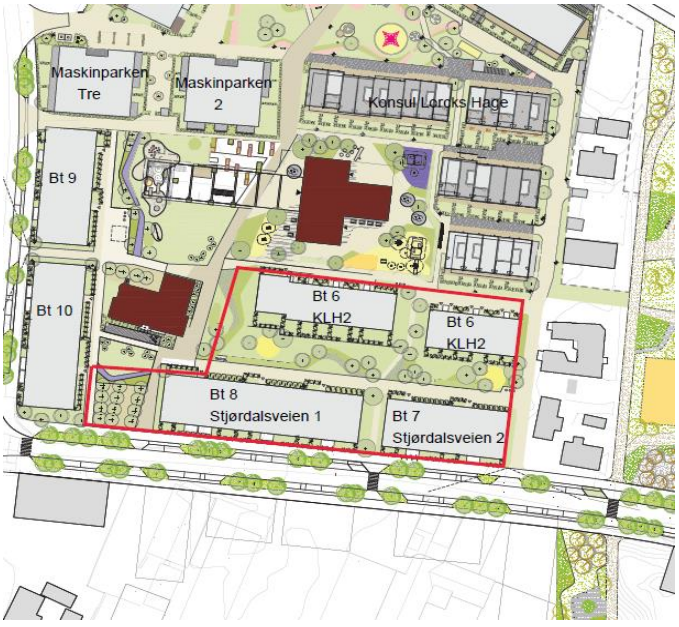


Figure 25 Illustration of the building stages at Lilleby- Fabrikkløkka

As in large parts of Trondheim, the main soil-type in Lilleby is clay. This is a particular complex soil-type to manage and can result in fatal consequences if wrongly calculated.

For Multiconsult, this kind of design project was familiar. Design project manager stated that this request was the third of the kind, which meant that two similar design projects has been conducted by Multiconsult in the area previously. In addition, this was a fixed price contract. The two previous design projects were hourly commissioned and Multiconsult had a good basis for pricing this design project fixed.

Course of the design project

Prior to the design project, Multiconsult conducted a feasibility study for the project owner, and prepared for a possible request. This resulted into elimination of both technical and subject-specific uncertainties, also from the project owner's side. Multiconsult used this opportunity to build a database of information during the feasibility study that could be used in the design project. This had a positive effect on time and resource-usage.

The communication between Multiconsult and Veidekke was reflected by past experiences and the relationship the two actors had built up together. Both informant from Veidekke and Multiconsult state that there were no uncertainties tied to communication, and the preferred way to communicate was through dialogue/meetings above e-mails. The informant from Veidekke points out that Multiconsult's team has been very proactive and included Veidekke in decision-making.

The design project was terminated successfully, and the project owner was satisfied.

Internal uncertainty management practices

The standard internal procedures, such as filling out quality assurance and uncertainty evaluation checklists were completed during the kick-off meeting with design project director and project manager from Veidekke present. Both design project manager and design project director felt that the uncertainties in this design project were manageable and that they had adequate knowledge to produce deliverables after project owner's request. No other uncertainty measures were therefore initiated.

The feasibility study done by Multiconsult allowed the team to prepare for the design project, with focus on information gathering and preparing the team from previous design projects for the same project owner. These preparations have benefited the design project severely. Uncertainties were reduced prior to the design project initiation, which has resulted in more efficient execution of design project, leading to economical profit.

The uncertainty management in this process can be characterized as *proactive*. Many of the uncertainties were dealt with up front and eliminated through experience with prior design projects executed for the same project owner.

Experiences

The experiences of this design project were firstly that standardized procedures as checklists are not always the key to success. Design project manager points out that it is more important to discuss the uncertainties to accentuate the awareness of them and plan actions for cases where the uncertainties may have a negative effect. This should be an area of responsibility handed to the design project director, which has the executive point of view on the design project.

Case 2- Regional mapping of quick clay in Molde and Rauma Municipality

In February 2018, Multiconsult entered a competitive tendering with four other competitors regarding a design project of regional mapping of quick clay in Molde and Rauma. Multiconsult won the tender and entered a contract with the project owner, NVE.

The purpose of the design project was to map and classify areas in risk of quick clay avalanches in selected areas of Rauma and Molde municipality. The design project was a framework agreement contracted according to NS 8401- fixed price, with some exceptions. The chosen areas are shown in Figure 26.

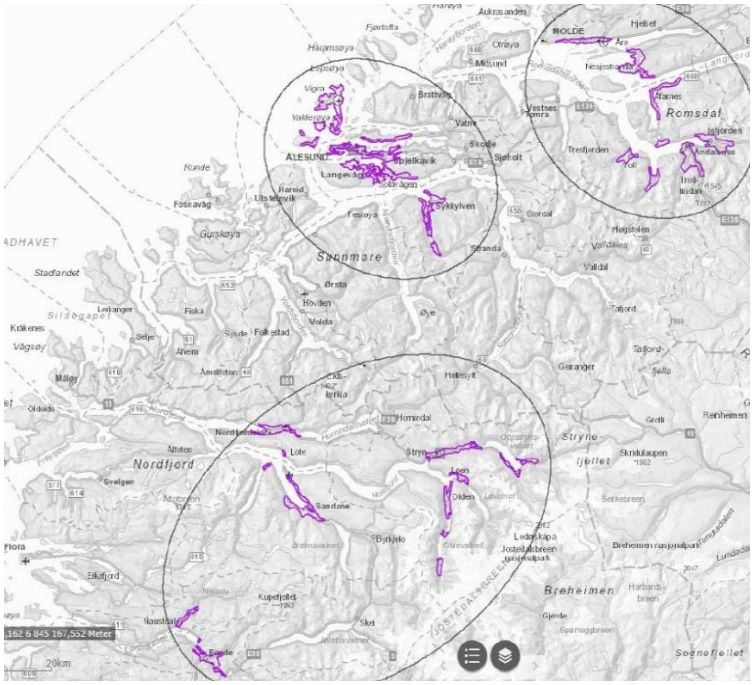


Figure 26 Illustration of the areas of regional mapping in Molde and Rauma Municipality

Course of the design project

In the starting phase of the design project, the major uncertainty regarded the expectation clarification of the design project scope. This uncertainty affected the pricing format of the design project as the overall design project had a fixed price, but some parts were commissioned by hours of work. The design project was internally categorized as standard management, due to its financial frame. Deliverables were focused on only one area of expertise, inclusive five workers. This meant that many of the procedures became either irrelevant or too complex for the nature of the design project.

The design project had a new format for Multiconsult, which made it hard to calculate how much time or cost each task would need. In addition, the design project director stated that the scope of the design project was partly unclear, and the detail-level of the reports was not entirely clarified. In the tendering phase, Multiconsult based their deliveries on the reports made by the Multiconsult Tromsø-office earlier, since no other basis existed at that point. NVE's informant also agreed with these arguments, where it was pointed out that they were aware of the nature of this design project and the uncertainties were not necessarily tied to the subject, but on the presentation of the work.

During the execution phase, the design project experienced some setbacks. A key team-member with a lower hourly rate became unavailable, meaning that a resource with a higher

hourly cost was appointed this position as a replacement. Another aspect was the detail- level, which has been an uncertainty in the early phase, led to disagreements, resulting in more time usage.

Both design project manager and client express that they were satisfied with the deliveries. The informant from NVE stated that the work Multiconsult delivered, would be used as examples for future similar design project.

The mission is not yet terminated, and minor aspects as evaluation meeting remains.

Uncertainty management practice

The standard internal procedures such as quality assurance and uncertainty evaluation checklist were roughly filled out prior the kick-off meeting and fully completed during the kick-off meeting with team-members and design project director present. According to the design project director, who had responsibility for over 100 individual projects, the checklists were considered to be too generic. Ideally, there should be more focus on the uncertainties that apply for geotechnical design projects. These checklists were therefore not of expected value or help to the design project.

As uncertainties were detected in the early phase of the design project, they were not acted upon until they started to show negative consequences. The uncertainty management in this design project is therefore characterized as *interactive*. The design project manager or design project director were feeling pressured during the design project and reacted to the uncertainties as they became reality (“fire-fighting strategy”). The detail- level of the deliveries is a good example. This uncertainty was identified early in the design project but was not dealt with before the team realized that they are to exceed the contractual time frame.

Experiences

The lessons learned from this design project were many. Design project manager stated that the most important experience was to learn how to price this kind of design projects correctly. By doing this, uncertainties covering all aspects will be reduced. In the situation, the design project manager felt that they could have been more determined on getting the cost for bringing the details of the reports to the expected level covered, but it was hard to do so in a pressured situation. Therefore, a lesson learned was that if a delivery in a design project is a report, the detail level should be clarified as early as possible.

Also, a better system for follow-up of the design project execution and change of personnel

was expressed as a need for a better practice and control uncertainties tied to these aspects.

Case 3- State analysis of buildings of purpose in Trondheim Municipality

In April 2018, Multiconsult won a tender for state analysis of purpose buildings, with Trondheim Municipality as project owner. This was the fourth period Multiconsult has taken on this kind of design project for the client, whereas each design project had a two- and one-year span.

The main design project was a framework agreement and contracted by NS 8402 with hourly commission, and some fixed priced parts. Deliveries included state analysis of 25% of the building mass owned by Trondheim Municipality in 2018 and 25% in 2019. This gives a total of 59 school buildings, 113 kindergarten buildings, 30 health buildings, 19 sports buildings and 24 culture and administration buildings.

As Multiconsult had completed such design projects before, they had good knowledge of the content of the deliveries, but the pricing of the design projects has been challenging in the previous projects.

Course of design project

The design project director explained that the design project had previously given a lot of additional work, and in the eight-year period where Multiconsult has completed this kind of work for Trondheim Municipality, there has been several different design project manager's involved. This kind of design project was also priced in a special way, as it was priced per square meter, not per hour labor.

Multiconsult tried to make the design project more effective in this tender, so that they could price it lower. The way of achieving that was to use Unizite, a program for mapping during the analysis. The result was that the design project was priced too low. This was partly because an unfortunate situation arose where project management-tasks exceeded their time budget. The design project manager stated that even with two resources analyzing buildings instead of three, the project was still at over 30% loss.

The reason for the financial adjustment was mostly tactical. Having Trondheim Municipality as a client was important, and by offering a lower price, they could continue that. Therefore, the largest uncertainty in this design project was the economic aspect.

As the design project was terminated, an economical loss was possible not to avoid. Both client and Multiconsult were satisfied with the deliveries, when taking the tight frames of both time and cost into account.

Uncertainty management practice

The design project manager explained that when they were going through the uncertainty evaluation and quality assurance checklist from the last design project, they experienced that there allegedly were no new uncertainties this time, except the financial part. The best solution was to work effectively and try to complete the design project below budget. The design project director pointed out a challenge that enlightened new uncertainties and the management of them; *"The understanding of the deliveries varied a lot. We were supposed to deliver an overall analysis, not the most detailed one. This was a common factor in a lot of discussions. It was challenging to have a common understanding of the final product and that our delivery was not supposed to be as we usually do it. We even entered into the templates what should be written on each bullet point to save as much time as possible, but this did not show effect until this year's design project. That is the worst uncertainty, understanding of task and the quality that should be delivered as a part of the final product"*

This design project was affected by situations that were results of uncertainties detected up front and is therefore characterized as *interactive* uncertainty management. Pricing of the design project should have been analyzed and evaluated in reference to the aspects that could affect the time and cost-frame. Time usage regarding the learning of a new program should have been detected as an uncertainty and could therefore have been planned in order to avoid negative consequences.

Experiences

This design project has showed that a wrongly priced mission and overestimating the savings due to technology can have large repercussions. The design project manager states that *"The tender was mostly tactical but also a mistake, given that the next lowest bidder had a price twice as high as Multiconsult."* The results of this design project have pointed to a need of clearer guidelines for the responsible roles internally, so that the design project director can be of a better aid.

This design project has all though attained a great amount of knowledge, among others that Sharepoint and Teams is a great tool for cooperation and more effective work.

Case 4- NTNU Valgrinda, stage 2

In 2018 Multiconsult entered a framework agreement with NTNU for geotechnical consultation and technical design. When the new campus project at NTNU was initiated, Multiconsult made the tender-specifications for NTNU and NCC won the design-build project. NCC hired Caverion as the technical construction contractor, where Caverion chose to use Multiconsult for technical design. This meant that Multiconsult went from being subordinated NTNU as project owner to Caverion as construction contractor.

For Multiconsult this design project included engineering services and design for electronic systems, preparation of contractor's work basis in detail design phase and construction assistance for a new building at Valgrinda (see Figure 27). This building was supposed to replace the current building for institute for Geosciences and Petroleum.

The design project was a part of a design-build project model and contracted by NS 8401 with fixed price commission.

Figure 27 Illustration of the location of NTNU Valgrinda Nybygg

Course of the design project

When the design project was initiated, the design project manager felt that the transition from having NTNU as a project owner to being subordinated Caverion was seamless. The client was different, but the project was still the same. The identified uncertainties were tied to project owner's need and subject specific uncertainties regarding technical solutions. The latter uncertainty appeared due to the state of the building at the time Multiconsult was hired; the building was not prepared for design of technical solutions. The room plans were not established, which resulted into delays regarding planning for technical solutions in these rooms. Other than this, the design project did not seem to have any large uncertainties.

During the design project, both design project manager and design project director expressed that new uncertainties arose. Design project manager stated that the change orders were especially hard to get approved. Typically, this happens due to the nature of the project. The design project manager explained that design-build project models are often challenging for design engineers, because the contactor usually does not want to push the project owner to use more money in the design phase. This reflected upon the change orders, where the client had difficulties understanding the changes that were not obvious. The design project director stated that uncertainties regarding solutions came forth during the design project, where a lot of the uncertainties depended on other subcontractors.

As the design project came to an end, some work was yet to be finished, but the design project manager tells that the client seemed satisfied with the result.

Uncertainty management practice

The standard procedures such as quality assurance and uncertainty evaluation checklists were according to the design project manager filled out, but not fully completed. Design project director explained that there should have been a larger focus on the identified uncertainties. The communication with construction contractor was however good in the early phase of the design project. With time it came forth that the project manager from Caverion lacked experience when it came to design-build-projects. The design project director stated that there should have been a clearer expectation clarification. It did not come forth what level of detail the construction contractor expected, which made it difficult to plan the work.

When assessing this design project, the results show that the identified uncertainties were managed in a *reactive* matter. As the uncertainties were not documented or taken action upon through the required uncertainty evaluation and quality assurance checklists, the design project manager and design project director lost an opportunity of taking actions upon these uncertainties up front. The management of uncertainties became therefore an action of damage control.

Experiences

The design project manager explained that the most evident experience from this design project was how to provide design services benefitting all in a design-build project model. The design project manager felt that it was challenging to be a subcontractor in such projects regarding financial frames of design projects.

Design project director explained that the experiences acquired in this design project were regarding expectation clarification. This would especially apply for projects with a complex organization, such as design-build projects. An expressed need is to improve the internal design project management with focus on follow-ups. Here, the economic system is a factor. Design project director stated that it can be too difficult for each team-member to get an overview of their own hours and how it complies to the total budget.

4.5 Model for a better practice of internal uncertainty management in Multiconsult Trondheim

Results from screening and the case studies made the basis for a model that purposes recommendations for a better practice of uncertainty management in Multiconsult Trondheim. In this thesis, the focus area of the organizational structure in the office has been the design, marked in red in Figure 28.

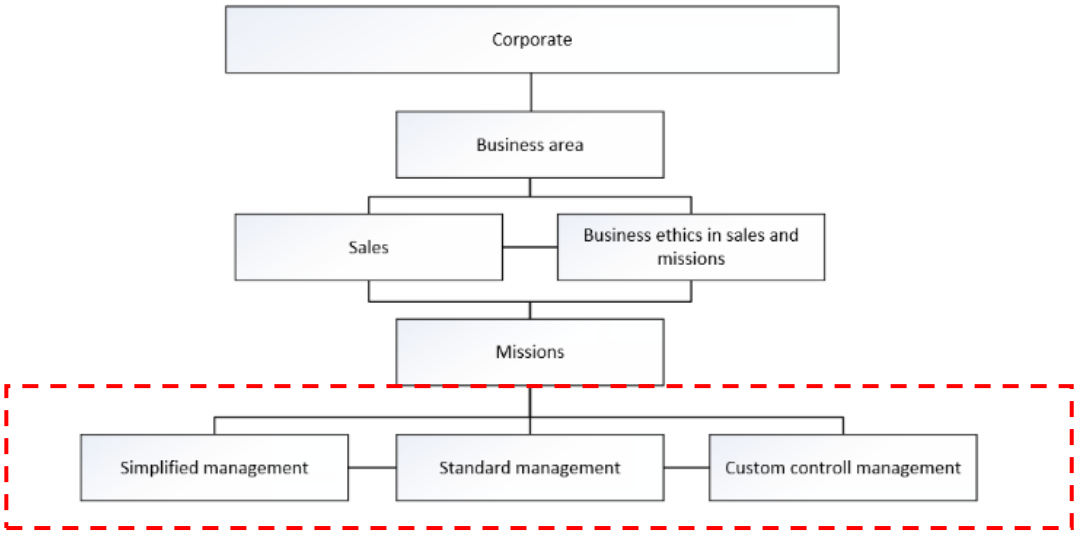


Figure 28 Illustration of the focus area in this thesis of Styringssystemet

Chapter 3.2 introduced PMI's six step model of management and analysis of uncertainties (See Figure 6). This model has been compared to today's practice of uncertainty management in Multiconsult Trondheim, to examine what steps are present today and what steps are still to be implemented in future practice. The reason for this decision is that PMI's model includes all the aspects that are important for the internal uncertainty management practice of Multiconsult Trondheim and would be a suitable framework for the recommendations based on the results. Chapter 3.2.1 stated that the focus is on the qualitative part of uncertainty analysis, therefore the quantitative uncertainty analysis is not considered in Figure 29.

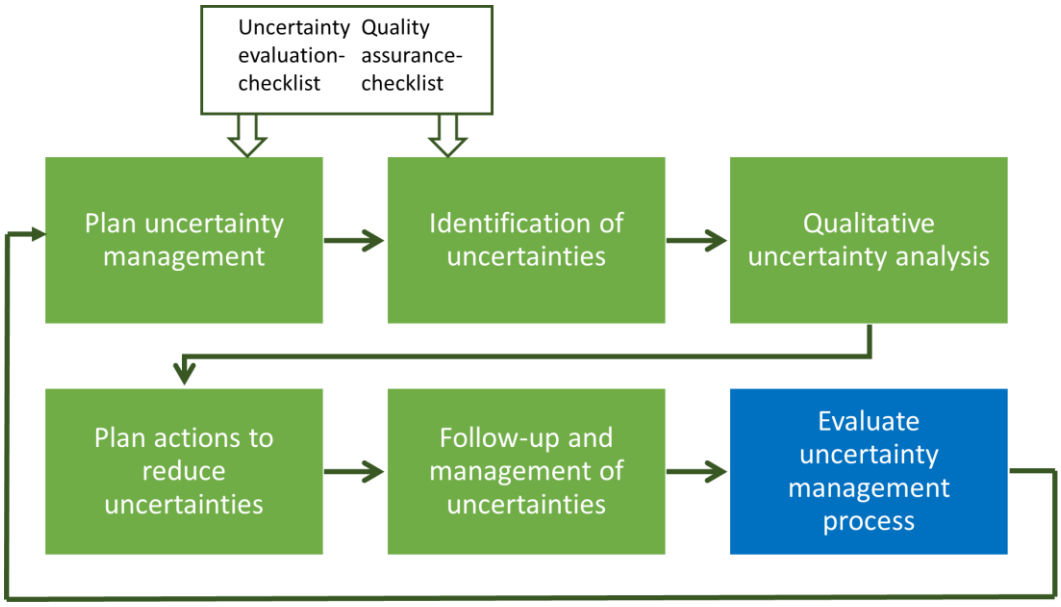


Figure 29 Suggested uncertainty management process for Multiconsult Trondheim, inspired by PMI's six step model for uncertainty analysis and management

PMI's model was compared to the required procedures and showed that only step one and two of it is implemented in the Trondheim office today. Also, a step from the PUS-model (marked in blue in Figure 29) has been added to this process. The reason is that evaluation of the uncertainty management process will help Multiconsult Trondheim learn from each project and collect lessons learned that can be valuable for the future. The case studies have showed that there is a need for an even more structured uncertainty management practice and a closer follow-up after the checklists are completed in the early phase of a design project.

To address the uncertainty management recommendations, the mentioned aspects have been divided in two categories: direct and indirect impacts on uncertainty management practice.

Table 10 Direct and indirect impacts on uncertainty management practice in Multiconsult Trondheim

Direct impacts on uncertainty management practice	**Indirect impacts on uncertainty management practice**
Qualitative uncertainty analysis	The roles of design project manager and design project director
Plan actions to reduce uncertainties	Economic system for design project and personal control
Follow-up and management of uncertainties	Capacity of personnel

The impacts shown in Table 10 are results from the comparison of the theoretical model of uncertainty management against the current structure of uncertainty management process in Multiconsult Trondheim, as well as the experiences shared through interviews. These impacts

are further broken down into elements characterizing the current practice which together with impacts give a foundation for recommending improvements.

Table 11 The characteristic elements of uncertainty management practice in Multiconsult Trondheim

Elements	Value	State	Use	Aspects to improve	Comments
Checklists (both quality assurance and uncertainty evaluation)	Medium	Room for improvement	15/19 design projects	Less complex and more tailored for design projects	Many feel that the checklists are irrelevant but are completed as they are required to be filled out.
Reporting and follow-up of uncertainties	Low	Room for improvement	3/19 design projects	More systemized follow-up and meeting procedures	Results show that only a few design projects updated their uncertainties in design projects, but wish they had a larger focus on it
Meetings regarding uncertainty	Medium	Individual	5/19 design projects	More focus on talking about uncertainty	Many uncertainties are eliminated through dialogue
Roles and capacity	High	Room for improvement	All	Design project directors and design project manager's need support or oversee less projects. Include project controllers	The roles are vital for management, but are characterized by time pressure, where prioritization needs to be made.
Internal economic system	Medium	Room for improvement	All	Simplify and adjust to daily needs	Many feel that the system is to large and does not give the simple outputs that are needed daily

Direct impacts on uncertainty management practice

The direct impacts on today's uncertainty management practice of Multiconsult Trondheim are those that can be grounded by theory. It has been showed in Figure 29 and in Table 10 that 3 out of 5 steps in PMI's uncertainty management and analysis model is not present in the uncertainty management of the Trondheim office.

Results from screening and case studies show that the procedures done in the early phase of a design project, are either inadequate or are left behind in the early phase. This means that uncertainties that have been identified are not followed up and, in some cases, forgotten. By having a larger focus on the uncertainties in a design project, and following them up either in reports or meetings, the Trondheim office can achieve a better uncertainty management practice. Another result show that meetings are a good way to communicate uncertainties and

discuss them with project owner, therefore a recommendation will be to implement this in a standardized matter to the uncertainty management practice. An uncertainty analysis done in a qualitative matter will help the design projects to fully understand the consequences of the uncertainties and perhaps also the opportunities.

Indirect impacts on uncertainty management practice

Results from screening and case studies have also enlightened upon aspects that have an influence on the uncertainty management process but are not directly explained by theory. These are related to the roles of design project manager and design project director. Case studies has shown that many design project directors have responsibility for a large number of design projects at once, creating challenges regarding prioritization and responsibility. Design project managers are often both team-workers and managers, and in some cases face challenges of managing the economical aspect of the design project.

Both screening and case studies has shown that many employees are not satisfied with the economic system and feel that it is not suited for control on a daily basis. To make this aspect better, a recommendation of using the supporting tool BizView to create design project- and personal report that use the input data from Maconomy to simplify the visualization of it. The management of personnel is an aspect creating uncertainties in design projects. This uncertainty has an influence on the outcomes of the design projects and are therefore a part of the operational uncertainties. An example for an economic report layout is shown in Table 12.

Table 12 Example of an economic report layout

Economic report for design project XX					
Task	Budget	Time spent	Hours left	Status	Comment

Model for a better uncertainty management practice

Based on the explained impacts, the theoretical guidelines and the organizational structure of the Trondheim office, a model that suggest a better uncertainty management practice is developed.

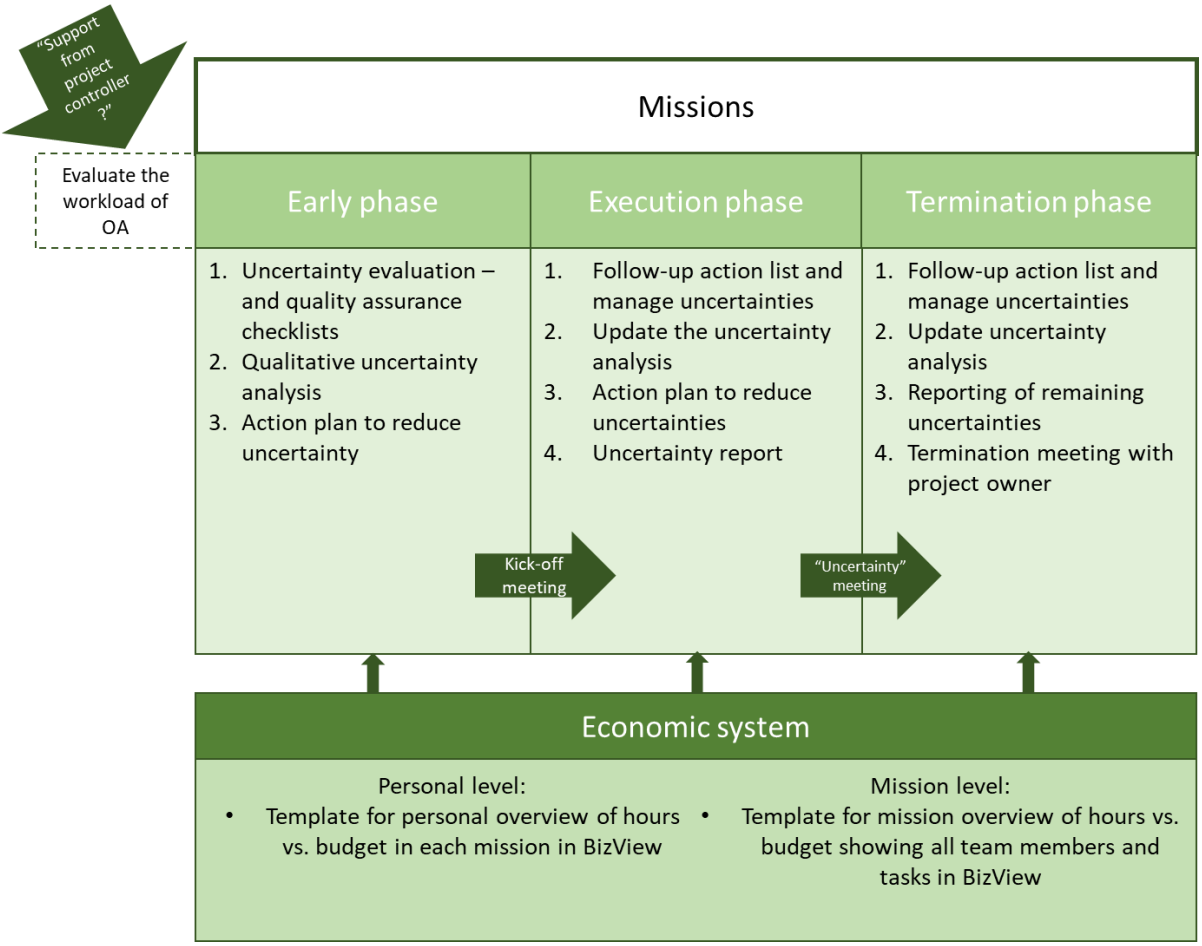


Figure 30 Suggested model for a better uncertainty management practice in Multiconsult Trondheim

Figure 30 shows the suggested model for a better uncertainty management practice for Multiconsult Trondheim. This model contains recommendations for each phase of a design project, starting from the tendering of a design project. Here, the suggestion is to evaluate the workload of the design project director appointed and assess whether a project controller should be included in the design project. A project controller would assist the design project by following up on the uncertainty management process, perform economic tasks as billing and keeping control of the time-budget of the design project. If a project controller is appointed for the design project, he/she needs to be included in the design project from the early phase. This way, a controller would have an adequate insight of the design project needs.

In the early phase of a design project, Figure 30 shows that the uncertainty evaluation and quality assurance checklists should be filled out. These checklists are under an ongoing development and are being adjusted for several types of design projects in 2020. The identification and categorization of uncertainties is done through these checklists and need to

be further evaluated against the impact they might have on the design project. Therefore, the further recommendation is to conduct a qualitative uncertainty analysis.

The qualitative uncertainty analysis is recommended to conduct in line with the presented method in Chapter 3.2.1 (See Table 7). The first step in this analysis is to categorize the uncertainties, this is done in the uncertainty evaluation checklist. Step two is to implement the uncertainties in a probability/impact matrix:

Probability / Impact	Low probability (1)	Moderate probability (2)	High probability (3)
Low impact (1)	Low probability, low impact (1x1=1)	Moderate probability, low impact (2x1=2)	High probability, low impact (3x1=3)
Moderate impact (3)	Low probability, moderate impact (1x3=3)	Moderate probability, moderate impact (2x3=6)	High probability, moderate impact (3x3=9)
High impact (6)	Low probability, high impact (1x6=6)	Moderate probability, high impact (2x6=12)	High probability, high impact (3x6=18)

Figure 31 Probability and impact matrix, derived from (Pritchard, 2015)

This matrix categorizes the uncertainties by the impact they might have on the design project and allows the design project to be compared to other similar efforts in terms of uncertainty (Pritchard, 2015). The impact the uncertainties might have, should be considered both from cost- and time perspective, as these are underlined the operational level of uncertainty explained in Chapter 3.1. The uncertainties ranked as low-low in this matrix, can be considered to neglected in further analysis, based on their limited impact and probability.

Further, the categorized impacts are to be tested against the prerequisites of the design project. This includes the consequences of uncertainties to be evaluated against the prerequisites made for cost, time, scope, and quality. Thereafter, the uncertainties are ranked by the results from the matrix. Uncertainties with highest score, will also be the uncertainties that are most urgent to appoint actions to.

Table 13 Matrix of evaluation of uncertainties against project prerequisites. Derived from (Project Management Institute, 2000)

Project prerequisites	Very low (0.05)	Low (0.1)	Moderate (0.2)	High (0.4)	Very high (0.8)
Cost	Insignificant cost increase	<5% cost increase	5-10% cost increase	10-20% cost increase	>20% cost increase
Time	Insignificant time increase	<5% time increase	5-10% time increase	10-20% time increase	>20% time increase
Scope	Insignificant change of scope	Small areas of scope affected	Significant areas of scope affected	Reduction of scope is unacceptable for project owner	Project deliveries unusable
Quality	Insignificant change of quality	Only highly demanding applications are affected	Reduction of quality requires approvement from project owner	Reduction of quality is unacceptable for project owner	Project deliveries unusable

A weakness of this matrix is the risk-view on uncertainties. The terms used in this matrix such as *"cost increase"*, *"reduction of quality"*, *"unacceptable"* and *"unusable"* refer to the negative consequences of uncertainty and shuts down the opportunities that might have a chance. To allow opportunities a place in such analyses, the opportunities should ideally be assessed in the same way as risks.

As a result of the uncertainty analysis an action plan will be formed. This plan will show the ranking of the uncertainties done in the analysis, what actions should be done in order to reduce risk or exploit opportunities and who is responsible for each uncertainty- action. The PUS-project call this structure a "top 10"-structure and an example of how this action plan can be formed is presented in Table 14.

Table 14 Example of an action plan

Uncertainty action plan for design project XX						
Uncertainty nr.	Ranking	Description	Responsible	Action	Status	Deadline
1.	Cost: Time: Scope: Quality:					

When these steps are completed in the early phase, the action plan can be presented in the kick-off meeting so that all team-members and project owner/construction contractor are familiar with it. This action plan can also be discussed before entering the execution phase of the design project.

In the execution phase, the follow-up and management of the uncertainties adhere to the action plan made in the early phase. When the follow-up of uncertainties is completed, it is time to update the uncertainty analysis and the action plan. These updates can be gathered in an uncertainty report, which can be presented for the project owner/construction contractor in meetings. The uncertainty report can have the same structure as the action plan, but in a subjunctive form. This means that the uncertainty report will show the uncertainties and their ranking, those responsible for follow-up, their conclusion of the action and the update of old/new/changed uncertainties.

Table 15 Example of an uncertainty report

Uncertainty action plan for design project XX								
Uncertainty nr.	Ranking	Description	Responsible	Action	Status	Deadline	Experiences	Further recommend ations
1	Cost: Time: Scope: Quality:							

In the termination phase, the same procedure of following up and updating uncertainties is repeated. The reporting of the remaining uncertainties will be useful for a termination meeting with project owner/construction manager. Here, the design project manager can present the remaining uncertainties that might affect the total project (if any) and the project owner gets

and opportunity of consulting with the design project manager and team how to manage these uncertainties in the construction phase of the project.

The following table summarizes the recommendations presented in this chapter:

Table 16 Recommendations, summary

Phase/aspect	Recommendation
Before early phase	Evaluate the workload of design project director and design project manager and decide whether a project controller is needed
Early phase	Identify the uncertainties by using the uncertainty evaluation checklist Conduct qualitative uncertainty analysis as a baseline for an action plan for uncertainties Appoint responsible persons for the actions Present and discuss the results from uncertainty analysis and action list in kick-off meeting
Execution phase	Follow-up the action list and manage uncertainties, document when an action is done Update the uncertainty analysis and add or change the uncertainties that have been managed ➔ Document experiences in uncertainty report Develop a new action plan for uncertainties Document the management of uncertainties in an uncertainty report and present report in uncertainty meeting with project team and client
Termination phase	Follow-up the action list and manage uncertainties, document when an action is done Update the uncertainty analysis and add or change the uncertainties that have been managed ➔ Document experiences in uncertainty report Report the remaining uncertainties in an uncertainty report and present the report in termination meeting with client
Economic system	Develop personal overview of time used against budget in BizView Develop design project overview of time and money spent against budget in BizView

When looking at all the results in this research, a pattern comes forth. The uncertainty management of Multiconsult Trondheim appears to be at a low stage, where uncertainties tends to lack management after they are identified. The procedures and the practice today, complete the first two stages of the most common uncertainty management processes. Recommendations were suggested as a mean to improve this practice and elaborated upon how these recommendations can be carried out and why. An important aspect to consider when managing uncertainties is the positive side of them, the opportunities. Johansen et al.

(2019) argue that opportunities can generate benefits for the external (e.g. project owner) and internal stakeholders (e.g. Multiconsult), and needs to be in focus when analyzing uncertainties. Risks that are shut down at an early stage can lead to a loss of opportunities that could have made the project better. A proactive uncertainty management, as mentioned in Chapter 3.1, will make a project team better equipped for managing both risks at an early stage and be aware of the opportunities that might appear. How the recommendations will help Multiconsult Trondheim accomplish this proactivity has been shown in this chapter, the remaining part is to discuss their effects and how they comply to the theory.

5. Discussion and practical recommendations

This chapter will consider the results of the research and provide a discussion that is grounded in theory. The main aspects of this discussion will be the characteristics of internal uncertainty management in Multiconsult, tied to the common practice in the industry, as well as the suggested model presented in Chapter 4.5.

5.1 Uncertainty as a challenge and management as a solution

The results of the screening process show that in 14 out of 19 design projects have identified uncertainties. DODGE Data and Analytics (2018) state that every project deal with uncertainties in the early phase, so the responses to the questionnaire points more towards the recipients' perception of what uncertainty is. This aspect is an important source of error as it can lead to further errors in the results of the questionnaire.

The interviews gave a more in-depth explanation of the uncertainties of each design project in the case studies. Most informants pointed out the fact that the uncertainties were tied to the requirements in contract or the lack of clarifications. Uncertainties were often in regard to the expected detail-level of the deliveries, which is according to DODGE Data and Analytics (2018) an aspect of expectation from the project owner. If the expectations are not clarified in the contract, it will often lead to a higher level of uncertainty in the design project. Farooq and Bubshait (2001) state that such aspects need to be discussed with the project owner/construction contractor in the early phase of the project, and can help prevent future disputes. When a design project is pressured by time and cost, as well as there is a certain agreement upon the deliverables, bringing up a discussion like this is easier said than done. In the related case studies, design project managers felt that they have understood the framework of the deliverables and planned their work thereafter. The unexpected turn of event is the changes or specifications provided by client during a later phase. Most of the design projects solved these challenges by either requesting a change order or resolving it in a meeting with client. In all the cases where changes of deliveries were a challenge, the design projects led to financial loss.

Another uncertainty that needs discussion, is the delays in design projects. 3 out of 4 case studies experienced delays in their design projects. According to DODGE Data and Analytics (2018), this is one of the most common uncertainties in the construction industry. Delays and alterations are also a part of the operational uncertainties explained in Chapter 3.1. Delays

regarding other contractors, internal delays in deliveries or delays in decision making are uncertain elements that affected all these cases, resulting in either a prolongation of design project or longer working hours. In a design-build project model, the designing engineers answer to the contractor and not the project owner (Lædre, 2006). When delays occur and the designers need more time or money, it is said in the interviews that the contractor tends to be resistant of taking this further to the project owner. This is usually because the design phase is one of the early stages in a project, and the contractor wants to avoid cost alterations at this early point. The complex organization of a design-build project can result in such situations, and according to Lædre (2009) the main contractor is partly locked to the fixed price of the project where alterations of cost is something they avoid bringing up before it is absolutely necessary. For the project owner, this is a way of minimizing uncertainties tied to project cost. The management of this uncertainty led to requirement of change orders to the contractor. As many uncertainties regarding technical solutions were present during the design project, it can be discussed if these could be identified in the tendering phase. When focusing on delays, all of the cases show to a change of personnel at one point of the design project. Uncertainties regarding capacity are present in most project, especially those who experience delays. Some informants expressed that when their design project was delayed, some resources were moved to other design projects that required their expertise. This is an unfortunate situation, but a situation that can be managed with thorough mapping of uncertainties up front. According to Hillson (2009), the human factor creates uncertainties in projects and such uncertainties should have been assessed prior to the arise of such situations.

The uncertainty management- way of thinking is an important aspect to consider when looking at how the uncertainties tend to be managed in the design projects from case studies. Only 1 out of 4 case studies showed a proactive uncertainty management, meaning that the uncertainties were identified and managed up front. The other case studies show that uncertainties were managed in present time or after the outcome of the uncertainties became a reality (“fire-fighting”). According to PMI (2013), a project without a proactive approach towards uncertainties is more likely to face challenges that has arisen from unmanaged threats. This is a statement that has been verified through the case studies, showing that the design project with most proactive focus on uncertainties also had the least challenges in the design project span. To engage upon a more proactive culture for internal uncertainty management in Multiconsult Trondheim, the model in Figure 30 presented in Chapter 4.5,

suggests measures that will bring more awareness of uncertainties from early phase to termination phase of a design project.

5.2 Characteristic elements as a basis for an uncertainty management model

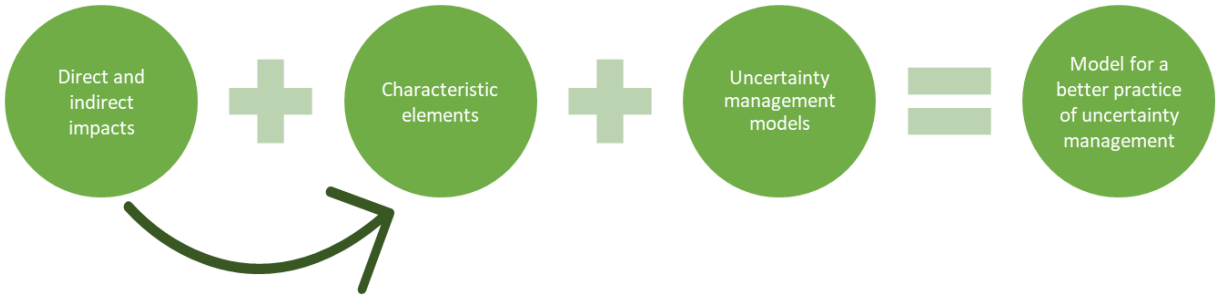


Figure 32 Illustration of the development of a model for better uncertainty management practice

Chapter 4.5 introduced the direct and indirect impacts on today's uncertainty management practice in Multiconsult Trondheim. These impacts were the results of the screening process and the case studies. Direct impacts were explained to be elements that affect the aspects of the most common uncertainty management processes, and the aspects that are missing in today's practice. These aspects are the required uncertainty evaluation- and quality assurance checklists as well as meetings with project owner where uncertainties are in focus. The missing element that is found in PMI's uncertainty management and analysis- model but not in Multiconsult Trondheim's practice, is the follow- up and reporting of uncertainties in a more frequent matter.

The indirect impacts of uncertainty management are the aspects that affect uncertainty management in ways that are not explained by the most common uncertainty management processes. These are the roles of design project managers and design project directors, the economy system used in design projects and the capacity of personnel. The impacts result in a list with characteristic elements that describe the good aspects of today's uncertainty management practice in Multiconsult Trondheim and the aspects that have room for improvement. Table 11 in Chapter 4.5 show the characteristic elements found in the research. Direct impacts are marked in green, while indirect impacts are marked in red.

Table 11 The characteristic elements of uncertainty management practice in Multiconsult Trondheim

Elements	**Value**	**State**	**Use**	**Aspects to improve**	**Comments**
Checklists (both quality assurance and uncertainty evaluation)	Medium	Room for improvement	15/19 design projects	Less complex and more tailored for design projects	Many feel that the checklists are irrelevant but are completed as they are required to be filled out.
Reporting and follow-up of uncertainties	Low	Room for improvement	3/19 design projects	More systemized follow-up and meeting procedures	Results show that only a few design projects updated their uncertainties in design projects, but wish they had a larger focus on it
Meetings regarding uncertainty	Medium	Individual	5/19 design projects	More focus on talking about uncertainty	Many uncertainties are eliminated through dialogue
Roles and capacity	High	Room for improvement	All	Design project directors and design project managers need support or oversee less projects. Include project controllers	The roles are vital for management, but are characterized by time pressure, where prioritization needs to be made.
Internal economic system	Medium	Room for improvement	All	Simplify and adjust to daily needs	Many feel that the system is to large and does not give the simple outputs that are needed daily

The first element of Table 11 is the checklist of uncertainty evaluation and quality assurance. Academics as Farooq and Bushait (2001), Johansen, Halvorsen, Haddadic and Langlo (2014) and Torp et al. (2018) state that uncertainties that have been mapped, planned and put into action-lists should be reviewed after a certain time. This is to keep continuity of the design project and to ensure the minimization of uncertainties in all project phases. The results, on the other hand, show that even though most of the design projects fill these out and evaluate uncertainties, only 3 out of 19 design projects updated the checklist and evaluated the identified uncertainties from the early phase. Many of the informants have expressed that these checklists are too generic and should be adjusted to the nature of the design project. A reason for such findings can also be grounded in culture and habits. If the workers do not see the value of the requirements, they might also not be benevolent to fill them out. Informants have also expressed that they see the checklists as something that must be done just because it is required, and not something that is done with the purpose to help the design project. The

time pressure of small design projects as well as lack of focus on uncertainty management can also be a motivator for the insufficient documentation and communication of uncertainties. This mindset is important to change, or at least show why such requirements are important and how they can benefit the design project.

During the interviews, an informant explained that there is an ongoing process of adjusting the checklists that are available today. The supervisor from Multiconsult, also verified that this is a process that has been ongoing since the announcement of the new corporate strategy in 2018. Therefore, the recommendations are not focusing on the content of the checklists.

To ensure a continuous uncertainty management process, the uncertainties must be followed up and communicated to client (Project Management Institute, 2000). Therefore, follow-up and reporting of uncertainties is an important aspect in the recommendations. This is an area with lack of systematization and needs to be more focused on in Multiconsult Trondheim. As mentioned earlier, only 3 out of 19 design projects updated their uncertainty evaluation checklist during the design project. This indicates low interest or focus on keeping uncertainty management as a continuous process. An important part of the uncertainty management process is documentation of uncertainties, in all phases of a project (Johansen, et al., 2019). Documentation is helpful for lessons-learned in design projects and to maintain transparency between consultants and project owner. However, different project owners have different demands, and if they require reporting of uncertainties, they usually provide the design project team a template. The recommendation is, regardless this fact, to implement a scheduled uncertainty reporting, with a follow-up period between monthly reporting.

The follow-up and reporting are closely tied to the next element, meetings. Meetings is the most effective method of information sharing and according to PMI (2013) *"meetings are more effective when all participants can be face-to-face in the same location"*. Meetings are also a mean to reduce uncertainty and plan actions for uncertainties that are already identified. Informants tell that in design projects where meetings regarding communication of uncertainty towards project owner has been held, they have resulted in efficient management of uncertainties. Not all design projects in the case studies used meetings to communicate uncertainties to project owner, but where it was used, the results show that it was easier to manage the uncertainties at hand. One of the interviewed project owners/construction contractors also expressed that meetings are a preferred way to communicate, as it makes it easier to share points of views and helps build a relationship between project owner and contractors. According to Eikeland (2001), the designer's role is also to be a consultant for the

project owner. Therefore, it is important to be transparent and communicate the uncertainties that can have an influence on both the design project and the overall project. The reports regarding uncertainties will help making a foundation for these meetings and guide the team through the established actions on a daily basis. By scheduling both reporting and meetings, the process of managing uncertainties can become more effective and standardized.

The indirect impacts to Multiconsult Trondheim's uncertainty management found in this research are the roles and capacity of personnel, as well as the state of the economic system used in design projects. The design project managers express in interviews that for those who are responsible for a large number of design projects, the prioritization of which design project needs more support is challenging. Often, the design project managers are left to manage the design project themselves, with a design project director only as approving role. For design project managers which also are a part of the expertise-team, balancing these roles can be difficult. Not only are they required to do design project management, but also do tasks that are a part of the deliveries. These roles will then add an aspect of uncertainty to the design project by increasing the complexity level for the design project manager. Many informants explain that they haven't thought about or have not had the need for appointing a project controller to assist with management-tasks, but when looking back at the uncertainties that arose, a project controller could be of help managing many of them. Therefore, a recommendation is to evaluate the workload of design project managers and design project director in the tendering of a design project, whether they have the capacity to manage the design project or if a project controller is needed. For Multiconsult, this solution will also add to the profitability-aspect of the corporate strategy explained in Chapter 1, where more personnel can be included in profitable design projects.

The last indirect impact and characteristic element of the internal uncertainty management practice is the economic system that is used today. Both screening and case studies has showed that the employees find the economic system, Maconomy, to be too complex and challenging to use on a daily basis. The main argument is that it is difficult to keep track of the time and cost spent against the budget. As the economic system touches upon the operational uncertainties where cost and time needs to be managed, the today's practice of it does not comply with keeping a proactive uncertainty management way of thinking. Most design project managers explain in interviews that they discover it way too late, when the design project is about or already have exceeded the budget. This usually puts the design project manager in a difficult position. A result is to communicate this to the project owner

and request a change order. This is a more interactive way of managing such operational uncertainties.

A similar aspect also applies to the team-members. Informants have expressed that it is hard to keep track of their personal time usage against the budget for the design project. Therefore, a recommendation is to create design project and personal economic reports, using BizView. These reports can show the time used against the budget for the task and against the design project and will help controlling the cost and time- aspect, which again will reflect upon the operational uncertainty management and add to a more proactive way of managing uncertainties. See Table 12.

5.3 How will a new uncertainty management model help improve internal uncertainty management practice of Multiconsult Trondheim?

The model presented in Figure 30 summarizes all the recommendations and implement them to measures that can be done in each phase of a design project. The characteristic elements made the baseline for the development of the model, together with the theoretical framework of uncertainty management process and qualitative uncertainty analysis. The overall recommendation is to implement a more structured uncertainty management process, which is continuous from early phase to termination.

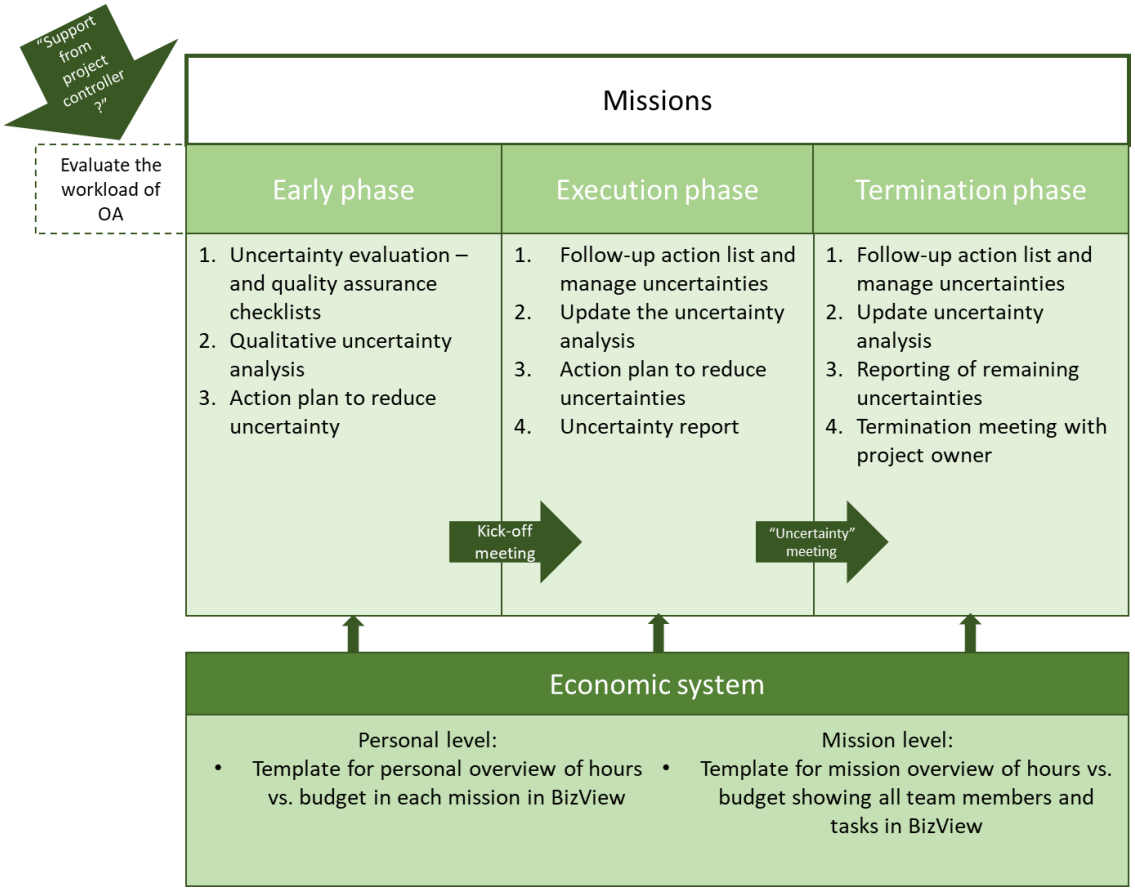


Figure 30 Suggested model for a better uncertainty management practice in Multiconsult Trondheim

The steps of the model, explained in Chapter 4.5, show how the different recommendations can be put to actions in design projects. When looking at the impact the model can have on the uncertainties regarding projects as a whole and the uncertainties that are design specific, there are several aspects that are relevant. From a general construction perspective, the model will foremost help managing changes. As owner-driven changes are a central uncertainty in all construction projects (Hillson, 2009), the continuous uncertainty management process will make the design project team better prepared for changes as they come along. This is by identifying, evaluating, and managing uncertainties that might have change of design project deliveries as an outcome. The assumptions of a project are also an uncertain aspect explained by Hillson (2009). Qualitative uncertainty analysis will be a mean to manage this aspect. By performing this analysis, the uncertainties are evaluated against the prerequisites of the design project, resulting into actions that are suited for the severity of the uncertainty.

Having a more continuous uncertainty management process will also affect the design specific uncertainties, explained in Chapter 3.4. According to DODGE Data and Analytics (2018), an uncertainty that affect most design projects is communication gaps. This

uncertainty can be managed by having frequent meetings or reporting. For uncertainty management practice, introducing standardized reports and establish monthly uncertainty meetings will make it easier for design team, project owner/construction contractor and other parties to discuss uncertainties. Communication gaps that could offer challenges, are more likely to be eliminated due to a larger transparency and ongoing feedbacks. Another uncertainty presented by DODGE Data and Analytics (2018) is uncertainty tied to accelerated schedules. Informants have also expressed that even though the design project deliveries change, the project owner often required deliveries within the same time frame. This is especially a challenge when a design project is contracted by NS 8401- fixed price. In these contracts, the time and cost frame are decided, in contrast to NS 8402 where the time frame is estimated, and the design project is commissioned by hourly labor. By identifying uncertainties regularly, such challenges can be predicted and acted upon at a certain level. This will lead to a more proactive uncertainty management where uncertainties are communicated to project owner before potential disagreements arise.

5.4 How does this apply to the industrial practice?

After conducting a document study with focus on other actors in the industry, it becomes more clearer that there is no standardized way for design engineering companies to manage uncertainty. For project owners, there are many more options, including the uncertainty analysis in the early phase, and 9-step framework for assessing uncertainties, Quality Assurance Scheme that was introduced for governmental projects in 2005 and so on (Johansen, 2015). For design engineering, there are no such methods, leaving each company to develop a model that fits their needs. It can also be argued if this is the reason for why many design engineering companies struggle with management of uncertainties in their projects. The five companies in the document study show various ways of managing uncertainty in projects. Some companies have departments that deal with the aspect, others offer services as uncertainty analyses for large projects and other focus on training their workers to understand uncertainty and be equipped to manage uncertainties in their future projects. The challenge of this document study is that none of the actors in the research have official records of their internal management, they publish only information on the services they provide. This makes an imbalance between the information attained about Multiconsult's uncertainty management and the information of these five companies. Whereas the information of Multiconsult is internal and focuses on the processes that manage uncertainty

in their design projects, the information from this document study point to the actions these companies do in order to manage uncertainties on a construction project-level.

The comparison that can be made, is what these companies bring into the project regarding uncertainty. All the companies in the document study have stated that they offer uncertainty analysis for the clients, where some actors even offer uncertainty consulting throughout the project and tailoring of tools and reports for specific projects or clients. Multiconsult also offer such services, but only in the largest office in Oslo. The smaller offices as the Trondheim-office, offer these services to clients by using Oslo-resources.

6. Conclusion and further work

This chapter is a conclusion of the master thesis and answers the problem statement, as well as the research questions. In addition, an evaluation of the work in this thesis will be provided and recommendations for further work will be presented.

The aim of this research was to give recommendations on how Multiconsult Trondheim can improve their internal uncertainty management, as an actor in design projects. Uncertainty is defined by the lack of information (Torp, et al., 2008), and is in design phases tied to project owner, contract, coordination/communication, environmental factors and delays (DODGE Data and Analytics, 2018). In 2018, a new corporate strategy was announced in Multiconsult, called “3-2-1 GO”. The strategy focuses on the aspects that can lead to larger profitability in design projects, including capacity and management expertise.

This research has had a focus on the elements defining uncertainty management in Multiconsult Trondheim today and the elements that might have a potential for improvement. To provide an in -depth study of the uncertainty management in the industry, five firms have been elected for a document study giving ground to compare different practices in the same industry. As a mean to uncover the experiences and points of views to this subject, a screening process was initiated in order to map 35 design projects and how they were executed with respect to uncertainties detected. This overview led to election of four case studies that provided a detailed description of todays practice of uncertainty management in the respected company.

The findings show that the most characteristic elements of uncertainty management in Multiconsult Trondheim are:

1. Checklists for quality assurance and uncertainty evaluation
2. Reporting and follow-up of uncertainties
3. Meetings regarding uncertainty
4. Roles and capacity
5. Internal economic system

These elements affect the uncertainty management practice of Multiconsult in two ways, directly and indirectly. The direct impacts are those who directly affect uncertainty management practice as checklists, reports, follow-ups, and meetings. The indirect impacts are those who indirectly affect the uncertainty management practice, such as roles and

capacity, and the internal economic system, Maconomy. These impacts are not supported directly by theory, but their influence is shown in the operational uncertainties of design projects.

As most of uncertainty management tools and methods are developed for project owners and construction contractors, design engineering firms have had to adapt these methods or develop procedures that are fit to their practice. The findings showed on the other hand that the available information regarding uncertainty management practice of the external firms, focuses mainly on the uncertainty management services they offer to clients, not how they manage internal uncertainties. This is an unfortunate finding, which only shows that many of the services other companies provide, can also be provided by the head office of Multiconsult in Oslo.

The result from the research is a model that shows a better uncertainty management practice, with complimentary recommendations.

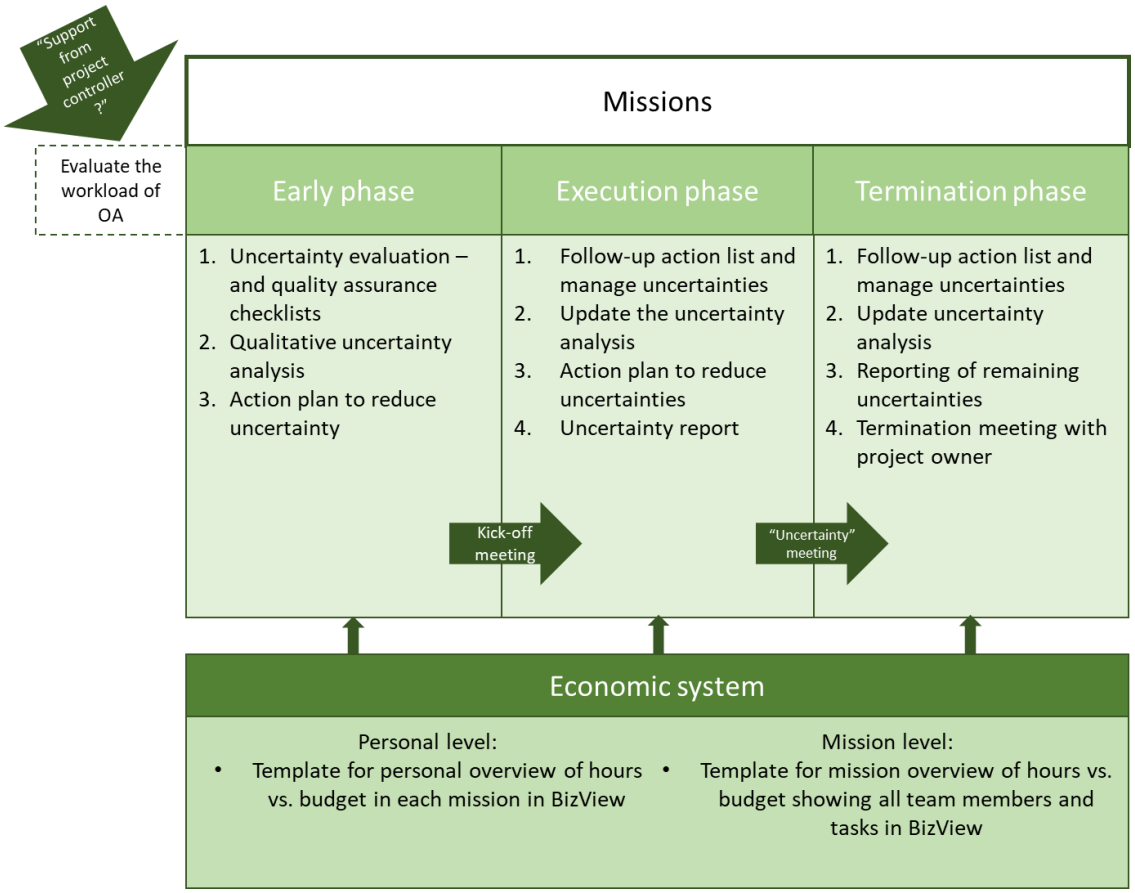


Figure 30 Suggested model for a better uncertainty management practice in Multiconsult Trondheim

This model shows how an uncertainty management process can be structured and is inspired by the most common practices for uncertainty management presented in Chapter 3.2. The model suggests keeping a continuous and structured method for uncertainty management and implements methods as qualitative uncertainty analysis, action plan, uncertainty reporting and uncertainty meetings with project owner. In addition, the two indirect impacts on uncertainty management are included in the model in Figure 30. The recommendation is to develop templates for personal and design project overview of time spent against the budget using BizView. This way, the team-members can keep track of their own hours spent and the design project manager can have a better control of the design project course.

The recommendations are intended to uplift Multiconsult Trondheim from an interactive uncertainty management practice towards a proactive uncertainty management. Having a continuous and structured process of uncertainty management will affect uncertainties at all levels and engage a larger transparency of uncertainties between design project team and project owner.

6.1 Evaluation and future work

When evaluating the research that has been done, there are several factors that can be considered in a critical matter. The first is that not all design projects in the screening were terminated at the point the screening was initiated. This means that these design projects did not hold all details to evaluate the outcomes of the design project and might be lacking experience that completed design projects could provide. A recommendation for further work is to conduct interviews with the respective individuals and evaluate if the findings can relate to their experiences. If not, a consideration of altering the recommendations is in place. Another large focus of the research is the model for recommendations presented in Chapter 4.5. This model shows only hypothetical recommendations, and since the model has not had the opportunity of being tested during the research, the results of the influence of the recommendations remain unknown. Therefore, a testing period of these measures is recommended to conduct and mapping the results after a certain period of time.

The document study of external tools and methods for uncertainty management among consulting firms has unfortunately shown generic results. The document study revealed therefore only what the services the firms are offering regarding uncertainty management, and not how the different firms preform uncertainty management internally. A recommendation

for further work is therefore to do a more in-depth study to discover different practices and compare them. This could be done as a separate study with interviews and more comprehensive questionnaires.

On the basis of the limitations of this study, and with the identified weaknesses in mind, this study is evaluated to be both valid and reliable. The sources of information are of good quality and the data gathered has proved to be correct when verified from several informants. All though there are aspects that can be further researched, there is a belief that this research will be of value for the respected company.

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