Vegard Knotten

Building design management in the early stages

Thesis for the Degree of Philosophiae Doctor

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Norwegian University of Science and Technology

Faculty of Architecture and Design

Department of Architecture and Planning

NTNU
Norwegian University of
Science and Technology

Preface

I have been a part of the architecture, engineering, and construction (AEC) industry in all my professional life. It started in a consultant company as a designer after completing my master, and after a short while I was sent to the construction site as a technical site supervisor correcting my own and other's design mistakes, bridging the gap between design and construction. After nearly eight years of working with designing I felt that my main interest was more on site, and subsequently spent more than eight years as a site supervisor, design manager, and project manager at a large hospital project. As with all projects, the project finished, and I once again had to decide where my primary interest lay. After eight years on site constantly addressing issues with design errors and non-buildable solutions, my interest was shifted to the role of design management. The management of the design process, to influence the key actors on how to solve the project with the best solutions possible and at the same time produce correct drawings for construction. As I had previously worked as a designer for a consultant company and in a client organization, it was natural to work for a constructor next, and I started as a design manager at Veidekke. Veidekke had embraced the thinking of Lean construction, and recognized the importance of design management to create value for projects. After working 3 years as a design manager for Veidekke I got the opportunity to start this industrial PhD, spending time researching the industry in which I had been a part of and at the same time contributing back to Veidekke with new knowledge.

My PhD is part of a research project of developing design management called Integrated Methodology for Design Management (Integrert Metodikk for Prosjekteringsledelse – INPRO), funded by the Norwegian Research Council. It is a four-year research project that started in October 2013. The project consists of several partners in both academia and industry. The industrial partners represent companies from AEC, shipbuilding, and offshore construction. A summary of the research project's intent is described in Knotten et al. (2014).

The research project has provided this PhD thesis with a framework of research, building design management, yet inside that field the options were wide. The industrial partners have supplied the cases for research. The research project and its principal members, both from academia and industry, have also had several workshops discussing aspect of design management. This has worked as an arena for presenting and discussing findings throughout the whole project.

In the research project I have collaborated closely with another PhD candidate, Fredrik Svalestuen, throughout the whole project and contributing on each other's publications. We are both industrial PhDs from Veidekke. However, our focus and topics of the PhD have been different. My focus has been in the building design management in early stages, while Fredrik Svalestuen focused on the communication between design and construction. We have conducted our research separately and combined results within the publications.

After working 19 years as a professional before starting with the task of doing a PhD made me both humble in the ways of learning, but also aware of my own professional bias. Through the research process I have tried to balance the bias of preliminary knowing the "real world answers" before starting the research and but at the same time using my professional knowledge to pinpoint areas of interest in the research.

Even though the focus of my research has not changed much during this period, my view has broadened, making me even more aware of the contextual challenges for building design management. I hope that my work can benefit both building design management researchers and practitioners.

Acknowledgments

After completing this PhD, I reflect on the different choices that eventually led to this work, some coincidental and some more deliberate. However, I think this work is not only the result of four years of research, but also the work of a professional lifetime. Bearing that in mind, I think all my co-workers throughout my career have contributed with insights, help, discussion, knowledge, opposition, and support, gradually forming my field of interest and my curiosity try and influence the design management AEC industry. I wish to thank my employer Veidekke, and Hege S. Dammerud and Trond Bølviken in particular, for having faith and giving me this opportunity. In addition, I wish to thank to my design management colleagues in Veidekke, especially in those Trondheim with whom I have shared and discussed design management throughout this period.

My main collaborators in the research project INPRO, both in academia and industry have also provided me with new knowledge, valuable discussions and help with the cases. A sincere thanks to you all, and to the participants in the industrial cases taking time to help me. In INPRO we are two industrial PhD candidates. We have collaborated with publications, discussing research, sharing experiences, and traveled together. Having a colleague with the same references has been very valuable, so thank you Fredrik.

Taking the step from a “routine job” as a design manager, and starting with research was a big step in the unknown and might not have happened if it was not for the first meeting with Geir K. Hansen, my main supervisor. During that first meeting, discussing the possibilities I felt encouraged that I might actually have something to contribute with in research. You have always taken time to answer short and long questions and have been an important support during these years. And a thank you to my co-supervisor Ola Lædre for always securing that my research is on track toward its objectives. Thank you both, for good supervision and collaboration in writing the publications.

Last but not least thanks to my family. My parents for support and who once persuaded me that higher education actually was important. And to my family; Torunn, Guro and Kjersti for allowing me time to pursue this PhD.

Trondheim, November 2017

Vegard Knotten

Summary

The AEC is an industry in change due to developing demands in environmental, sustainability, technology, and other regulatory demands. For projects to successfully comply with the changes this needs to be dealt with in the early stages of projects in the design phase, where the influence of solutions are high and the cost of changes are low. This PhD work examines building design management at the early stages of design.

The PhD thesis is conducted as a PhD by publication and consists of ten publications, and this thesis as the overarching essay. Each of the publications addresses different topics relevant to building design management. The research is based on qualitative case studies, learning from the practitioners to achieve an in-depth understanding of building design management.

The main research question of this PhD thesis is: How should building design management handle the early stages of the design phase in building projects? This is answered first through trying to define what building design management is. The definition used is: Building design management involves planning, organizing, and managing people, their knowledge, and the flow of information to obtain specific project goals and objectives.

Further, the thesis examines the challenges in the design phase of the early stages, to provide characteristics of the design process that need to be addressed. The challenges lie in the complexity of the interdependence of the design task, where tasks need to have reciprocal interdependencies to create a better solution, while constraints in time, for example, need the design to stop at a certain deadline. The fragmentation of the AEC also creates challenges at the organizational and personal levels. These challenges need to be handled by building design management.

The thesis also examines the success factors of building design management. A list of ten success factors is presented based on the literature and is discussed based on empirical findings. However, the research also shows that the success factors needs to be aligned with the project, the actors of the project, and building design management since they might not have the same relevance for all projects.

Moreover, the thesis examines the learning potential in building design management from similar project-based industries, such as offshore construction and shipbuilding. Offshore construction uses the building information model (BIM) in a more mature way in both planning and progress reporting. The shipbuilding design team works almost autonomously, creating ship designs and rapidly responding to changes.

To answer the main research question of how building design management should handle the early stages of the design phase in building projects, the thesis proposes a framework. The framework emphasizes the importance for building design management to plan not only the building design process but also the building design management process. The framework is made to be generic and starts with an assessment stage to assess the specifics of the project, then an initialization stage to plan the design management strategy, and then the execution stage to execute the design management strategy to handle building design management in the early stages.

Sammendrag

Bygge-, anleggs- og eiendomsnæringen (BAE) er en næring i endring. Det skjer store endringer i miljøkrav, energikrav og bærekraft samtidig med at næringen kritiseres for å ha lav produktivitet samt for å levere produkter med mye feil. Disse utfordringene må løses tidlig i prosjekt, dvs. i fasene for prosjektutvikling og prosjektering. De tidlig fasene av prosjektet regnes også som de mest utfordrende og mest krevende å lede. Sammenlignet med byggeprosessen har prosjekteringsfasen og prosjekteringsledelse fått lite oppmerksomhet i forskning. Denne doktorgraden tar sikte på å bidra til den allmenne forskningen om prosjekteringsledelse ved å utgi publikasjoner, samt at den ser på prosjekteringsledelse i tidligfase spesielt. Målet med oppgaven har vært å si noe om hvordan prosjekteringsledelse i tidligfase av byggeprosjekter bør håndteres.

Et av spørsmålene som belyses i avhandlingen er: hva er utfordringene i tidligfase av prosjekter? Utfordringene er sammensatte, men prosjekteringsprosessens natur, med avhengigheter som er sekvensielle og resiproke, gjør at prosjekteringsprosessen må styres på forskjellige måter for å oppnå effektive prosesser. Det at bransjen i tillegg er fragmentert, med stort sett nye aktører for hvert prosjekt, bidrar heller ikke til å redusere utfordringene. Prosjekteringsledelse forstås i denne avhandlingen som det å organisere, planlegge og styre personer, deres kunnskap og informasjonsflyt.

Avhandlingen har også undersøkt suksessfaktorer for prosjekteringsledelse. Gjennom analyser av litteratur ble det identifisert ti suksessfaktorer: kommunikasjon, beslutninger, planlegging, kunde, grensesnitt, team, risiko, kunnskapsstyring, HMS-fokus og evaluering. Disse ble igjen prioritert av en gruppe prosjekteringsledere. Imidlertid prioriterte ingen av prosjekteringslederne disse ti suksessfaktorene helt likt, noe som indikerer at suksessfaktorer for prosjekteringsledelse må tilpasses prosjektet, aktørene og prosjekteringsledelsen.

Avhandlingen har også sett på prosjekteringsledelse hos offshore engineering og skipsdesign for å finne mulige forbedringspotensialer hos byggebransjen. Ikke uventet er offshore engineering bedre på planlegging, oppfølging samt utnyttelse av bygningsinformasjonsmodeller (BIM) som en informasjonsbærer i prosjekteringsprosessen. Tilsvarende så vi at design-team i skipsbygging opererte

nesten autonomt, noe som støtter tidligere forskning om at komplekse prosjekteringsprosesser krever stabile team med tydelige definerte roller og åpenhet.

Avhandlingen har bidratt med en generisk modell for prosjekteringsledelse i tidligfase. Basert på resultatene foreslår modellen at prosjekteringsledelse må være mer proaktiv og gjøre en nøye vurdering av prosjektet for å kunne foreslå en strategi for gjennomføring av prosjekteringsledelsen. Prosjekteringsledelsen bør ikke bare vurdere en strategi for gjennomføring av prosjekteringsprosessen, men også en strategi for prosjekteringsledelse. I modellen foreslås det tre faser: vurderingsfase, initieringsfase og gjennomføringsfase. I vurderingsfasen fastslås alt som er spesielt med prosjektet, prosjektets mål, hvilke aktører som er tilgjengelig samt prosjekteringsledelsens nødvendig kompetanse og kapasitet. Basert på dette vil det i initieringsfasen lages en strategi for hvordan prosjekteringsledelsen best kan gjennomføres med tanke på organisering (av personer og kunnskap), planlegging og informasjonsflyt. I gjennomføringsfasen benyttes denne strategien som en gjennomføringsplan for prosjekteringsleder, med konstant evaluering av måloppnåelse av både prosjekt og prosessmål. Modellen tar ikke hensyn til spesielle verktøy, men forskningen viser at involvering av personer, samt å benytte samhandlende verktøy, for eksempel integrated concurrent engineering (ICE), bidrar til større kunnskapsflyt, bryter ned læringsbarrierer, og reduserer utfordringen med sub-optimalisering på tvers av aktørene.

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List of Abbreviations

AEC – Architectural engineering and construction (Industry)

BDM – Building design management

BIM – Building information model

CCM – Constant comparative method (of analysis)

CDM – Collaborative design management

CE – Concurrent engineering

CPD – Collaborative planning in design

ICE – Integrated concurrent engineering

LOD – Level of development

MA – Mutual assessment

MRQ – Main research question

OC – Offshore Construction (industry)

PDM– Project delivery model

PEM – Project execution model

RQ – Research question

SB – Ship building (industry)

TMM– Temporal mental model

VDC – Virtual design and construction

Publications and the Author's Contribution

Table 1: Publications and the author's contribution.

No.	Publication	Contribution / Role in Preparing the Publication
P1	Knotten, V. and F. Svalestuen (2014). **Implementing Virtual Design and Construction (VDC) in Veidekke - using simple metrics to improve the design management process**. 22nd Annual Conference of the International Group for Lean Construction., Oslo, Norway.	First author and responsible for collecting the data, leading the discussion along with co-author.
P2	Knotten, V., F. Svalestuen, G. K. Hansen and O. Lædre (2015). "**Design Management in the Building Process - A Review of Current Literature."** Procedia Economics and Finance **21**(0): 120-127.	First author and contributing with theoretical knowledge, leading the discussion along with the co-authors.
P3	Knotten, V., F. Svalestuen, O. Lædre and G. K. Hansen (2015). **Organizational power in building design management.** 23rd Annual Conference of the International Group for Lean Construction., Perth, Australia.	First author and responsible for collecting the data, leading the discussion along with the co-authors.
P4	Knotten, V., F. Svalestuen, O. Lædre, J. Lohne and G. K. Hansen (2016). **Design Management – Learning across trades.** Proceedings of the CIB World Building Congress 2016: Volume I - Creating Built Environments of New Opportunities, Tampere University of Technology. Department of Civil Engineering.	First author and responsible for collecting the data, leading the discussion along with the co-authors.
P5	Knotten, V., A. Hosseini and O. J. Klakegg (2016). **"Next Step" - A new systematic approach to plan and execute AEC projects**. Proceedings of the CIB World Building Congress 2016: Volume III - Building Up Business Operations and Their Logic, Tampere University of Technology. Department of Civil Engineering.	First author and contributing with theoretical knowledge, leading the discussion along with the co-authors.

P6	Knotten, V., F. Svalestuen, O. Lædre and G. Hansen (2016). **Improving Design Management With Mutual Assessment.** 24th Annual Conference of the International Group for Lean Construction, Boston, USA.	First author and responsible for collecting the data, leading the discussion along with the co-authors.
P7	Lohne, J., F. Svalestuen, V. Knotten, F. O. Drevland and O. Lædre (2017). **"Ethical behaviour in the design phase of AEC projects."** International Journal of Managing Projects in Business **10**(2): 330-345.	Third author and contributing with collected data, theoretical knowledge, leading the discussion along with the co-authors.
P8	Knotten, V., O. Lædre and G. K. Hansen (2017). **"Building design management – key success factors."** Architectural Engineering and Design Management, 13(6),479-493	First author and responsible for collecting the data, leading the discussion along with the co-authors.
P9	Svalestuen, F., V. Knotten, J. Lohne, F. Drevland and O. Lædre (2017). **"Using Building information Model (BIM) devices to improve information flow an collaboration on construction sites."** ITcon **22**: 204-219	Second author and contributing with theoretical knowledge, leading the discussion along with the co-authors.
P10	Svalestuen, F., V. Knotten, O. Lædre and J. Lohne (2017). **"Planning the building design process according to Level of Development."** Lean Construction Journal, in review	Second author and contributing with collected data, theoretical knowledge, leading the discussion along with the co-authors.

The listed publications are the basis of this PhD thesis. The reference to the publications and their use in the thesis are annotated as P8 (Publication 8: Building design management – key success factors), for example. The publications are included in Appendix B.

1 Introduction

The architecture, engineering, and construction industry (AEC) is an industry in constant change with increasing complexity by adapting to the new challenges, such as sustainability, energy consumption, technology development, and other climatic changes. The AEC industry is struggling with quality and productivity issues (Love & Li, 2000; Love et al., 2003; El. Reifi et al., 2013; Bråthen, 2015; Mejlænder-Larsen, 2015) and has been criticized for not increasing productivity compared to other comparable industries (e.g., offshore construction (OC) and shipbuilding (SB)). Even though B. Andersen and Langlo (2016) pointed out that there are flaws in the measurements leading to this impression, there is still a potential for improvement in the AEC industry.

The AEC industry is described as a fragmented industry relying on many different actors from the start to finish of a project (Kerosuo, 2015; Zidane et al., 2015). This can cause problems with communication and teamwork within the projects. Large project-based organizations can even experience communicational challenges between the temporary project and the permanent functional organization (Dainty, Moore, et al., 2007). Further, an AEC project is organized in several phases and consists of several different actors from different organizations; thus, more opportunities for communicative problems can arise. This typically arises out of the fact that different organizations involved in the project have different tasks, cultures, and objectives. The scope of work in the AEC industry also varies in both economic size and complexity, affecting the organization in competence, size, and culture (Dainty, Green, et al., 2007). All this portrays the challenges of adapting to changed context in different projects.

A key to combat these challenges successfully lies in the early stages of the AEC projects, and in the design stages. The building design process is where key technical and structural decisions are made. Decisions made here influence the whole lifecycle of the building. In the early stages of a project, the influence of the project is strongest and changes have less effect on the final cost (Samset, 2008).

Several researchers acknowledge the challenges in the design phase (e.g.,(Ballard & Koskela, 1998; Hansen & Olsson, 2011; El. Reifi & Emmitt, 2013)), and there is a consensus that the early stages of the design phase are important to improve the quality of the project (El. Reifi & Emmitt, 2013). However, the research on this issue in building projects is limited (Emmitt, 2016).

Design work, compared to physical production, is different in the sense that is potentially infinite. There is always a better solution to be found (Lawson, 1997). The design activities and their interdependencies differ from the activities in the construction phase, as they are more complex in their interdependencies and thus need another form of management.

Design management is about organizing, planning, and managing the design process (Sinclair, 2011). It can also be described as a complex social situation where value can be a socially constructed phenomenon and making decisions can be inherently unpredictable (Kestle & London, 2002).

Design management has existed as a discipline since the 1960s, but the focus of its significance for the building process has finally been acknowledged in the twenty-first century (Emmitt, 2017). Yet, several researchers still point out the fact that design management in built environments or building design management is an under-researched field (Tilley, 2005; Gilbertson, 2006; El. Reifi et al., 2013; Emmitt, 2016). The field is gaining increasing attention; however, to further evolve the field of building design management, there is a need for more research.

In his work, Grimsmo (2008) pointed out that industries such as OC and SB have evolved faster than AEC. As AEC projects increase in complexity, could AEC learn from other trades who are recognized to handle such complexity? The OC and SB are typically both recognized as being characterized by a high level of complexity (Aslesen & Bertelsen, 2008; Gaspar et al., 2012; Lia et al., 2014). In addition, the AEC, SB, and OC industries are all project-based industries, mainly consisting of designing and manufacturing unique products for different customers, indicating that there might be similar challenges in the management of the design process.

1.1 Aim of the Research and Research Questions

Adapted from Rogers (2003) work of diffusion, Figure 1 illustrates the need for further research by showing how the diffusion of the research or how the research is communicated over time will influence the maturity of the research. There is a need to communicate the importance of building design management research and to increase the research attention to evolve the research innovation in the field. Critical mass is the point where the field has received so much attention that it is self-sustaining, and the attention and maturity of the research rises. If the diffusion fails, the attention drops, and development of the research will decline accordingly.

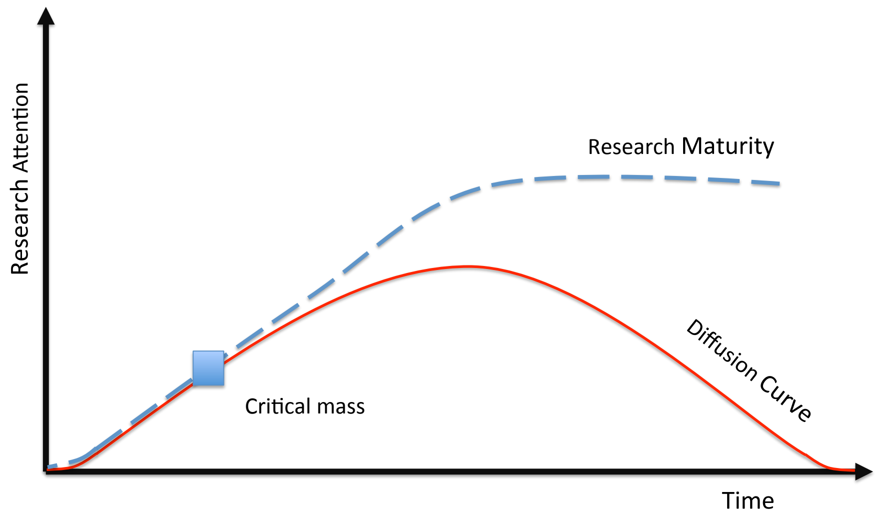


Figure 1: Building design management - research development (adapted from Rogers (2003)).

To frame the interest of this PhD research further, to address key challenges of the AEC industry, one needs to influence the project in the early stages. This is done in the design stages, a stage of the AEC industry that still needs research. To influence the right decisions and solutions to address the key challenges, the early stages need adequate building design management.

The purpose of this PhD thesis is therefore two-fold. Primarily, it seeks to understand more about building design management in the early stages. What kind of management is needed? What are the challenges, and how can management be improved? Can building design management learn something from other comparable industries, such as OC and SB? Second, as a PhD by publication, it seeks to contribute research and to communicate this concerning the importance of building design management as a separate field in AEC research. This will contribute to knowledge in both academia and the AEC industry.

The aim of this research is formulated as the main research question (MRQ), which follows:

How should building design management handle the early stages of the design phase in building projects?

In this research, the early stages are defined not only as the beginning of the project but also as the early stages of design. The development and design stages are where there are complex design activities with a high degree of iterative processes. This is usually from the start of the project and in the earliest part of the detailed design. There are several different definitions of these stages and their content based on the context and who defines them (e.g., the Royal Institute of British Architects (RIBA, 2013) plan of work). This can cause confusion; thus, to promote a more holistic approach of the Norwegian AEC industry, "Next Step" was developed (P5). Next Step tries to clarify the different steps and their content in AEC projects, so different actors can define and expect the same deliveries in the projects (Klakegg et al., 2015). In the definition of Next Step (illustrated later in Table 4), the design stages are referred to as strategic definition, brief development, concept development, and detailed design. The early stages discussed in this PhD thesis refer to the strategic definition, the brief development, the concept development, and the earliest part of the detailed design.

To answer the MRQ: How should building design management handle the early stages of the design phase in building projects, I propose some themes to support the MRQ. These themes are organized as sub-questions and referred to as research questions (RQ). First, to establish a reference frame for this research, it is necessary to understand what building design management is (RQ1), and who and what are managed. Second, to examine what building design management must handle in the early stages, what are the challenges in the early stages (RQ1a)? Third, "how should" emphasizes that there are some things the building design management should do more of, which could be described as success factors. Which factors or drivers contribute to successful building design management? (RQ1b). Fourth, since AEC is often compared with OC and SB, while portraying OC and SB as more successful, it is interesting to see whether there is something the AEC can learn from OC and SB concerning building design management (RQ2). Does the way engineering managers or naval architects handle design management provide methods of improvements for building design management?

In summary, the PhD thesis aims to answer the following RQs;

MRQ:

How should building design management handle the early stages of the design phase in building projects?

RQ1: What is building design management?

How is building design management defined in literature, and how is it handled in practice based on this research?

RQ1a: What are the challenges in the early stages?

What kind of challenges does building design management encounter in the early stages and how does that affect the building design management?

RQ1b: What are considered success factors in building design management?

What drivers or factors are important to focus on for building design management, and how does that affect building design management?

RQ2: What can building design management learn from engineering management?

Is there something that the OC and SB does better than the AEC from which building design management can learn?

1.1.1 Limitations

To perform a thorough study of the RQs there must be a limitation of the scope. The focus of the research is building design management, more precisely, in the early stages of the design phase. ´Early stages´ refers to the stages of design where the activities are iterative with a high interdependence across disciplines. Even though some of the publications address the whole lifecycle of AEC projects, the focus of this PhD thesis is only on the early stages.

In all the cases, a contractor or equivalent in OC and SB executes the role of design management. The work does not discuss how the perspective building design management might differ if an architect, client, constructor, or independent consultant executes it.

The choice of doing a PhD by publication also presents some limitations and opportunities. A limitation lies in the restrictions made by the publishers and conferences, primarily in the size of the publications. The advantage of a PhD by publication is the ability to publish throughout the whole PhD period. The publications are peer reviewed, aiding the quality of the publication. The conference publications are all presented at international conferences, contributing to direct feedback and dialog with other researchers.

As a PhD by publication, this thesis focuses only on the ten included publications, tying them together to answer the MRQ and RQs. More research and publications have been done during this PhD work that are not included in this thesis. Some of the work is published but not included, and some of the work is unpublished.

1.2 Structure of the Thesis

This is a PhD by publication consisting of ten different publications (listed in Table 1) and an integrating essay. Each publication represents individual research concerning different aspects of building design management. All the publications are double blinded and peer reviewed and are published in recognized journals and conference proceedings. This PhD thesis is thus an integrating essay, tying the publications together to answer the MRQ and RQs.

The structure of the thesis is as follows:

- Chapter 1 Introduction: Introduces the PhD work, and presents the research questions (MRQ and RQs).
- Chapter 2 Research Design and Methods: Describes the main research design and methods used in the PhD thesis.

- Chapter 3 Theory: Presents an extract of the literature used in the different publications included in the PhD thesis, presenting topics relevant to the MRQ and RQs.
- Chapter 4 Findings: First, it presents a short summary of the publications included in this thesis. Second, it answers the RQs by presenting the main findings from the publications, organized by the RQs. This is illustrated in Figure 2.
- Chapter 5 Discussion: Discusses and summarizes the RQs.
- Chapter 6 Conclusion and Further Research: First, it answers the MRQ of the PhD thesis and then offers a conclusion and suggestions for further work.

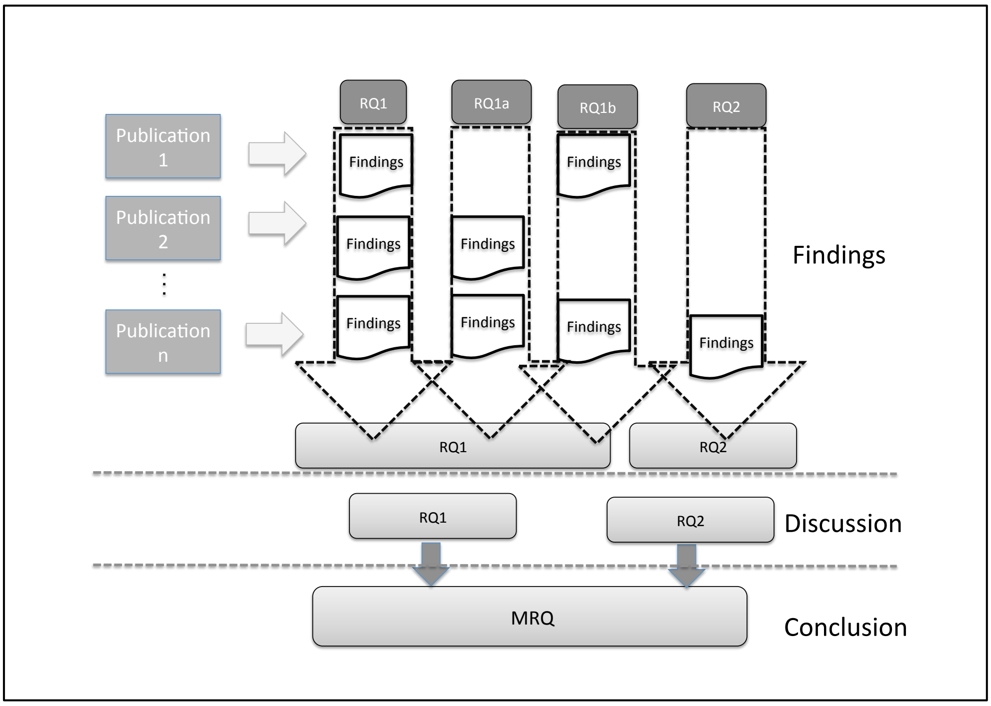


Figure 2: Answering the MRQ and RQs with the publications.

2 Research Design and Methods

This chapter describes the research process of this PhD thesis. An overview is illustrated in Figure 3.

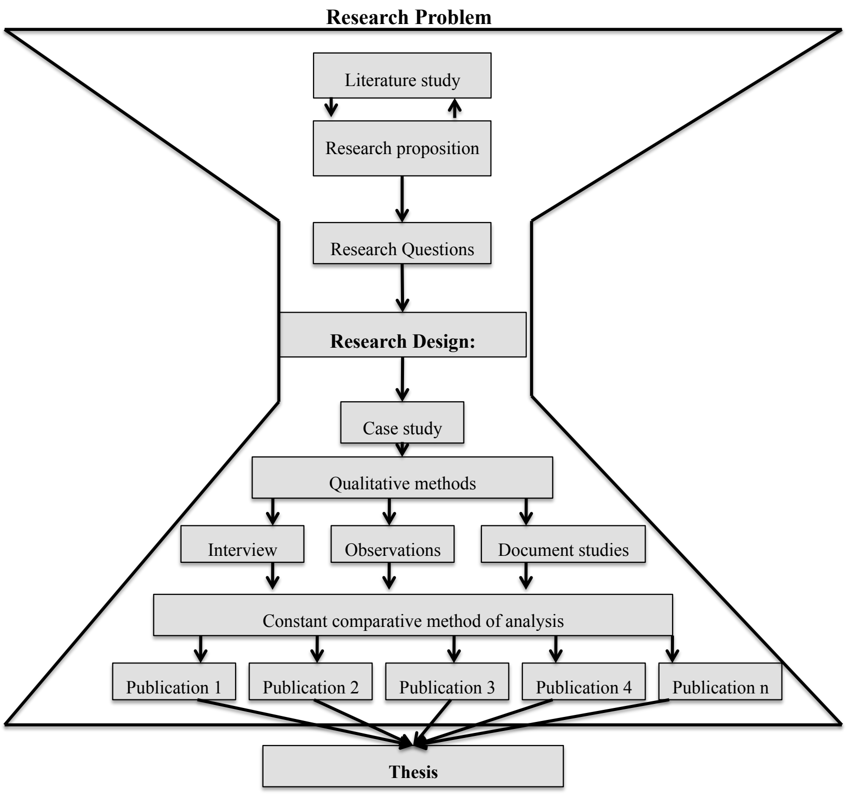


Figure 3: Research process of the PhD thesis based on Creswell (2012) .

2.1 Research Design

"A research design is the logic that links the data to be collected (and the conclusions to be drawn) to the initial questions of study. Every empirical study has an implicit, if not explicit, research design" (Yin, 2014, p. 26). Creswell (2003) argued for three questions to be addressed to design research. They are the question of the knowledge claim being made by the researcher, what kind of strategy of inquiry will inform the procedures, and what methods of data collection and analysis will be used.

2.1.1 Knowledge claim

Researchers start a project with certain assumptions about how they will learn and what they will learn during their inquiry. This is referred to as a knowledge claim (Creswell, 2003). There are different ways to conduct research in design management, depending on the expected outcome and research topic. Learning more of the behavior of the people participating in a design phase tends to focus the research on sociological understanding and results rather than a metric-bound understanding. In research connected to sociological studies, it is important to know the theoretical perspective and theory of knowledge before the research is planned and executed (Creswell, 2003; Alvesson & Sköldberg, 2009). These perspectives or philosophies of science will influence the researcher, and the research should be addressed in advanced. Alvesson and Sköldberg (2009) listed three main philosophies of science (post) positivism, social constructionism, and critical realism.

A key assumption of post positivism is that the absolute truth can never be found and that the evidence established in the research is always imperfect (Creswell, 2003). In post positivism, research is the processes of making, retesting, abandoning, and then refining claims. Research tries to develop relevant true statements, which can explain the situation of concern. The objectivity of the research is important, and the researcher must examine the methods and conclusions for bias.

Social constructionism views reality as socially constructed, in contrast to positivism, which believes that data already exist. The research focus is to explore how this social construction appears and happens (Alvesson & Sköldberg, 2009). An assumption is that the individual seeks understanding of the world in which we live and work. In social constructivism, it is believed that the individuals are formed through interaction with others and through history and cultural norms. Key assumptions are that humans construct meanings by the way they live, act, and learn. Humans make sense of the world they live in using their experience of history and social perspective. All meanings arise from social interactions. As all these assumptions point out, this affects the researcher, as experience influences the interpretation of the findings (Creswell, 2003).

Critical realism asserts that there is a world independent of human beings and that there are deep structures in the world that can be represented by scientific theories (Alvesson & Sköldberg, 2009). Critical realism views the research process at a continuous digging process, and the realities that are found at a surface level are discarded. This rules out empirically given reality departing from social constructivism or positivism, for example. Critical realists view experiments as the best way to generate elementary knowledge because it is possible to isolate and identify the mechanisms.

The use of theory in research can be described in two approaches; inductive or deductive (Saunders et al., 2009). The inductive approach is to collect data and develop theory based on the data and analysis, while the deductive approach is to develop theory or make a hypothesis and use the research design to test it (Saunders et al., 2009).

The knowledge claim of this PhD thesis is based on constructivism, since the focus is on humans and their meanings, behaviors, and interactions based on their interpretation of the world and society. The research has an inductive approach since its aim is to learn more about building design management from the practitioners to contribute new knowledge.

2.1.2 Strategy of inquiry

To establish the right form of research process, one must look at the research questions. The goal is to gain a better understanding of the design process and the people involved. Yin (2014) argued that there are different relevant situations for different research methods, such as the experiment, survey, archival analysis, history, and case study. There are three conditions that will help to determine the best-suited method. These are the type of research questions posed, the extent of control over the actual behavioral events, and the degree of focus on contemporary as opposed to historical events. This research on building design management best fits the category of a case study since 1) the MRQ is regarding ‘how and why,’ 2) there is no need to control behavioral events, and 3) the focus is on contemporary events.

Using qualitative research, as the method is most suited for this research since it helps gain an in-depth understanding of human behavior in the building design process. Qualitative methods start from the perspective and actions of the subject studied

(Alvesson & Sköldberg, 2009). Thus, to be able to learn from the practitioners in the design management process, it is important to study them.

The form of the research was partly descriptive and partly exploratory. The descriptive part, stating the situation as it is, was important to gain more understanding of how things are today. The exploratory form was to understand the means of improvement by learning from the cases.

In building design management publications, there is a small difference in the use of qualitative research vs. quantitative research (47% vs. 40%; (Knotten et al., 2017)). The remaining, 13% were described as mixed methods. Quantitative research was mainly linked to the research of management tools. The most common qualitative research approach is to use a case study with interviews. This research design is thus a common strategy in building design management research.

2.1.3 Research methods

The six most common sources of evidence or data collection, according to Yin (2014), are documentation, archival records, interviews, direct observations, participant observation, and physical artifacts. The case studies in this PhD thesis used document studies, direct observations, and interviews and are further described in Sections 2.2.1 and 2.2.2. The main analytic approach is the constant comparative method (CCM) of analysis, which is further described in Section 2.2.3.

2.2 Case Study

Defining this case study is a major part of the research design (Ragin & Becker, 1992). To design the case, it is important to define the extent and the boundaries of the case (Yin, 2014). The case studies were set up as single-case designs, where each case and industry are treated separately. Even though the contexts of the case studies are somewhat similar, they are not similar enough to set up as a multiple-case design. The context of the studies was how design management is executed and perceived by different participants on design teams. The cases or unit of analysis was studying the design team members of different industry partners.

There are four single-case studies conducted in the research as the basis for the PhD work. The execution of the case studies was planned and conducted as recommended by Yin (2014). An overview of the cases is presented in Table 2, and more details of the cases are presented in the publications.

2.2.1 Selecting the cases

The cases in this work are conducted at the industrial partners of the research project. The partners have represented an AEC constructor, an OC specializing in constructing derricks, and an SB specializing in offshore vessels. There are similarities of the industries, making a comparison relevant (P4 and P10). The industrial partners have participated in other research projects previously and wish to improve their performance; thus, they were open to sharing.

An aim of the case studies was to conduct them connected to ongoing projects. This was to study a functional working team to better learn of the similar and different views of the team members on the same project. This was done in Case 2 and Case 3 (Table 2). However due to regression in oil, this was impossible for Case 4. This changed the boundaries of Case 4 to focus more on the design manager's (naval architect's) role in ship design.

The aim for Cases 2, 3, and 4 was to interview not only the design manager but also members of the design team and the project managers. This was to learn how the different design team members viewed the design management process.

Table 2: Case studies of the PhD work.

No.	Case name	Boundaries of the Case	Data Collection Method	Contribution in Publication
1	Power in building design management (pilot)	Learning how organizational power is executed in building design management.	Interviews (5)	P3, P7, P 8
2	Building design management in AEC construction	Learning how building design management is executed by a contractor through a project	Interviews (7), Observation (5), document studies	P4, P 7, P 8
3	Engineering management in offshore construction	Learning how engineering management is executed by an offshore constructor through a project	Interviews (6), Observation (2), document studies	P4, P10
4	Design management in shipbuilding	Learning how design management is executed by a ship designer company.	Interviews (10), document studies	P4, P10

Case 1 consisted of interviews and its aim was to learn more about how organizational power affected the design process and its management (P3). The interviewees consisted of design managers at the AEC partner and one architect. It also worked as a pilot to try out the case-study approach, as recommended by Yin (2014). The result of the pilot also highlighted the importance of meetings, thus leading to the focus of observations as a research method in building design management.

Case 2 was to study an AEC project. The project was organized in three sub-projects and had three design managers (P8). Observation was conducted at design meetings and interviews. The focus of the case was to learn how design management was executed in the construction project. The case showed how three different design managers executed their management to solve their challenges in three different parts of the same project.

Case 3 was to study an OC project. The OC was responsible for the drilling equipment set at a new oil rig. The focus at this case was the same as for the AEC project, to learn how engineering management was executed in the project. The case provided insight into the industry and how engineering management worked in large offshore projects.

Case 4 was to study a design department at a shipbuilder to learn how they work together when they design ships. As it was impossible to follow a project, the focus was to learn the details and roles of the participants in design and the naval architect. The case provides insight into how a ship design team works and collaborates, solving customer requirements and innovating the industry.

The findings from the case studies are used in several of the publications. The case contributions to the publications are presented in Table 2.

2.2.2 Data collection in the case studies

There are four principles of data collection that will strengthen the sources of evidence (Yin, 2014). The first principle is to use multiple sources of evidence. Using multiple sources of evidence, the researcher can triangulate the evidence, finding support and confirmation in the different sources. This was done using interviews, observations, and documentary evidence.

The second principle is to create a case-study database. The database should be divided in two separate collections, consisting of the collected data and the researchers reports, comments, etc. The data should be carefully arranged and organized to be easily accessible. In this way, the reliability of the research is increased. The collected data were stored and organized using the software MAXQDA in Cases 2, 3 and 4. In Case 1, the data were meticulously recorded with detailed information. The databases were organized and sorted so the collected material was divided, and my own memos were linked to the relevant data.

The third principle is to maintain a chain of evidence. This includes the necessary citations and clarifications of where the documentation or evidence originated and how and when it was obtained. This was also maintained as previously described. This also increases the reliability of the research.

The fourth principle is to exercise care when using data from electronic sources. The information available through the web and social media is overwhelming and might not be accurate. The literature is assessed from academic books or peer-reviewed publications.

Interviews

Kvale and Brinkmann (2009) described the importance of the research interviewer to conduct a successful interview. It is recommended that the interviewer have experience with the art of interviewing and knowledge in the field of the subject. To be most prepared for the case studies, there was a pilot study to train for interviewing, transcribing, and analyzing.

The interviews were primarily conducted as semi-structured one-to-one interviews. A one-to-one interview is a meeting between a researcher and one participant. It is easier to arrange and follow up since only one set of data is presented (Denscombe, 1998). The semi-structured interview is used when the researcher has a list of questions or topics to be addressed but lets the participant talk more freely. This way the participant can elaborate on his/her point of interest as well that of the researchers. Some of the case-study material was based on group interviews with two people.

The interviewees were primarily design team members, project managers, architects, principal designers, design managers, and clients. The interview with the design manager was important to learn of their role, but the views of the others are just as important to learn about their perception of the design management. For Cases 2 and 3, the interviewees were all from the same project. For Cases 1 and 4, the interviewees were from different projects. The number of interviews in each case is summarized in Table 2 (e.g., five interviews for Case 1).

The topic of the interviews was designed to answer the RQs by pursuing the interviewees' perceptions of what they regarded as the best practice for design management and their roles in the design process. The data from the interviews were audio recorded and transcribed. This made it possible to focus on the conversation instead of taking notes in the interview.

Even though a case study is a good research tool, it has some potential weaknesses as well. The study is very reliant on the quality of the interviews. To obtain good interviews, an interviewer needs to be a good interviewer and have a good interviewee.

The interviewer can increase his or her skills with pilot studies, but attaining the right interviewees can be more difficult. The ability of the interviewee to talk freely and wish to contribute is important. It is also important to determine whether the interviewee has a personal motivation that could influence the answers. The same set of open-ended questions was the basis of all interviews, but depending on the subject, the interviews lasted from approximately half an hour to one and half hours, which varies the information from the interviewees considerably. The group interviews contributed interesting facts, but the interviewees influenced each other's answers. This was both by filling in and by answering on behalf of the other part. They might have given different answers if the interviews were conducted as one-to-one interviews.

Observations

To obtain a deeper understanding of the way the project participants coordinate and operate, observations were conducted. This consisted of participation in the design/engineering meetings. Observation can be defined as the act of noting or studying a phenomenon in the action. "It occurs in the natural context of occurrence, among the actors who would naturally be participating in the interactions, and follows the natural stream of everyday life" (Adler & Adler, 1994, p. 378).

Before the researcher starts, it is important to plan the observation process (Adler & Adler, 1994; Postholm & Jacobsen, 2011; Creswell, 2012). The observation procedures are based on the recommended steps by Creswell (2012). The first steps are addressed before the observations begin, then there are steps to be addressed during the observations.

Step one is to bound the observation in place and time, so the researcher can study the phenomena (Adler & Adler, 1994; Postholm & Jacobsen, 2011; Creswell, 2012). This refers to the observation location, whom the researcher intends to observe, and when to observe them. In addition, how many times the observation is to be conducted should be considered. I have chosen to use the design meeting as an observation stage. This was because the design meetings summarize the status of the design process, and it is one of the most direct arenas of direct communication where the key stakeholders are present. This was also highlighted in the pilot study (Case 1) regarding building design management (Knotten et al., 2017). Each observation session was planned to last for the entire meeting.

Step two is to determine the researcher's role in the observation. I have chosen to take a role as a peripheral member/researcher (Adler & Adler, 1994) with no participation in the design meeting (strictly as an observer). Since only a few observations at each project were planned, the role also fits Gold (1958) observer-as-participant description.

The third step is to ensure the access to the observation site. For my work, this was done through the company liaisons, and then at the level of the design managers and with the consent of the participants.

The fourth step is to plan how to conduct the observations, as either unfocused or focused. An unfocused observation is based on the inductive approach with an undefined aim of the observation (Adler & Adler, 1994; Postholm & Jacobsen, 2011). A focused observation is based on the deductive approach, where the observer has a predefined scope of the observation. The observations can start as unfocused and then, after interesting themes appear, it can take a more focused form. Fangen (2010) recommended beginning with some overarching questions to have a starting point. Even though a focused observation has a predefined aim, the observer is also free to note other things (Postholm & Jacobsen, 2011). The observations were conducted using a focused observation approach. This is because I wanted the observations to reveal the dynamics in the design meetings regarding management. The major themes of focus were participant roles, meeting management, and meeting type.

The fifth step is to prepare and plan how to record the observations, considering what kind of information will be observed. Both Postholm and Jacobsen (2011) and Creswell (2012) recommended writing down both the actual happenings of the observations and the reflections on key happenings, using descriptive and reflective field notes. Fangen (2010) also indicated the difference between observations with verbal and non-verbal communication. As I have chosen a focused approach, I planned a few key topics that I could comment on during the observations. I used pen and paper to take notes.

The sixth step is the observation. Researchers should make themselves known, but should not interfere with the work. Researchers should be introduced so the participants are aware of them and why they are involved.

A strength to document the observations could have been to video record the meetings. However, I think this would have influenced the meeting. Just sitting at the end of a table or in the corner silently made it possible for the other meeting participants to ignore me as an observer. By choosing a focused observation approach, I was better prepared and had planned key topics to watch for in advance.

Document studies

For a case-study research, the most important documents are those that support evidence from other sources (Yin, 2014). Regardless of the case study, documents can provide information that is useful for the researcher. However, documents must be viewed carefully since they might be selected to show one special side, which is biased or incomplete (Creswell, 2003; Yin, 2014).

The documents studied from the cases were meeting memos, company presentations, and other documents that were presented by the case companies. Meeting agendas and minutes give an overview of what was planned to be covered in the meetings. These also provided insight about the preparation of the design manager and how the meeting was executed, supporting the observations. The AEC project used a series of spreadsheets to summarize the integrated concurrent engineering (ICE) sessions. The spreadsheet included the design plan, decisions plan, and action plan for the next two weeks. This provided easy access of information; however, not all participants were comfortable with the document and asked for traditional meeting minutes. Presentation of the working structures and processes presented by the industrial companies in the cases also exemplified the design process in terms of how they perceived it or how they would like it to be. This worked as a reference in observations or interviews.

2.2.3 Methods of analysis

Yin (2014) argued for research strategies and methods that are transparent and replicable and a strategy for analyzing the findings of a case study. Gioia et al. (2012)

stated that qualitative research lacks scholarly rigor and that qualitative research requires a systematic approach. An answer to this is the constant comparative method (CCM). The CCM was first mentioned by Glaser and Strauss (1968) but has since been adapted and evolved by other researchers (e.g., Corbin and Strauss (2008)). The CCM is a versatile method used in social science research and can be used not only for grounded theory (Glaser & Strauss, 1968) but also for case studies and phenomenology (Postholm, 2005; Savin-Baden & Major, 2013).

The basis of CCM is to compare incidents to classify data. The similarities of the incidents are then grouped together at higher level of descriptive concept (Corbin & Strauss, 2008). The three primary ways to handle the data are as follows: 1) Open coding is examining the text, either line by line or by paragraph to grasp the essential of what is said. 2) Axial coding is comparing the open codes and relating them together in categories or concepts. 3) Selective coding is attempting to find the main theme of the research. This is to be a core category that fits with the theme of the research and can explain what the research entails. The process is illustrated in Figure 4.

Creswell (2003) listed six steps of data analysis and interpretation. The process of data analysis is to try to make sense of the collected text (interviews, notes, and documents). This was the framework of the analytic process. As recommended by Corbin and Strauss (2008), I used memos to summarize first impressions of observations and interviews, which was helpful later in the analytic process.

The first step is to organize and prepare the data for analysis. This involves transcribing the interviews, typing up notes and observations, and combining them with documents.

The second step is to obtain an overall picture of the case. This is achieved by reading all the data. After reading the material, the researcher formulates a general sense of what it is and what it means, including the ideas and meanings the interviewees share. In this step, the researcher writes small comments or highlight points of interest.

The third step is to start the analysis. In their chapter on the CCM of qualitative analysis, Glaser and Strauss (1968) suggested an approach using explicit coding and analytic procedures. To start coding, a text is chosen (e.g., interview) and read while marking interesting meanings and quotes, while always keeping in mind what the interviewee was trying to express. The markings are the start of the coding procedures. The process is repeated with the rest of the material, while always keeping track of the markings to determine whether similarities appear. These topics are rearranged by level of importance. It is important to keep track of the notes of the coding, and why it is important (Glaser & Strauss, 1968). This process is a reflective process, and the aim is to have a unified coding/ topic, which then can be applied to the text again. This can also be described as open coding (Corbin & Strauss, 2008).

The fourth step is to generate descriptions of the settings or people for categories or themes for analysis. The descriptions of the categories or themes are narrowed and will be the findings of the case study. This can also be described as axial coding (Corbin & Strauss, 2008).

The fifth step is to determine how the descriptions and themes will be presented in the report. The audience of this study are scholars or design process participants. They will have some knowledge of the themes, but findings must be explained and illustrated with figures. The reports of the cases are primarily done through different publications.

The final step is to interpret the collected and sorted data. What are the lessons learned? In this step, it is important to reflect on the researcher's background and bias.

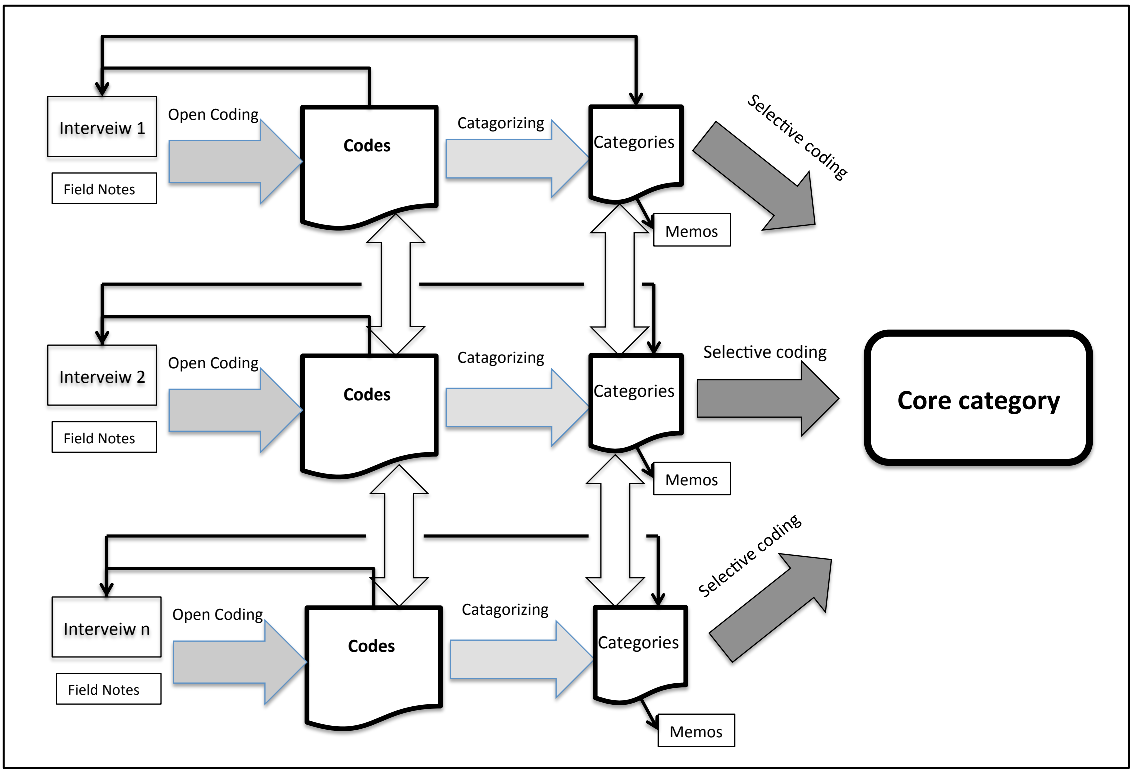


Figure 4: Constant comparative method of analysis.

The analysis started with an open-coding process to organize what is said. This is repeated several times, until I was satisfied with the codes. This was done with all the material, and the codes were compared across the interviews in the case. This helps to structure the nuances of the codes and reduces the number of codes. Then, the process of categorizing starts. The process examines the codes, theming them together in several steps and reducing the number of categories for each step. The categories are then compared with the codes and text to see if they still make sense. In the pilot study, this was done manually on paper, but in the case study, this was done using the MAXQDA computer program (Verbi, 2015). Throughout the process, categories were documented by making memos (Corbin & Strauss, 2008).

The last part of the analysis is the selective coding, or trying to obtain the core category. This is the most emergent category, which ties everything together. When using the case-study findings in publications, the categories were helpful in presenting and sorting the findings.

2.3 Literature Study

Throughout the research, there has been an extensive literature study. The review of current literature concerning the topic is important for the researcher to better understand the studied topic, to limit the scope, and also to understand the relevance of the research to others (Creswell, 2003). Being up-to date in the researched topics helps the researcher to better design and execute the research.

The literature study aims to look at relevant literature, primarily trying to answer the RQs. The outcome of the literature study was to describe previous research and theory in the field and to give a description of the current status. The literature study is based on the recommendations of Creswell (2003).

The results of the literature studies is presented in the publications of the PhD thesis and consists of literature directly concerning building design management, but also literature concerning other adjacent fields relevant for the publication. This is for example, organizational power, ethics, shipbuilding and offshore construction. An overview of the literature relevant for answering and discussing the research questions of this PhD thesis are presented in Chapter 3.

The search of relevant literature was primarily done through the databases of Scopus, Web of Science, Bibsys, and Oria. These are credible databases that should cover the main publications of the field. A challenge that was noted is that "building design management" is not a term often used in literature, leading to the need to rephrase the search strings. The topic is sometimes described as a part of construction management literature, making the relevance not so obvious, while the search of "design management" also led to findings in other publications fields (e.g., product design, computer science, and chemistry).

2.4 Quality of the Research

Yin (2014) argued that, in the design of the research, one should judge the quality of the research design and of the research itself, accordingly. The two main themes are research validity and research reliability. Validity and reliability do not have the same implications in qualitative studies as they do in quantitative studies; this concerns the nature of the research (Creswell, 2003).

Flyvbjerg (2006) argued against the following five common misunderstandings regarding the use of a case study as a research method.

1. Theoretical knowledge is more valuable than practical knowledge.
2. One cannot generalize from a single case; therefore, a single case cannot contribute to scientific development.
3. The case study is most useful for generating hypotheses, while other methods are more suitable for testing hypotheses.
4. The case study contains a bias toward verification.
5. It is often difficult to summarize specific case studies.

Regarding these misunderstandings as false, the case study is a powerful tool for the researcher to learn about building design management. In the interviews, the researcher focused on the practical knowledge and expertise of the interviewees. By using case studies with a low number of cases, the possibility of an in-depth understanding to reveal important issues is higher (Ragin & Becker, 1992).

2.4.1 Reliability of the research

The reliability of the research indicates whether the research can be repeated by different researchers in different projects (Creswell, 2003). Yin (2014) suggested that, to secure the reliability of a case, the researcher needs to document the steps of the case study. Using a case-study protocol and a database for collecting and storing the data helped achieve this. The case-study protocol is like a strategic document for executing the research, containing detailed information and research procedures. The protocol used for this research included the same interview guide for all one-to-one interviews and focus points for the observations.

The transcription was primarily done by the researcher using a software called Inqscribe (Inqurium, 2013), which provides timestamps in the transcription. All transcriptions were checked for accuracy before the analytic process started.

The collected material was analyzed using the CCM, with the use of memos to support the process of coding as recommended by Corbin and Strauss (2008). The same analytic procedures were used with all the material. To further secure reliability, the collected data were stored electronically. In the pilot case, the collected data were logged in a spreadsheet. In the other cases, all collected data were stored and logged in the analytic computer program MAXQDA (Verbi, 2015). The same program was used for coding and categorizing to keep all data together.

2.4.2 Validity of the research

Validity is determining whether the findings are accurate from the standpoint of the researcher, participants, and readers (Creswell, 2003). There should be multiple strategies for the researcher to assess the accuracy of the findings and convince the readers of that accuracy (Creswell, 2003). Yin (2014) divided validity in three subgroups: construct validity, internal validity, and external validity, and proposed different tactics to secure validity in research. Construct validity primarily takes place in the data collection phase. Key tactics are multiple sources of evidence, establishing a chain of evidence, and having key interviewees study the case-study reports. The collected data are from interviews, observations, and documents (i.e., multiple sources). The chain of evidence is maintained using MAXQDA. The case has been discussed with interviewees, and there has been a discussion of findings with supervisors and research partners throughout the process, as a member checking process.

Internal validity has received the greatest attention in experimental and quasi-experimental research, and is mainly a concern for explanatory case studies, so that the researcher can draw the right inference (Yin, 2014). Addressing internal validity in this research has been done using a strict and methodical approach of the CCM of analysis. This, along with using memos and field notes, provides extra sources of evidence to support the analysis. The categorizing process, by viewing the codes first, then categorizing and checking if it makes sense, is the background of inference.

External validity deals with the problem of knowing whether a study's findings can be generalized in other cases beyond the case study (Yin, 2014). Ragin and Becker (1992); Flyvbjerg (2006), among others, highlighted the cases study's ability to provide knowledge despite the small number of cases. This does not give the possibility of a statistical generalization, but an analytical generalization, which might lead to expanding the theory (Yin, 2014). However, case studies are not replicated with the aim to test the findings of previous case studies, a possible tactic described by Creswell (2003) to obtain generalization. The findings of case studies are presented in different publications and discussed with relevant theory, arguing for their relevance in their context and leading to new understanding of the field.

The understanding of the context is important when trying to use the knowledge from the cases. The cases are all done in a Norwegian context with a high degree of independence of the designers and collaborative culture. This could be said to affect the possible usability across borders. However, the findings are discussed and compared with mainly international literature in the field, thus making this relevant for an international context as well.

2.4.3 Role of the researcher

The researcher now has more than 20 years of experience in the AEC industry in Norway. This experience gives the researcher a good practical knowledge about the industry and how it operates. This is also valuable experience when it comes to understanding the operations of the other industries. The same experience might also create a bias, which needs to be considered when analyzing the results, since it is important to think and act as an academic researcher and not as a "problem solver" in the business. This was addressed using a thorough and rigorous analytic approach (CCM).

The researcher is doing research on behalf of the Norwegian University of Science and Technology (NTNU), but is simultaneously employed by Veidekke. This might raise the question of secondary interests in the research. Since the other industrial partners are in different industries, none of the findings or disclosures learned via the case study will directly influence their competitiveness. The sharing across the industries in this research project is believed to enhance the businesses abilities for all partners.

One of the cases was a Veidekke case, and doing research in one's own company might lead to difficulties (Wennes & Nyeng, 2006). There are two issues that need to be addressed. First, the researcher knows too much about his own organization and therefore is biased toward the interpretations of the case study. Second, the role the researcher has or had in the organization can be an issue. This could lead to a hierarchical issue, disclosure of information, or an assumption that the researcher knows everything about the organization. The awareness of these issues is important. The AEC case was done in a different part of Veidekke from where I previously operated. Wennes and Nyeng (2006) recommended the approach of an apprentice when dealing with one's own organization and to have a sparring partner to check interpretations. I used the same approach with an explicit contact to organize the introductions and interviews both in Veidekke and in the other cases.

3 Theory

In a PhD by publication, each publication presents the relevant literature for its theme. This chapter presents an overview of the literature presented in the included publications, to link the themes to the MRQ and RQs. The MRQ is: how should building design management handle the early stages of the design phase in building projects? The chapter presents literature discussing design in the early stages, the design process characteristics, its stakeholders, and its management. It also presents some of the characteristics of OC and SB. At the end, it summarizes the definitions of building design management.

Building design in the early stages

In the building design process, key technical and structural decisions are made for the project. Decisions made here influence the whole lifecycle of the building. The stakeholders' influence is high early but decreases toward the end of a project (Samset, 2008). Changes made early have little effect on the final cost of the project, but changes made late in the project are costly. To focus on the early stages and the brief are therefore important. The word brief can vary in meaning, but Blyth and Worthington (2001, p. 3) defined it as "an evolutionary process of understanding an organization's needs and resources and matching these to its objectives and its missions." However, this is an important and under-researched area of the AEC (Tilley, 2005; Gilbertson, 2006; El. Reifi et al., 2013). The briefing phase is also a complex stage to manage. If the management of the briefing phase is poorly conducted, opportunities to improve the project are likely to be missed (Tilley, 2005; Gilbertson, 2006). For an office building, Gilbertson (2006) described that design cost is 20% of construction cost, yet maintenance and building operating costs are five times the construction cost, and business operating cost can be as much a 200 times the construction cost. However, others, such as Hughes et al. (2004), indicated that the ratio of building to maintenance to operations (B:M:O) is not as high as 1:5:200 but may be 1:0.4:12 instead. The numbers might be debated, but the indication is that design has a considerable effect on business operations; yet, the design cost is only a fraction compared to the business operations. This emphasizes the importance of a good brief based on the actual needs of the owner, user, and facility manager, and thus involvement in the early stages.

The needs of the owner, user, and facility manager can be referred to as their perspectives, and the importance of these perspectives in AEC projects is discussed by Samset (2010). The perspective will, in some aspects, represent the priority of the stakeholders and should be balanced (Klakegg et al., 2015). It also influences the value focus, which differs from the different stakeholders.

Value can be regarded as something that improves the project, either at the final product or in a successful process (Eikeland, 2001). Waste can be regarded as something that does not improve the project (e.g., features that the client does not need or rework of design material or rework on site).

The value realization in a design process can be viewed from three different viewpoints (Eikeland, 2001):

- To increase the inner efficiency of the design process: The cost for the design process is reduced due to increased efficiency for the design team. The value potential is marginal in the projects' scope.
- To increase the inner efficiency of the production process: The cost of the production process is reduced due to a better outcome from the design process. Drawings are flawless, delivered at the right time, and the solutions are buildable. The value potential is significant in the projects' scope.
- To increase the outer efficiency for the total process: The value of the project is increased, (i.e., achieving a more functional, esthetical, technical, and economical building). The value potential is significant in the projects' scope.

Linking the value realization to (Gilbertson (2006) 0.2:1:5:200 (D:B:M:O)) inner efficiency influences design (D) and building (B) while outer efficiency influences facility management (M) and business operations (O). The design process needs to attend to all these views of value.

Building design process characteristics

The process of design is thus important to create and realize value. In the early stages of the design phase, such as preparation and brief, concept design, etc., the processes are creative, iterative, and innovative. These are processes in which many solutions, thoughts, and ideas are shared between the stakeholders in the project, and they need to be open to enable the best solution to arrive (Hansen & Olsson, 2011). The process has an iterative form (Kalsaas & Sacks, 2011), and each iteration will hopefully contribute to increase the end value of the project. Lawson (1997) defined designing problems and designing solutions as interdependent. Design problems cannot be comprehensively stated. There are no optimal solutions to design problems, and design solutions are unlimited in number. This points out the need for the management of the design process but also describes a major challenge: the design process can be viewed as an endless iterative process.

The design process can be considered a two-dimensional logic, which happens at the same time to some degree:

- Sequential logic is the predictable process where the deliverables from each discipline within the design team are interdependent on each other in a serial form (e.g., contractual milestones, stage gates, briefs, and reports).
- Reflective logic is a more unpredictable process where the deliveries are interdependent with more than one discipline.

To explain these logics, it can be relevant to compare this with the description of the process by Bølviken et al. (2010). Based on the definition by Thompson (1967), they described the different processes of design and their interdependencies: pooled interdependence, sequential interdependence, and reciprocal interdependence. Bell and Kozlowski (2002) introduced a fourth dimension called intensive interdependence (Figure 5). These processes and interdependencies will emerge at different times and at the same time in the design phase. This also needs a form for coordination, which is described as coordination by standardization (pooled), by plan (sequential), and by mutual adjustment/ negotiation (reciprocal/intensive). "Design decision making is often negotiated amongst groups and teams, it is an iterative process." Kestle and London (2002). At the early stage, the design process consists of more reciprocal and intensive interdependent tasks, while the tasks are more sequential at the end.

The development of the project will not happen gradually, but in leaps. L. Andersen (2011) described the coordination as negotiations, mutual adjustment, and opinion, based communication. The relations in the process follow different logics. One of the logics describes an "everlasting movement," where everything is connected to each other. To be able to proceed, decisions must be made regarding an element or structure; if not, the process stops or will not start. A concrete decision of a solution might then start a sequential process; yet, a decision to turn down a solution might just set off a new reciprocal process. Another logic will be to pursue the decisions, so they again set off a chain of solutions and new decisions. Lawson (1997) summarized it as analysis-synthesis-evaluation. This process can go on forever, creating better solutions. However, the nature of a project, where the project is a temporary endeavor undertaken to create a unique product, service, or result (PMI, 2013), also indicates a time frame. This temporary endeavor has a time frame in which the problem needs to be solved.

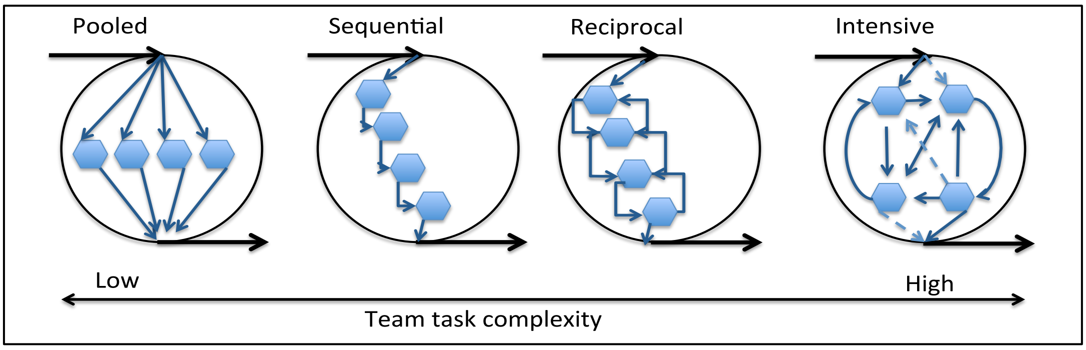


Figure 5: Different types of dependencies in team tasks (Bell & Kozlowski, 2002).

The characteristics of the design process also change during a project. Eikeland (2001) divided the AEC process in three major categories, the core processes, the management processes and the public processes. The core processes are the actual processes such as programming, designing, and building, while the management and public processes are support processes. The management processes consist of planning and procurement, while the public processes are the activities linked to for example public permits. As the characteristics of the design process change, so will also the management process. To describe this, there are several definitions of the steps in an AEC project. An example is Plan of Work (RIBA, 2013) or Next Step (P5) (Klakegg et al., 2015). These definitions, define the main elements in steps, making it easier for the stakeholders to anticipate the work that needs to be done. In the first steps dealing with concepts and making briefs, the design processes are mainly of a reflective nature, while detailed design processes are mainly of a sequential nature in the last part. This means that the management of the process needs to adapt to the different steps of the project.

Stakeholders of the building design process

”Buildings require the combined efforts of many individuals, working and designing collaboratively to provide value to their clients” (Emmitt & Ruikar, 2013). The design process is also reliant on its stakeholders to achieve good design processes. The AEC industry is a fragmented industry and relies on many different stakeholders to complete a project (Kerosuo, 2015). Each one has a different perception of the objective and the success of the project, and these stakeholders will most certainly try to optimize their own operation (Aapaoja et al., 2012). This leads to sub-optimization of projects (Zidane et al., 2015). The right stakeholder involvement is important to create value in projects. Displaying key stakeholders and together aligning their objectives can help to conquer some of the differences (Yang et al., 2009).

Keeping the most important stakeholders in mind, it is important to focus on their needs. Samset (2010) referred to this as perspectives and listed them as the owner perspective, user perspective, and executing perspective. The owner is the one who normally has a long-term interest in the investment that the project represents and is the initiating and financing party. The user is the party who will utilize the result of the project for operating their business. The executing party (or parties) is the project organization, (i.e., the architects, engineers, and contractors who are executing the project on behalf of the owner). The owner typically has an interest in the strategic performance of the project, while the executing parties usually limit their interest to the tactical performance (Slevin & Pinto, 1987).

Depending on how the project is organized and procured, there is usually a need to transform a group of stakeholders into a team. The purpose of a team is to use the different members´ complementary skills to solve multidisciplinary tasks. The team will vary in size and competency, depending on the task to solve. Eynon (2013) emphasized the importance of all the disciplines working together holistically.

However, there is a benefit if the design team has a good, long-term relationship based on respect and trust (Gray, 1994; Gray & Hughes, 2001; Jerrard et al., 2002). Boyle (2003) stated that a key factor for achieving success in AEC projects is directly linked with the personnel involved (i.e., the team). To have a collaborative working team, involving the designers and designing subcontractors is important (Sinclair, 2011; Fundli & Drevland, 2014; Svalestuen et al., 2015).

The team members can also influence the team on a personal level by using their influence or power for a personal or company gain. Organizational power is regarded as an important factor to explain organizational affairs (Morgan, 2006). Power can be described as "one party´s attempt to impose an outcome on the other party" (Killian & Pammer, 2003). The sources of power and how they influence the team varies, creating challenges for the management. However, the reason of using power also varies and can in some cases be described as unethical behavior.

Mohammed et al. (2015) discussed the importance of the team mental model (TMM) in aligning the team and introduced temporal TMM. A temporal TMM is an agreement in a group concerning the deadline of task completion, the speed of the activities, and the sequence of the actives to improve team performance. The "client" is an important part of the team, as the client is responsible for the available time, budget, and scope of the project. "A key to successful design rests with the client and not the designers" Boyle (2003, p. 2). This is highlighted through the focus and importance of the brief, aligning the client's needs to the project's execution (Blyth & Worthington, 2001; Boyle, 2003; Eynon, 2013).

The learning potential of the AEC industry has been debated by several authors (e.g., (Lantelme & Formoso, 2000; Christensen & Christensen, 2010; Skinnarland & Yndesdal, 2014)). Learning barriers has been mentioned as a challenge for change. Skinnarland and Yndesdal (2014) pointed out problems with unlearning, organizational structures, and norms as barriers to learning. Christensen and Christensen (2010) raised the question of the difficulties of learning because of syntax, semantics, and motivation between the disciplines in AEC projects. These barriers will affect the teams since the design process needs the contribution of the whole team and since addressing these barriers is important to achieving learning and improvement.

Management of the building design process

Kalsaas and Sacks (2011) addressed an important issue when they argued that it is important to understand the dependencies in the design process to handle them. Since building design consists of pooled, sequential, reciprocal, and intensive processes, the managing of the process is complicated. A standard project management approach (e.g., (Pinto, 2013; PMI, 2013)) can help manage the pooled and sequential processes but will not be an effective tool to manage the reciprocal or the intensive processes. Based on Mintzberg (1983), the processes with reciprocal and intensive interdependencies can be described as adhocracy. Adhocracy consists of a highly organic structure with little formalization of behavior, high job specialization based on formal training, and groups of specialists in functional groups (i.e., a multidisciplinary design team). Regarding managing, this presents a context of chaos and unpredictability. Project culture, clear responsibilities, real-time information, and transparency have become increasingly important as the complexity of the project increases (Bell & Kozlowski, 2002).

The interaction between the design team members is important. One of the important tasks that need to be performed by designers is coordination (Azlan-Shah & Cheong-Peng, 2013). The main purpose in a design phase is the exchange of information and the transformation of information to ideas and solutions presented for others in the project. This exchange process is difficult to plan and follow up on, and it is equally difficult to foresee the implications that each exchange might have. The approach such as Last Planner (Ballard, 2000), and collaborative planning in design (CPD) (Fundli & Drevland, 2014; Knotten & Svalestuen, 2016) are examples that address these difficulties in planning the design process.

Communication is therefore also important. Synchronous communication is information flow between two or more parties directly using hearing and sight (e.g., meetings, telephone, etc.) and asynchronous communication is a remote flow of information, that is not simultaneous (e.g., email, drawings, and models) (Otter & Emmitt, 2008). The more complex processes, the higher the need for synchronous communication. Flager et al. (2009) showed that as much as 58% of the time in design is spent managing information.

Synchronous communication is important, and this is supported by the approaches of concurrent engineering (CE) and ICE. The use of extreme collaboration by National Aeronautics and Space Administration (NASA) (Mark, 2001) created a possibility for faster and more higher quality design, thus leading to ICE (Chachere et al., 2004). ICE together with building information model (BIM), production management, and metrics constitutes the main parts of virtual design and construction (VDC) (Kunz & Fischer, 2009), an initiative to improve the AEC industry. Other initiatives, such as Knotworking (Kerosuo, 2015) or Scrum (Kalsaas et al., 2014) are deemed equally suitable for extreme collaboration in AEC projects. However, knowing when to use synchronous and when to use asynchronous communication is important on a project with a high degree of complexity. Clearly, it is not efficient to use synchronous communication on routine topics, such as calling in meetings, reports, etc. Synchronous communication should only be used on non-routine topics, where the outcome is unknown and requires collaboration.

The use of the BIM in the construction industry is increasing, and this is a powerful tool for asynchronous communication, such production information, but also as a tool to use in synchronous communication, such as ICE. Moum (2008) described how a BIM could ease the difficulties to understand complex problems and solutions. The benefits of a BIM in communication is good (Clemente & Cachadinha, 2013), and the possibility to increase the quality by early clash detection can benefit the economy of the project (Khanzoode et al., 2008).

To properly manage a design process it is important to set up metrics of the processes. Drucker (2008) argued for the importance of measuring the work of organizations and described that one needs “controls” (different measurements) to attain control of the process. The need for metrics to improve the design process is also debated in the works by Carvalho et al. (2008); Leong and Tilley (2008); Succar et al. (2012). Even though is it important to measure the project outcome of time and cost, it is equally important to set up metrics to control the quality of the design, the exchange of information, and other processes. Management needs to adapt to the type of design processes and their interdependencies, organizing the coordination and communication to support this and evaluating the processes to have control.

Objectives of the building design process

In project management literature, there are many definitions of success. Yet the *Oxford Dictionary of English* simply states, “Success is the accomplishment of an aim or purpose” and failure is the “lack of success.” Samset (2010) stated, “Projects are initiated to solve problems or satisfy needs.” Thus, we can assume that project success is linked to its ability to solve those problems or needs.

The time of the assessment is linked to the set goal. If a goal is linked to the total time or economy of a project, a post-project evaluation is fine (Samset, 2010). On the other hand, to assess goals concerning the process of the project, an interim evaluation is more suitable. The timing of the assessment is closely linked to the learning potential. To change the process, the assessment must be made so that it is possible to try out the changes. Jerrard and Hands (2008) pointed out problems in trying to create design audits vs. traditional metrics. The design audits should consist of both quantitative and qualitative data and view both social and economic measures, while traditional project metrics usually consist of quantitative economic measures.

The identification of problems and needs and the process of solving them are important steps to be able to define the project and the aim or purposes to achieve success. Samset (2010) also argued to assess AEC projects in a larger context rather than to only solve the immediate problem. He claimed that monitoring a project should be on both the tactical and strategic levels. The tactical level deals with what most regard as the important success indicators in a project: cost, time, and quality. Tactical success in projects is associated with the term “project management success” (Cooke-Davies, 2002). The strategic level examines indicators, such as effect, relevance, and sustainability. Strategic success is associated with “project success.” Success factors are factors that lead to success, while success criteria are criteria that are used to determine whether the project is a success. Jerrard et al. (2002) pointed out that design management skills are a success factor for AEC projects. However, success factors for building design management is rarely directly stated as in for example Gray et al. (1994), but more indirectly mentioned in design management literature (e.g.,(Blyth & Worthington, 2001; Sinclair, 2011; Eynon, 2013)).

Even though failure is defined as the lack of success, Meland (2000) presented important failure predictors for design management. Important predictors were lack of support from the client and the lack of managerial skills of design managers, especially regarding communication, planning, goal setting, and information handling. This highlights the importance for building design management to have clear objectives and goals.

Offshore construction and ship building characteristics

A main trait of the OC industry is the widespread outsourcing of services, relying on suppliers to deliver one or more of the undertakings required in projects. The main ambition underlying this strategy consists of cutting costs by focusing on their core competencies (Khan et al., 2003). The OC industry has also begun outsourcing high complexity engineering services in addition to services like IT support (Olsen, 2006). However, little proof has been found in later years concerning the cost savings of outsourcing (Olsen, 2006).

The OC has a rationalistic approach to planning; yet, it fails to capture the dynamics often found in design and engineering (Kalsaas, 2013). The OC projects are also regarded as complex and large scaled with significant financial effects if delayed, and this argues for a strong QC/QA system, and documentation focus. Mejlænder-Larsen (2017) described how systematic approaches, such as project execution models (PEM) structure the design process of OC projects. A PEM typically describes the requirements of the design and when it should be delivered.

The SB industry is equally characterized as an industry where external suppliers undertake significant parts of the production. This takes the form of the use of clusters consisting of several different companies working together in alliances to form the whole supply chain (Wickham & Hall, 2006). The SB industry is competing in a global market, which has changed the Norwegian industry over last two decades, making the work more multi-located and dispersed (Kjersem & Emblemsvåg, 2014). The increasing complexity of the vessel’s task has been observed to lead to more complex products (Aslesen & Bertelsen, 2008). Kjersem and Emblemsvåg (2014) maintained that the flexibility of the Norwegian industry to produce complex vessels that are adapted to the client's needs must be considered a competitive advantage. Dugnas and Oterhals (2008) listed four key-production phases in SB, notably hull fabrication, primary outfitting, final outfitting, and testing. The hull is typically produced in low-cost countries, while both primary and outfitting are done at a Norwegian yard, in addition to the testing program.

Building ships is a complex exercise, and ship designing is even more so. The ship as a system is a complex unit formed by many often-diverse parts, subject to a common plan or serving a common purpose (Gaspar et al., 2012). The vessels used in, for example, the offshore industry consist of a wide range of systems and components that need to secure the desired functionality. The functionality not only depends on the functions of the components but also the holistic interaction of the components (Killaars et al., 2015). Their dependencies are both direct and indirect. One of the most complex tasks for the naval architect is to manage changes during design (Killaars et al., 2015).

The general design diagram, or design spiral by Evans (1959) has been a guidance for an ideal design process in designing ships; however, the process is inaccurate in today's design approaches. The design spiral starts with a general arrangement (GA), but in reaching a GA, there has been a lot of design work, tradeoffs, and assumptions (van Bruinessen et al., 2013). A notion from Killaars et al. (2015) is that the design process very much depends on the experiences of the naval architect to succeed, making the design process vulnerable.

Defining building design management

Jerrard et al. (2002) mentioned effective design management skills as a success factor and that there is a need for strategic focus on design management to create a competitive advantage. The design management roles and activities are about bringing together ideas, connecting, integrating, communicating, innovating, and collaborating (Eynon, 2013). Sinclair (2011) defined design management as the discipline of planning, organizing, and managing the design process to bring about the successful completion of specific project goals and objectives. Emmitt and Ruikar (2013) described design management as managing people and information. There is also the focus of traditional project management approaches, as Eynon (2013) highlighted the focus of time, cost, and quality as important for design management. Kristensen (2013), however, argued for a more holistic definition of design management including not only management but also leadership.

These examples of defining building design management focus on bringing the right stakeholders together and planning and organizing settings for the collaborative exchange of ideas and information based on the challenges to address in a way that solves the project objectives and goals.

4 Findings

To answer the MRQ of this PhD work: "How should building design management handle the early stages of the design phase in building projects?", there was a set of themes with sub-questions, (the RQs) that need to be answered. This chapter summarizes the main findings of the RQs. The first part, Section 4.1, presents a short overview of the publications. The second part, Section 4.2, uses findings from the publications to answer RQ1 (a and b). Section 4.3 uses the findings from the publications to answer RQ2.

The layout of the findings chapter is illustrated in Figure 6.

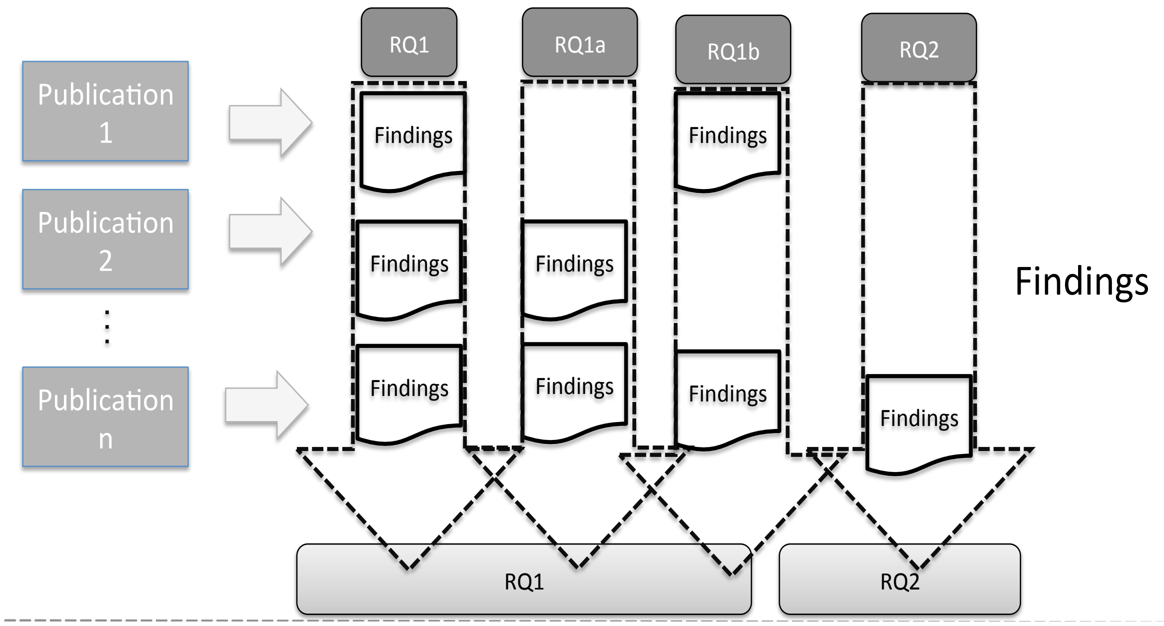


Figure 6: A model of the findings chapter layout.

4.1 Presenting the Publications

Each of the ten publications (Table 1) is presented briefly to give an overview of the main findings relevant for this PhD work. The full versions of the publications, included in the appendix, should be read to understand the total implication it has for the PhD work.

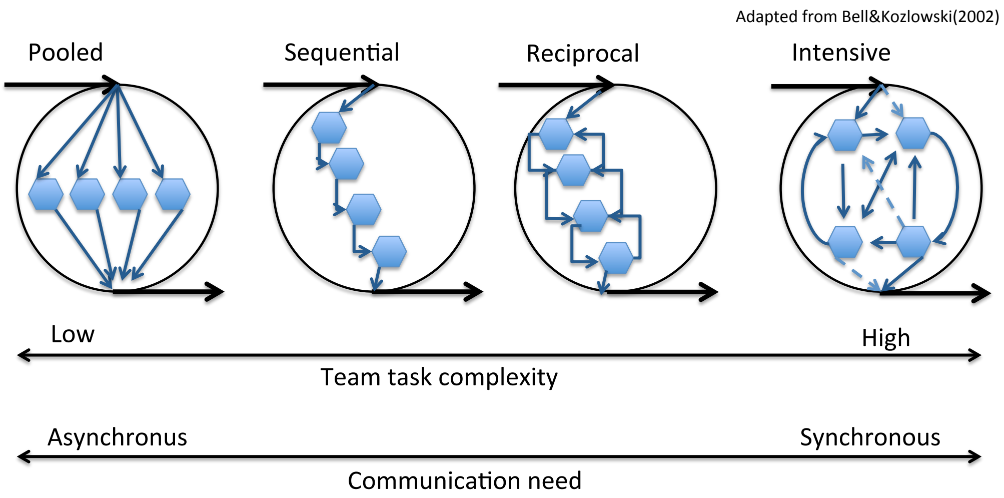
4.1.1 Publication 1: Implementing virtual design and construction (VDC) in Veidekke – using simple metrics to improve the design management process

The aim of the paper was to report on a constructor's implementation effort of virtual design and construction (VDC). The VDC is primarily oriented around the use of models, and the BIM is essential. Other important tools of VDC are ICE, process management, and metrics. The paper (P1) presents time saving efforts with the use of BIM in quantity take off (QTO) instead of drawings, and illustrates the BIM as an efficient tool to explore different possible solutions in early design and tender work. Another important tool of VDC is the use of ICE, which was developed by NASA's jet propulsion laboratory in the mid-1990s, by a group called Team–X. The ICE enhances extreme collaborations and key success factors are preplanning, clear objectives, agendas, and a productive environment. Moreover, ICE can contribute to reducing time spent handling information in design and latency. The paper presents how well-organized ICE sessions can increase efficiency in design. The process management refers to the planning and handling of the process. Metrics are important to evaluate the performance of the processes and the project to ensure that the projects objectives are met. The paper introduces VDC and shows different ways of using simple metrics to improve the design process, thus contributing as a valuable tool for building design management.

4.1.2 Publication 2: Design management in the building process – a review of current literature

The paper (P2) examines the current literature concerning building design management, describing the challenges of the building design process and the challenges of its management. The building design process is described as challenging since there is usually more than one solution to a design problem, and a proposed solution might trigger new problems to solve. The design tasks are highly interdependent in different ways. The dependencies can be described as pooled, sequential, reciprocal, and intensive and require different coordination and management approaches. This is illustrated in Figure 7, adapted from Bell and Kozlowski (2002).

A challenge for the AEC industry is that the management of design is treated equal as the management of construction, where the process and interdependencies are more of a sequential nature. The processes of reciprocal and intensive dependent tasks have a more chaotic nature and need another management perspective. The planning of complex building design processes is a continuous process, requiring the removal of constraints and re-planning during the entire design process. The paper suggests that the most suitable approaches for building design management are the use of Last Planner; collaborative planning in design (CPD); agile approaches, such as Scrum and ICE; and the use of BIM not only as a design tool but also as a tool of communication. The paper also points out to focus on the right form for communication when dealing with more complex tasks, arguing that complex design tasks need synchronous communication to be efficient.



Interdependence	Pooled	Sequential	Reciprocal	Intensive
Coordination	Standardization	Plan	Mutal adjustment	Mutal adjustment/ negotiation

Figure 7: Interdependencies and coordination (P2).

4.1.3 Publication 3: Organizational power in building design management

In every new building project, there is usually a new organization assembled that rapidly needs to function as a team. The organization will also vary through the project, depending on the different stages. This paper (P3) addresses the organizational sources of power in the design phase, using Morgan (2006) 14 sources of power as a conceptual framework. The paper is based on a case study with interviews.

The paper describes the sources of power and the influence they can have on the design management process. To achieve an efficient design process, the interviewees highlighted well-functioning teams, flat formalized structures, and transparency regarding everyone's responsibilities and tasks. For the design manager, the sources can be viewed as follows:

- Strengths - where the sources contribute to empowering the design manager;
- Challenges - where the sources directly influence the design process;
- Threats - where the sources contribute to create powerlessness for the design manager.

Table 3: Source of power - summarizing the findings (P3)

	Source of Power (Morgan, 2006)	Influence	Tools
Strength	1. Formal authority 11. Symbolism and the management of meaning 13. Structural factors that define the stage of action 14. The power one already has 3. Use of organizational structure rules, regulations, and procedures	Increases the control for the design manager	Good teams
Challenges	2. Control of scarce resources 4. Control of the decision process 5. Control of knowledge and information 6. Control of boundaries 7. Ability to cope with uncertainty 8. Control of technology	Reduces impact on the design process	Last Planner, CDM, ICE.
Threats	10. Control of counter organizations 12. Gender and the management of gender relations 9. Interpersonal alliances, networks and control of informal organizations	Reduces the control of the design manager	Good Teams, ICE, CDM, Last Planner

By investing time in building a good team and using tools, such as Last Planner and ICE, one can reduce the sources of power that can create problems for the design process. Likewise, by enhancing the sources that empower management one can strengthen the design process. If the sources that threaten the process are reduced, one can equally reduce waste in the design process. By first dealing with these sources, the team can better focus on the sources, creating challenges for the design process.

The knowledge of how organizational power appears in the building design process can be used for the design manager to better plan, organize, and manage the design process. By focusing on how the sources of power influence the process, a more efficient design process can be achieved. An overview is illustrated in Table 3.

4.1.4 Publication 4: Design management – Learning across trades

The AEC, SB, and OC industries are all project-based industries, mainly consisting of designing and manufacturing unique products for different customers. These similarities make the comparison of these three trades or industries interesting. In addition, the OC and SB are typically both recognized to have a high level of complexity. As AEC projects become more complex, this makes knowledge transfer between these industries pertinent.

A comparison of the AEC, SB, and OC shows that there are many similarities, but also some differences. The main differences are that the SB and OC have in-house design teams, fixed production sites, and compete on the global market, while the AEC procures external designers, changes production sites, and usually operates in a more local market. There are also several contextual differences regarding framework, culture, etc. The similarities are mainly in the fact that they are project-based producers of unique products and that they have similar contract forms. This makes it useful to learn across the trades.

However, the paper (P4) displayed three different approaches to handle the design stages in the different trades, illustrated in Figure 8. In an AEC project, the designs evolve and change until it is necessary to finalize the drawings. This can create a situation in which it is difficult for the design manager to follow all possible consequences. Alternatively, SB was very clear to reduce all changes and developments and produce drawings of the project agreed upon in the contract. This approach could miss value-creating activities. Conversely, OC choses an approach of letting the design process evolve, but at the same time, locks down some areas and trades, while the rest can develop around that. This led to a better control of the design process, while some of the value-creating activities could continue.

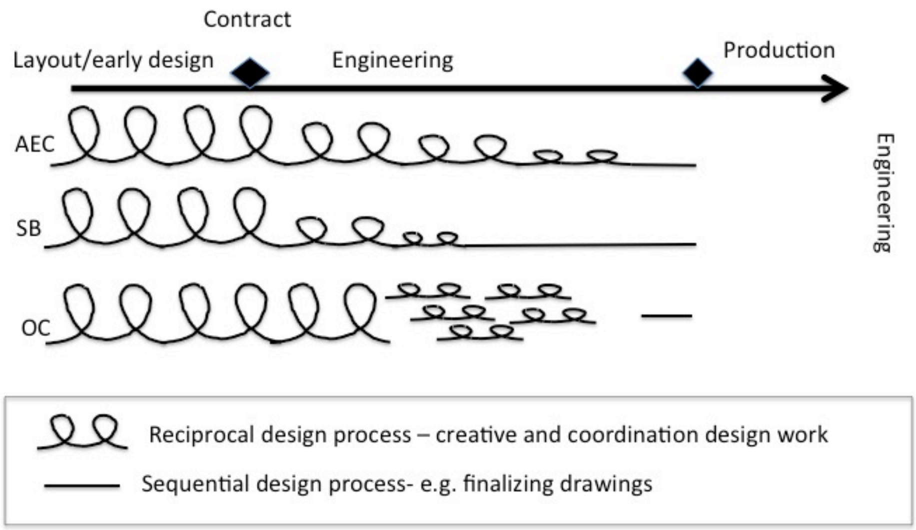


Figure 8: Design process in different trades (P4).

The paper (P4) highlighted two key processes: the planning and coordination of the design phase. These are equally important to all the trades. The approach to plan and coordinate the design phase is different in each trade, but they struggle with some of the same issues.

The paper concludes that the AEC industry has learning potential by implementing planning and coordination methods used by the OC industry. The OC industry has implemented a method of planning and executing the engineering, thus exploiting more of the benefits of the BIM in planning. By producing production drawings at the last responsible moment, they let the coordination processes last longer, leaving time for the design to evolve and mature.

4.1.5 Publication 5: "Next Step" – a new systematic approach to plan and execute AEC projects

The AEC industry is portrayed as an industry with serious challenges ahead. Among observed problems that often happen in AEC projects are the decisions, which are made at the wrong time or at the wrong level of the organization, and the solutions executed in the project without being aligned with corporate strategies. The paper presents a new systematic approach introduced in Norway to handle the many difficult challenges in the AEC industry. The systematic approach is called the "Next Step" (Neste Steg) and is a framework inspired by the RIBA Plan of Work (Table 4).

Table 4: Outline of the framework Next Step (P5).

<table>
<tr><th>Step</th><th>1
Strategic definition</th><th>2
Brief development</th><th>3
Concept development</th><th>4
Detailed designing</th><th>5
Production</th><th>6
Handover</th><th>7
In use</th><th>8
Termination</th></tr>
<tr><td rowspan="4">Core process</td><td colspan="8">Owner perspective</td></tr>
<tr><td colspan="8">User perspective</td></tr>
<tr><td colspan="8">Supplier perspective</td></tr>
<tr><td colspan="8">Public perspective</td></tr>
<tr><td colspan="9"></td></tr>
<tr><td rowspan="6">Management process</td><td colspan="8">Planning</td></tr>
<tr><td colspan="8">Procurement</td></tr>
<tr><td colspan="8">Communication</td></tr>
<tr><td colspan="8">Sustainability - economics</td></tr>
<tr><td colspan="8">Sustainability - environment</td></tr>
<tr><td colspan="8">Sustainability - scocial</td></tr>
</table>

The new framework identifies the key steps (eight in total), and tasks in a project lifecycle from the strategic definition to the termination of the building. The new framework suggests examining the different steps in this systematic approach through different perspectives since the different stakeholders have different objectives within the project. By focusing on the perspective of the owner, user, supplier, and public, the project is driven to achieve strategic goals and leads to a more efficient process and sustainable outcome. The framework focuses on project execution and the critical decisions on a corporate level, involvement of the proper stakeholder perspective, and a sustainable development of the AEC industry.

4.1.6 Publication 6: Improving design management with mutual assessment

Mutual assessment (MA) is an approach for continuous improvement of the design team in a pre-planned setting. Moreover, MA was developed by a Scandinavian contractor to improve client satisfaction. Using a survey, the design team evaluates each other, creating a common understanding of needed improvements. The MA gives all major participants a chance to systematically assess the team and creates room for dialog and improvement. Improving the design teams also to helps align the design and construction.

The MA starts with a common planning session, where the team agrees on two major things. First, they determine the assessment plan, in terms of when to assess the team's performance. Second, they agree on what goals are important for the team in this project and how they should be assessed. The assessment consists of three elements. The first is a survey to measure the performance of the teams regarding their goals. Second, this survey functions as a topic for an assessment session where the team discusses the survey and how they can change their way of working to improve their performance. The last element is to agree on an action plan pinpointing the action needed and when it is to be implemented.

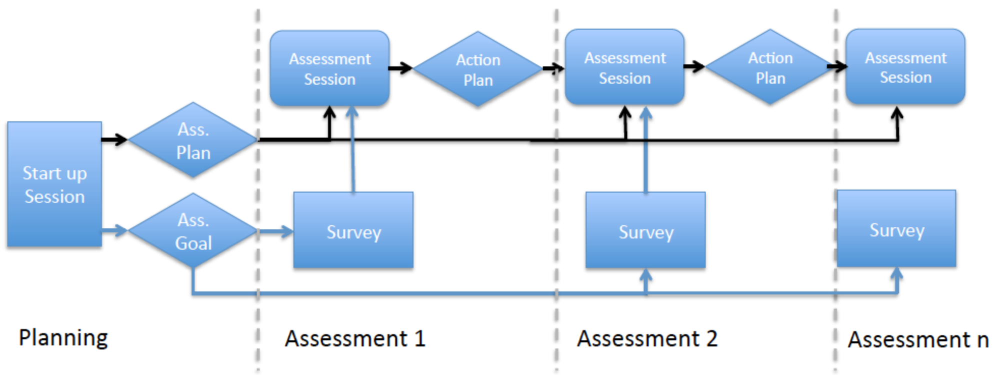


Figure 9: Mutual assessment (P6).

In addition, MA addresses several challenges in the AEC industry. First, it addresses the challenge of a fragmented industry working with unique products and temporary workers by collaboratively making a design team. Second, MA addresses the performance and improves the performance through a collaborative dialog. Third, MA creates an opportunity for learning during the project, instead of hoping that something is learned when the project is finished.

4.1.7 Publication 7: Ethical behavior in the design phase of AEC projects

This paper (P7) reports on the studies on ethics in the design phase in Norwegian construction projects. The paper establishes a descriptive picture of ethical challenges that practitioners meet in the design phase to raise awareness among them. The study was undertaken to address the framework conditions for handling ethically challenging situations, challenges of an ethical nature that practitioners commonly encounter in the design phase, and finally, the structural (systemic) reasons for such challenges. The designers have economic incentives to produce solutions that satisfy the minimum requirements but nothing more. These are unlikely to satisfy the clients´ true needs or be optimal for other users of the building. The designers will therefore often find themselves in an ethically difficult situation, where they must choose between doing what is rationally best for themselves and legally unproblematic, and what is best for the client and other users of the building. The paper finds indications of actors maneuvering in the design phase for their own benefit at the expense of other actors. The main findings of unethical behavior based on interviews with the actors are presented in Table 5. The findings are divided between pre-contract and post-contract behaviors.

Table 5: Main findings of unethical behavior in design (P7)

Pre-contract	**Post-contract**
Pricing the tender documents	Exploiting cost reimbursement contracts
Company size	Shifting loyalty after transfer of contracts
Change order tactics	Transfer of workload
	Sticking to agreements
	Greed
	Avoiding decisions
	Company size
	Exploiting uncertainties
	Change order tactics

A conclusion from the paper is that, if what is perceived as unethical but still lawful is not explicitly described in the ethical frameworks of the major players of the AEC industry but only exists as tacit knowledge, the field of design will be exposed to unethical behavior. This unethical behavior can create extra challenges for building design management.

4.1.8 Publication 8: Building design management – key success factors

The building design management process involves planning, organizing, and managing people, their knowledge, and the flow of information to obtain specific project goals and objectives. The paper (P8) has identified ten key success factors for building design management, first through a literature review, then through a case study. Finally, design managers ranked the success factors in order of their importance.

Table 6: Key Success factors rated by design managers (P8)

Survey (n=22)			**Case study**	
Success factor	**Average**	**s**	**Interview**	**Observation**
Communication	2.18	1.53	yes	yes
Decision making	3.55	1.63	yes	no
Planning	3.91	2.29	yes	yes
Client	4.05	1.62	yes	yes
Interface management	4.36	2.06	no	yes
Team management	5.05	2.28	yes	yes
Risk management	7.55	2.65	yes	no
Knowledge management	7.77	2.07	yes	yes
HSE focus	8.09	1.63	no	yes
Performance evaluation	8.50	1.41	(yes)1*	no

The ten success factors were present in the case study and acknowledged by the practitioners, but they were not equally prioritized or equally handled. The success factors are presented in Table 6, where the design manager rated the success factors (e.g., communication as most important and performance evaluation as least important).

However, a conclusion from the paper is that the importance and relevance of the success factors depend on the project, design team, and design manager, implying that the ten success factors might not be entirely relevant for all building design management processes. By addressing these success factors in a proactive manner, the design manager should be better positioned to plan, organize, and execute the building design process and thus contribute to the successful management of the project and the project success.

4.1.9 Publication 9: Experiences with BIM devices for improving communication in construction projects

The AEC industry has been successfully using BIM as a tool for improving the design process for some time now. Lately, we have seen an increase in the use of the BIM in the construction process with BIM devices like BIM stations and tablets. The presented research (P9) has studied the advantages and challenges with the use of BIM devices on a construction site and used the communication theory to explain why these tools are more effective than the traditional approach.

The main finding is that the BIM, used as a mediating artifact in a synchronous communication option, provides far more effective communication than other types of synchronous communication (Figure 10). The BIM as a documentation option is superior to all other media because it has a higher bandwidth and is self-documenting at the same time. The most prominent challenges with BIM devices relate to the implementation process and are not necessarily unique to BIM devices. Any new system or tool that is implemented will require some sort of training, and proper training of all the involved practitioners will be necessary before implementing a BIM device.

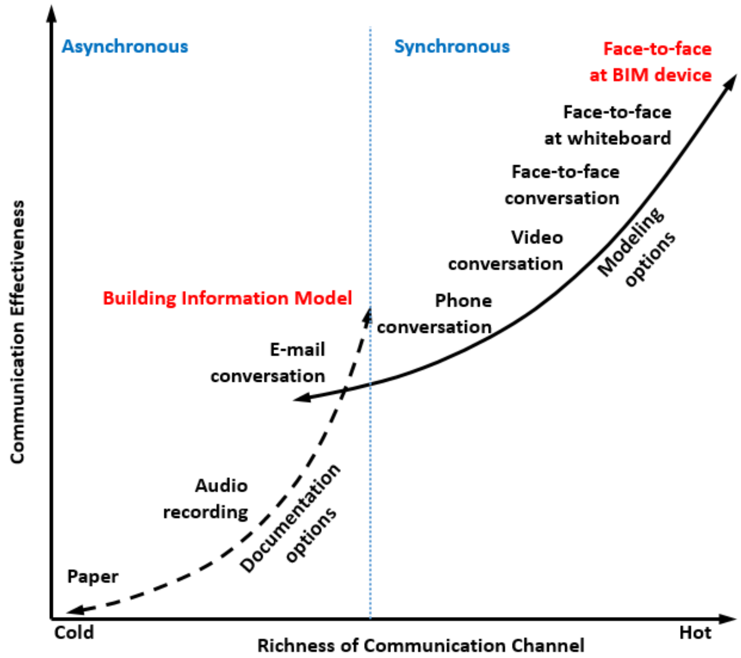


Figure 10: Communication channels (P9)

This study also shows that it is important to know when to use asynchronous and when to use synchronous communication. Although the latter is far superior in effectiveness, using synchronous communication on routine topics can be counterproductive.

4.1.10 Publication 10: Planning the building design process according to level of development.

This paper compares the SB, OC, and AEC industries through case studies and planning. The paper discusses the advantages of lessons learned from OC in planning and using the BIM to convey maturity and design status. Similar efforts have been tried in AEC with the use of the level of development (LOD). A proposition of this paper is to use the LOD along with CPD to agree on the specifics of the LOD in the project, using this LOD framework, first, to plan the design work and then to link that to the needs of production. It also presents an additional element by combining the LOD and 4D in the design plan. The 4D presentation of the LOD increases the communication bandwidth, helping to represent a clearer picture of the plan to the actors. Another lesson, learned from SB, is that in-house continuously working teams can achieve almost autonomous designers, efficiently handling the challenges of rapid time frames and changing work scopes.

4.2 RQ1: What Is Building Design Management?

To summarize RQ1, What is building design management?, I use the definition presented in P8. This definition is primarily based on definitions by Sinclair (2011); Emmitt and Ruikar (2013); and is presented as follows:

Building design management involves planning, organizing, and managing people, their knowledge, and the flow of information to obtain specific project goals and objectives.

Design management can be divided in two parts: the management of the process and leading the design (P6). Design management aims to keep the process on time, on budget, and at the right quality. This includes different strategies of planning, such as Last Planner (P2) and CPD (P6), using the Plan of Work or Next Step as a framework for planning the process and defining the stage gates (P5) and adapting design management to the chosen project delivery method (PDM) (P5). The design manager also needs to address what tools and approaches are available and efficient for the projects (e.g., VDC (P1), BIM (P1, P2, P9, and P10), Knotworking, or Scrum (P4)).

The design leadership aims to gain the most from the knowledge and creativity of the team. The high flow of information and the need for decisions calls for a strong collaborative environment (P6). This also includes working with the people in the process to understand how they act and their influence on the process (P3 and P7) and the ability to facilitate the design team and its development (P6 and P8).

4.2.1 RQ1a: What are the challenges in the early stages?

The design process is based on a two-dimensional logic consisting of both a sequential and reflective logic (P2). The design process consists of a series of activities that needs to appear in a sequence to complete the design, but many of these activities are of a nature that needs reflectivity, redoing, and learning before they are finished. These activities are more prominent in the early stages of the design process. The activities have strong interdependencies with other activities, decisions, or disciplines. This is referred to as reciprocal or intensive interdependencies, and coordination needs a form of mutual negotiation to close the process (Figure 11). This presents a challenge in both planning and managing the design process since the traditional management literature relies on activities that are sequential. The sequential logic of the design process is important to keep milestones and deadlines; however, the reflective logic is where the value creation of the design process is made. A challenge for the building design management is to identify the different interdependencies of the processes and coordinate accordingly.

The coordination of these interdependencies varies, whereas the sequential interdependencies can be coordinated by plan, the reciprocal and intensive activities must be coordinated by mutual adjustment and negotiation, requiring a close collaboration with synchronous communication.

The reciprocal or intensive processes are never-ending processes and require a decision to end. Decision making in design is thus important. The decision making appears on all levels of the design process, from internal decisions at the designer level to the client's decisions connecting the design to the project objectives (P5). Getting the decision at the right time by the right actor is also a challenge. The different actors have different responsibilities and interests in the project. By trying to focus on the perspective of the key actors in the design process, one might help to mitigate some of the challenges of decision making.

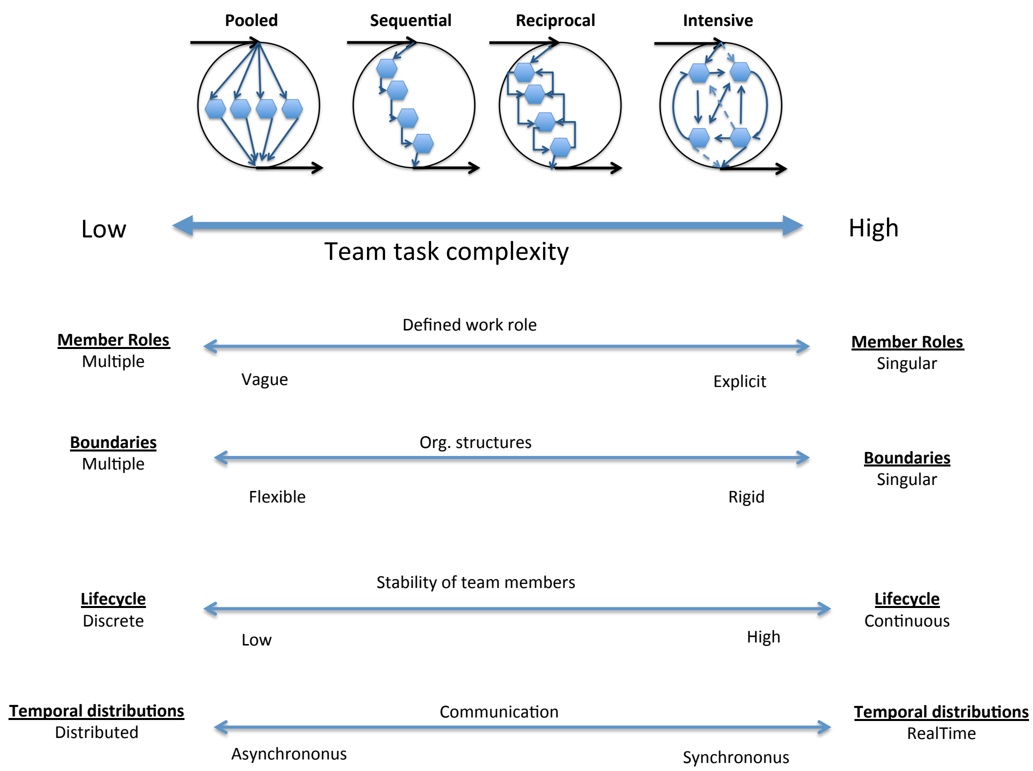


Figure 11: Team task complexity and characteristics (P10).

Building design management is very much about organizing and managing the people and their knowledge to fulfill the design process. The consultants and architects are engaged in the project because of their knowledge to solve the project. However, their knowledge needs to be made explicit for the project members to solve the design issues. Due to the fragmentation of the industry, the actors in the design teams are typically loosely coupled, connected only in the project in a limited time frame (P6). The project delivery method affects the contracts and again affects the actors (P5). The design teams could be set up with actors from the same company with prior common work experience or individuals from separate companies. Their personal and professional behavior will have a strong effect on the design process, and thus the management of the process (P3 and P7). A professional or personal sub- optimization by an actor can raise challenges for other actors and management, creating a hostile environment with low collaboration. A key challenge is to transform the group of actors into a working design team to use complimentary skills to solve the project objectives. Different team task complexities also need different organizational structures of the team to work properly (P2 and P10). High complexity needs explicit team roles, rigid organizational structures, and a stable team (Figure 11).

Most of these challenges could said to be relevant for all the stages of the design process, but the earlier in the project, the more complex the interdependencies are, thus creating more uncertainties for building design management.

4.2.2 RQ1b: What are considered success factors in building design management?

The topic of P8 was RQ1b and dealt with success factors in building design management. Success factors in building design management are not always explicitly stated in the literature but are more implicit. Derived from the literature review, ten success factors were identified and are presented in Table 7. The literature review also showed a low number of publications in building design management dealing with success factors (P8). The success factors in Table 7 are presented in alphabetical order not in prioritized order. Even though P8 also presents a table prioritized by design managers (Table 6), a conclusion from the paper was that the relevance and importance of the success factors is dependent on the project, design team, and design manager.

The ten success factors were first derived from building design management literature discussed through case studies in P8. The importance of these success factors has been mentioned in contexts through other publications as well. The client perspective is discussed in P7. Communication is highlighted in P2, P9, and P10. The importance of decision making is discussed in P5. The challenges of interface management are reviewed in P2. Performance evaluation is discussed in P1 and P6. The importance and challenges of planning are presented in P2, P5, P4, and P10. Team and team management are emphasized in P2, P3, P6, and P7.

Table 7: Key Success factors (P8).

Success factor	Keywords	Reference
Client	A good budget, brief, client team, understanding the clients need	(Blyth & Worthington, 2001; Boyle, 2003; Eynon, 2013)
Communication	Communication, network, negotiation, meeting structure, coordination, flow of information, design solutions	(Blyth & Worthington, 2001; Gray & Hughes, 2001; Jerrard et al., 2002; Boyle, 2003; Sinclair, 2011; Eynon, 2013)
Decision Making	Timely decision making, client involvement, getting it right the first time, crucial points of decision	(Gray, 1994; Blyth & Worthington, 2001; Gray & Hughes, 2001; Emmitt & Ruikar, 2013)
HSE Focus	Health, Safety and Environment focus	(Eynon, 2013)
Interface management	Design dependencies, control of interfaces	(Boyle, 2003; Sinclair, 2011)
Knowledge management	Feedback of experience, set of tools, stakeholders, knowledge organized and contracted	(Gray, 1994; Blyth & Worthington, 2001; Gray & Hughes, 2001; Jerrard et al., 2002; Boyle, 2003; Sinclair, 2011; Eynon, 2013)
Performance evaluation	Audit in design, measurements, benchmarking drawings, process measurements (social and performance)	(Jerrard et al., 2002; Sinclair, 2011; Eynon, 2013)
Planning	Defining the process, planning, cost plans, change control, quality plan, time, progress reports	(Blyth & Worthington, 2001; Gray & Hughes, 2001; Jerrard et al., 2002; Boyle, 2003; Sinclair, 2011; Eynon, 2013)
Risk management	Managing risk	(Sinclair, 2011)
Team management	Relationships, management support, subcontractors, procurement, delegation of work, involvement, holistic working	(Gray, 1994; Blyth & Worthington, 2001; Jerrard et al., 2002; Boyle, 2003; Sinclair, 2011; Eynon, 2013)

4.3 RQ2: What Can Building Design Management Learn from Engineering Management?

Another pursued line of interest was what building design management can learn from engineering management in OC and SB. The industries have a lot of similarities, such as project-based industries and contract forms but also have several differences, such as in-house design capacity and fixed productions sites. This made a comparison of the industries both relevant and interesting.

To describe how the design process in SB and OC is conducted, a graphical presentation was presented in Figure 8. The OC industry aimed to keep the design processes going for as long as possible, locking down some design solutions at the time and letting the design evolve around these. The SB industry had a very intensive and creative pre-contract design process, keeping the post-contract design changes to a minimum (P4 and P10).

Especially for SB, the challenge in the early stages was the workload. There are highly complex products and many decisions are to be made in a short time frame. The process started with a tender or a lead from the client, where sales staff communicated with the client and then with the naval architect. The naval architect communicated with the other principal designers. The naval architect was responsible for different segments of products and needed to prioritize the use of all design resources. The concept and pre-contract work was also very dependent on which yard would build the ship, leading to different requirements in the tender.

Both SB and OC had in-house design and production capacities. When both designing and producing a project, this could lead to less production material (i.e., drawings and details), and instead, to a dialog between design and production. This was emphasized as positive by both industries, especially since many designers had previously worked with production. However, when dealing with production offsite, the design deliveries were more formalized, and small issues with drawings could lead to potential contractual disputes. This is similar to situations found in the AEC. Both SB and OC could run design teams based on qualifications, since they had in-house designers; however, this was not always the case.

The AEC can learn from the planning and engineering process of the OC industry. The OC industry plans and executes the design process with many concurrent processes and design freezes and uses the BIM to plan, coordinate, and show the development of the design (P4). The key takeaway from the SB industry was how to solve basic and concept design challenges. The in-house design capabilities are delivered through high periods of workload. The group of designers act autonomously, knowing exactly what was expected and where to achieve the right information within the design team (P10).

5 Discussion

As presented in Figure 6, Chapter 4 summarized the findings organized by the different RQs. This chapter discusses the main findings from RQ1 (with RQ1a and RQ1b) and RQ2.

5.1 RQ1: What Is Building Design Management?

To answer the MRQ, "How should building design management handle the early stages of the design phase in building projects?", there were three proposed themes. The first theme was to define building design management regarding this research. The second theme was to examine the challenges design management must handle in the early stages, and the third theme was to examine the success factors of building design management to determine what to improve. These were answered through the sub-questions (RQ) in Chapter 4.

Based on the findings in RQ1, a summarized definition of building design management is as follows: Building design management involves planning, organizing, and managing people, their knowledge, and the flow of information to obtain specific project goals and objectives. This fits with the summary from the theory in Chapter 3. Building design management focuses on bringing the right stakeholders together, planning and organizing settings for the collaborative exchange of ideas and information based on the challenges to address in a way that solves the project objectives and goals.

To support the definition presented in RQ1, this chapter discusses its different aspects on building design management. This includes the main findings from RQ1a and RQ1b as well. The main findings from RQ1a described the challenges with the nature of the design process and its combination of reflective and sequential logic. It further presented challenges with decision making, perspectives, and the way building design management needs to organize and manage the design process to achieve its objectives. Furthermore, RQ1b discussed success factors in building design management and highlighted the importance of planning and communication in building design management. Thus, the definition presented in RQ1, embraces the challenges described in RQ1a and the success factors in RQ1b. To further continue the discussion of RQ1, a decomposition of the definition and a discussion of its elements can help, thus project goals and objectives, organizing, planning, information flow, and managing are discussed below.

Project goals and objectives

Oxford Dictionary of English states: "success is the accomplishment of an aim or purpose" and "failure is the lack of success." Moreover, "Projects are initiated to solve or satisfy needs" (Samset, 2010). To solve or satisfy this, the need must be defined. This argues for an explicit aim, purpose, goal, or objective to achieve a successful project.

This can further be divided in project management success and project success. Project success is the link to the overall objectives of the project (i.e., effect, relevance, and sustainability), while project management success is linked to the performance of the project regarding cost, time, and quality (Cooke-Davies, 2002).

The lack of clear goals and objectives can influence the decision-making process and the planning and organizing of the project. This indicates the importance of clearly stating the project goals and objectives. One of the first things building design management should do is to know the specific project goals and objectives. This also influences the client's links to the company's business model. It is important to link the business model for the client to the project, making it clear how the project can help achieve a successful business (P5).

The AEC case (P8) presented a typical problem. The solutions made by the architects did not meet the goal of cost expectancies of the client. This was not uncovered before the contractor was engaged and resulted in a major redesign for the architect to meet this goal. This meant changing the layout of the hotel and the apartments to make the project viable for the client. If the cost goal had been properly set and if the necessary means to achieve it had been discussed in the early design team, major changes might have been avoided.

Organizing

The people, stakeholders, or actors in different PDMs will affect the organization of the design process, and the design processes. This could be how the design team members are procured and contractually organized. Is the design manager a part of the client's organization, an architect, a designing consultant, a contractor, or an independent consultant? Which actors are present and available during the design phase, and how will that affect the results?

In the AEC case (P8), the contractor was responsible for design management. Except for the architect and structural engineer, the subcontractors employed the rest of the designers. This method of organizing the project meant that the design manager could not pick his own designers but had to create a new design team. It took time to set the new design team. However, it also resulted in a strong participation of the subcontractors in the design, contributing valuable input to the process.

Focusing on the perspectives of the different actors and identifying their needs throughout the process is important (Samset, 2010). The three main perspectives are the owner perspective, user perspective, and executing perspective. Organizing the needed knowledge is tightly linked with the people. Assessing the needed knowledge to achieve the goals to ensure that the people in the design team have the right knowledge or competency when it is needed is an important part. In addition, another important point is creating a TMM to get the actors to work as a team and not as individuals (Mohammed et al., 2015). The AEC case also revealed the importance of the TMM. The team worked better after a start-up session with some social bonding (P8). By investing time in building a good team, one can reduce the sources of power that can create problems for design management (P3).

Planning

Planning the design process is important and is regarded as a success factor (P8). The design process consists of sequential logic. The sequential logic is linked to deadlines, milestones, and often activities linked outside the project. When the clients set their goals, it usually consists of timely goals as well. This could be the end date of the project, the construction start, a public permit deadline, or a report deadline for corporate decision making. All these time constraints set off a chain of decisions. In this sequential logic, there are design processes both in parallel and overlapping.

However, the way the design process works by the design experts suggesting solution to overcome problems to fulfill the project's objectives is more of a reflective logic. Lawson (1997) defined designing problems and designing solutions as interdependent. There is no exact solution to a problem, just a proposal, basically creating a never-ending design loop. The interdependencies between the activities can be characterized as reciprocal or intensive (Thompson, 1967; Bell & Kozlowski, 2002). This constitutes a challenge for the process of planning the design process, keeping the time frame, and letting the design evolve as much as possible to create value (Hansen & Olsson, 2011). This argues for a layered planning, planning the overall process first in a coarse plan, then increasing the details when approaching the period of execution, using the principles in the Last Planner (Ballard, 2000).

The planning or use of knowledge exchanges is best done collaboratively (Fundli & Drevland, 2014). The design team members are "experts" in their field of contribution with both academic knowledge and experience, thus contributing to the best knowledge of tasks and interfaces. The plan should focus on information exchange and flow rather than on just finalizing drawings. The pilot case (P3) indicated that planning can reduce uncertainty. The planning needs to be a collaborative effort. As one design manager said: "it is not the mapping process but the discussions that are important," referring to a collaborative sticky note session, where each participant uses sticky notes to map the most important deliveries of their discipline. From the AEC case (P8), the different design managers had different planning approaches. One used the collaborative planning approach, letting all designers use sticky notes to map their deliveries and identifying the necessary tasks to help them carry out their work. Another approach was for the design manager to plan the design process and then get the designers to confirm that it was feasible. This last strategy needs a very experienced design manager, and the commitment of the designers to succeed. However, all the design managers admitted that they should have spent more time with the plan.

Information flow

The planning of information flow is equally important. This comprises how we communicate in the project, which mediators of communication we use, and how we communicate the necessary information between the design team members. Communication was also regarded as an important success factor (P8). The interdependencies of the activities require different types of communication or information flow. The reciprocal or intensive interdependencies need synchronous communication to be effective, while sequential or pooled interdependencies can settle for asynchronous communication (P2;Figure 7). Through mapping different types of activities and dependencies, building design management can plan which coordination effort is best suitable for the process.

The use of the BIM as a communication mediator is a rich channel aiding effective communication (P9). Combining the uses of the BIM with collaborative work setups, such as ICE, Scrum, or Knotworking, the design team is best equipped to deal with intensive and reciprocal interdependencies. The need for precise communication was exemplified in the AEC case when a design team participant asked the others to be much more precise in their requirements of information exchange (P8). This could lead to less misunderstanding, and the designer only needed to produce the information necessary, reducing waste as well.

An example of this is the information exchange of drawings or the BIM. A BIM could provide only the information required, while many designers feel they need to complete the drawing before it is released (P8). From the OC case, the use of the BIM as an information flow or communication tool was also something the OC used. In the BIM, the object completion status was added so everyone looking at an object would know if the object was mature enough to use for further design work (P4 and P10).

Managing

Managing the people, knowledge, and information flow in this context can be viewed as the supervision of the design process by planning and organizing. The management of the people is about managing the team and members. Due to the fragmented nature of the industry, there are different interpretations of roles, responsibilities, and goals. This needs to be aligned in the team to reduce sub-optimization and unethical conduct (P3 and P7). Keeping the process of planning and organizing transparent for the team members helps to reduce sub-optimization, power plays, and unethical behavior. The performance of the team also needs to be evaluated during the process to be efficient (P1 and P6).

Knowledge management (i.e., managing the knowledge and information flow to ensure that the needed knowledge is present when needed) is also an important management task. This could be everything from public documentation to hiring additional expert consultants. The use of ICE requires clear agendas and the right stakeholders present (experts) to solve the design tasks (P1).

Managing is also about performance evaluation. To control the situation, controls (metrics) are needed to evaluate the process (Drucker, 2008). These controls could be the performance of the design team, evaluation of the chosen solutions, and ensuring that the project fulfills the project objectives and goals. In addition, MA is a way to develop the design team during the design process, instead of at post-evaluation. The contractor who developed MA reported more satisfied clients and team members in projects using MA (P6), thus arguing for the importance of performance evaluation.

The management of the design process will be highly affected by the choices made by the client, building design manager, and other stakeholders in the planning and organizing stage of the process, indicating that building design management is strongly connected to the project and its stakeholders. In the AEC case, the design manager wanted to use ICE as a tool for designing and solving the design problems. However, the client did not want to make decisions in these sessions but in separate meetings with the contractor. This practically stopped decision making in those sessions (P8).

5.2 RQ2: What Can Building Design Management Learn from Engineering Management?

What can building design management learn from engineering management in the SB and OC industries? From the OC industry, the conclusion was that planning was an area for improvement in AEC projects, and, from the SB industry, the area for improvement for AEC projects was the autonomy of the design team members.

Mejlænder-Larsen (2017) described how systematic approaches, such as PEM, structure the design process of OC projects. A PEM typically describes the requirements of the design process and when it should be delivered, reflecting the logical sequences of the process. A PEM aids the design team in knowing the organization and planning the design process. By focusing much more on using the BIM as a tool to both develop solutions and communicate design maturity, the whole design team knows of the progress of the design.

This effort has been introduced in the AEC industry with the use of LOD. The OC had a database connected to the BIM in which they could report the readiness of the design. They had an extreme focus on the schedule, and everything was focused to comply with the milestones. However, when engineering the project, they would split the project up in geographical parts and trades and introduce maturity levels. These maturity levels could be, for example, 1) all types of pipes in an area, 2) all types of pipes with the right dimension in the area, or 3) all pipes with the right dimension and at the right place. The different maturity levels were communicated across the design team and let the others know what information was present and what interfaces to address (P4 and P10). The use of LOD as a framework of design maturity, aligned specifically in each project using CPD, would adjust the LOD to the objects relevant for the project and create a common understanding of the deliveries.

An observation from the SB industry was on the autonomy of the design team members in the early design of ships. They were designers with long work relations who knew what was expected from of them, dealing with several highly intensive dependent activities simultaneously (P10). This argues that more stable design team members could contribute to a better design process since the interpersonal relations and definitions of roles, responsibilities, and knowledge are already defined. Due to previous training and experience, several of the designers could alternate as naval architect if needed.

This agrees with the work of Bell and Kozlowski (2002), which argued for singular roles and a stable team to successfully handle more complex tasks. Even though these informal autonomous teams functioned, the formal flow of information was to go through the naval architect, leaving him/her as an information hub in the process. The naval architect and the project leader in sales were the only people to communicate formally with the client. The designers would like to practice design based on the design circle (Evans, 1959), yet time constraints seldom made this possible (P4 and P10). This argues for the AEC to further pursue design teams with prior relationship and experience before they start the project, instead of assembling new teams for each project (P8).

The OC industry presents a new way to plan and utilize the BIM and illustrates an industry with an extreme focus on the design plan. Comparing the AEC case and OC case showed a great difference in the focus and significance of planning. Their planning also presented well- defined information exchanges across disciplines. The use of teams with prior knowledge of each other and the method of collaboration, were presented by OC and SB as important. For the AEC to achieve this, they need to re-evaluate their PDM. A closer collaboration with more stable design team members based on the experience from the OC and SB industries could be valuable.

6 Conclusion and Further Research

This chapter concludes the research by first answering the MRQ: "How should building design management handle the early stages of the design phase in building projects?" Subsequently, the chapter concludes the research of this PhD work by describing the implications and proposing further work.

6.1 Answering the MRQ – How Should Building Design Management Handle the Early Stages of the Design Phase in Building Projects?

The aim of this research was to describe how building design management should handle the early stages of the design phase in building projects. A definition of building design management was done through RQ1. Building design management involves planning, organizing, and managing people, their knowledge, and the flow of information to obtain specific project goals and objectives (P8). The early stages in this sense were from the strategic definition until the first part of the detailed design (P5). These were the stages with high value creating potential and where the design activities consist of a high degree of iterations. The handling of the building design management process is described as challenging due to the nature of the design process and the variation of scope, project delivery methods, and fragmentation of the actors in the AEC industry, as presented in RQ1a. These variations make it important for building design management to understand the actual context of the project, the stages, the deliverables, the available time frame, and who the actors are and what they want.

This indicates a need to address each project individually. A conclusion from RQ1b was that success factors of building design management depend on the specifics of the actual project, the actors (team) involved, and building design management (P8). The need for a strong situational management of the design process was also highlighted when dealing with the behavior of the individuals on the design teams, such as organizational power (P3) and ethics (P7). This argues for building design management to assess what kind of issues this can present early and to take proactive measures to prepare for this. Additionally, is the importance of transparency in the design processes regarding structure, roles, and responsibilities to diminish the problems of personal influence sub-optimizing the design process (P3).

The second RQ asked what building design management could learn from other comparable industries, such as OC and SB. The learning from SB was concerning the importance of stable teams when dealing with complex design tasks (P4 and P10). Stable transparent teams with explicit roles and responsibilities are preferable. In AEC, this is not always possible due to client strategies, (e.g., PDM). However, building design management needs to focus on transforming the design actors into a well-functioning team during the whole design phase.

The insight from OC was regarding the focus on planning and plans. Their planning approach used predefined design maturity levels at milestones. This gave engineering management an easier task to check progress during the design process and allowed room for value-creating design activities if the milestones were met, thus combining the sequential logic and reflective logic of the design. This, along with structuring maturity in the BIM by defining the level of development, improves the planning process.

Next Step, a generic framework, was presented for project execution, focusing on the perspectives of the key actors as well as planning, procuring, communication, and sustainability (P5). The framework's main purpose was to help the actors in the project with defining common key tasks, deliveries and coordinating their involvement.

The planning of the design process was acknowledged as a success factor for building design management, but the planning of the design management process is equally important (P8). Therefore, it is important to assess the project attributes and devise a strategy of building design management based on this. There will always be similarities in projects, but treating all projects using the same management strategy might not make the process optimum for the project, and securing project success (P8). This will also influence the design management tools that the design manager wants or needs to use in the project. The use of ICE is an effective tool for enhancing collaboration; however, if the key actors are unavailable or unwilling to participate (as described in the AEC case), another form for coordination and information flow needs to be considered. This assessment and strategic planning will also make the building design management more aware of the constraints in the project and have an opportunity to discuss this with the client to try to change the process.

In summary, the MRQ regarding building design management of the early stages depends on the context (e.g., the project, actors, stage, objectives, client, available time, and budget). Thus, instead of trying to find a specific building design management strategy to handle the early stage, this research proposes that building design management needs to handle all projects individually, by assessing the context and planning the building design management, (i.e., making a design management strategy).

6.2 Building Design Management Framework to Handle Early Stages of the Design Phase in Building Projects

Based on the conclusion of the MRQ along with the other RQs, I propose a generic framework to help building design management handle the early stages of the design phase in building projects. Based on the definition of building design management from RQ1, this is what building design management needs to handle: addressing challenges and amplifying success factors. The framework is illustrated in Figure 12.

The framework consists of different elements. The first element is to separate the design management process into three stages (illustrated in Figure 12 as A, B, and C). This is based on the findings from P8, dealing with RQ1b on success factors. First, there is a need to assess the actual project, referred to as the assessment stage. Second, there is a need to plan and organize the design management process before the project starts. This stage is called initialization, referring to the start of building design management. Third, the stage of execution is where the design processes are conducted, and building design management must follow up and manage the process.

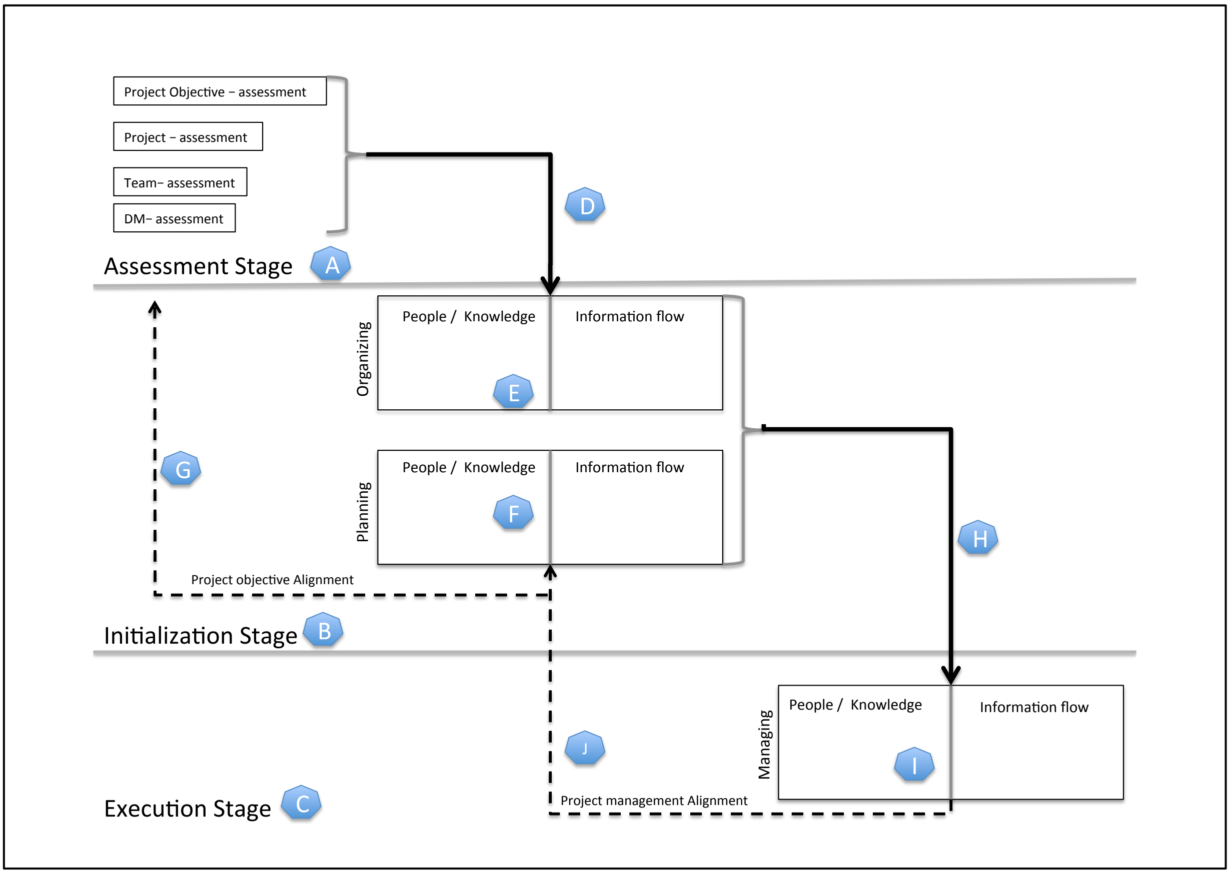


Figure 12: Framework for handling building design management in the early stages

The result of the assessment gives an overview of the project and functions as input to the next stage (illustrated in Figure 12 as D), and the result of the initialization stages provides input to the management stage (illustrated in Figure 12 as H). This could be described as the design management strategy.

The second element is based on the definition from RQ1: building design management involves planning, organizing, and managing people, their knowledge, and the flow of information to obtain specific project goals and objectives. By decomposing this definition and structuring this in segments, this can work as a support when initializing and executing design management (illustrated in Figure 12 as E, F, and I). This is the same decomposition as was discussed in Section 5.1.

The third element is the focus of the project goals or objectives, referred in this framework as objectives. The need to align the objectives throughout the process is important to achieve success (illustrated in Figure 12 as G and J).

The framework is generic in the sense of project and work scope and can be used in the different stages of a project: basic design, concept design, or detailed design. This makes the framework compatible with the Next Step framework (P5), as it could be used for a single step or for several steps, depending on the project delivery method. However, it should address the attributes of the different stages.

Assessment stage

This is the first step for the design manager to assess the project, its objectives (goals), and the design team and perform a self-assessment (P8). Using the success factors as key topics to assess the project is a good start (Figure 11). It is necessary to assess the project-specific goals and objectives and to discuss them with the client to ensure a common understanding of the objectives. The design manager aims to contribute to the project success and to have project management success for his/her area of responsibility (design management success). However, sometimes there are no clearly defined goals, objectives, aims, or purposes set for the project. There might be indicative goals, and they might shift throughout the process. By discussing and challenging the client, one is closer to obtaining the correct information regarding what is the most important for the client and addressing the issues of use, as raised by Gilbertson (2006).

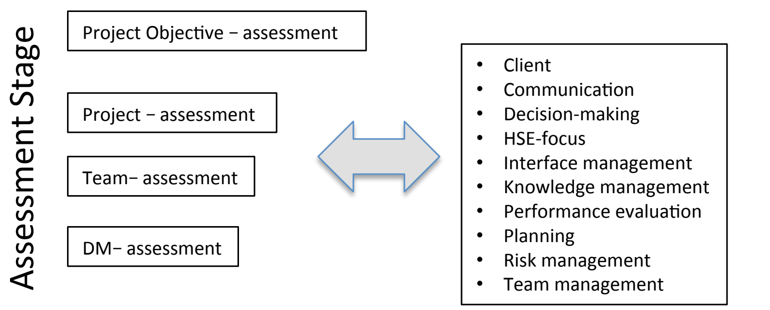


Figure 13: Assessment stage

The assessment of the team will be of a two-fold nature: first, to assess what team members are available from the client's organization, consultants, etc., and, second, to assess what team members are necessary to achieve the project objectives. The design team will typically increase with the development of the project, but assessing the resources compared to the expectations of the different project phases is important.

The self-assessment is basically for the design manager to reflect on whether he/she has the right competence and capacity to manage the design process of the specific project. What are the design manager's strengths and weaknesses, and how will that influence the project? Who the design manager represents might also influence project. The focus of the design manager might be different if he/she is a part of the client's organization, or if the role is combined with being a principal designer, a representative of the contractor, or just an external consultant. Moreover, how it might influence the project should be addressed.

Based on these assessments, the design manager can better focus on and identify the challenges of this project and the success factors. The design manager now has the knowledge to take necessary actions accordingly to ensure that he/she is prepared to manage this project.

Initialization stage

The initialization stage consists of organizing and planning to achieve the project objectives. Organizing and planning the design process are dependent on each other and should be addressed simultaneously. The stage of the project and its outcome will also influence the design process. The client's project objectives should be translated into specific objectives for the actual design stage.

The initialization stage (illustrated in Figure 12 as E and F) and its content and tasks are based on Table 8. The keywords in Table 8 and Table 9 are themes from the findings chapter that the design manager should address, and the publications are referenced for further information.

When planning for the design process, it is important to address the milestones, decision gates, and required output for the process (e.g., a design brief or a concept report). What kind of output is required and at what level of detail? All this information will influence the available time for problem-solving activities. From this, a milestone plan of the design process can be made, listing the sequential activities. The plan will provide an overview of the available time to perform the different design tasks. To address the challenges with the reciprocal or intensive activities, the use of Last Planner techniques or CPD would be beneficial. This utilizes the knowledge available in the project, when planning, acknowledging that everything cannot be planned. More detailed planning will be performed with the design team members, creating better transparency and involvement in the planning process, and acknowledging that plans will most certainly be re-assessed. Combining the plan with the BIM also helps to show and exemplify the interdependencies.

Table 8: Initialization stage – organizing and planning (keywords)

Organizing: Transparency, roles and responsibilities (P2 and P3), stable team members (P2), contract (P5), perspectives (P5), stakeholders (P5), experts, team creation and development (P6)	**Information flow:** Synchronous / asynchronous communication channels (P2, P8 and P9), Co-location, reduction of bottle-necks, ICE (P2) Knotworking, Scrum (P4), meeting/coordinating structure
Planning: Milestones, decisions, stage gates (P5), interdependencies (P2 and P10), interfaces (P2 and P8), Lean planning (P2), VDC (P1), CPD (P2, P4, and P10), sequential vs. reflexive logic (P2)	**Information flow:** BIM (P1, P2, P4, P9, and P10), LOD (P4 and P10)

The organizing of the design team is dependent on the client and the chosen form of contract. The availability of stakeholders influences the knowledge available for the design process. Including the right stakeholders at the right moment is important to ensure that the perspectives of the client, users, and other stakeholders are covered. The next step is how to utilize the stakeholders and their knowledge. A close collaborative environment with co-location is deemed successful. This could be full co-location or partial co-location through, for example, ICE sessions. The roles, responsibilities, and workload for each expert should also be clarified.

The initialization process will end in a strategy for the design manager regarding how to execute the project, which success factors are important, and which tools to use. This should follow the objectives for the project, and the design manager should also propose his/her own objectives for the design management process.

The use of the BIM as an information mediator in construction projects today is regarded as "compulsory" in this framework. The BIM and the use of LOD present better opportunities for information exchange both between the designers and between the other stakeholders and decision makers. However, the use of the BIM in the different phases of a project should be planned and addressed in advanced so the BIM can contain the right amount of information at the right time, making this an important part of the design management strategy.

Execution stage

The execution stage is doing what was planned and organized (illustrated in Figure 12 as I). There will always be a need to follow up on the initial plan and the organization of the plan to assess whether it works. The nature of the design proposes a need for a layered form of planning. The sequential plan is made, then re-planned and confirmed by the design team. As the time nears the implementation of the tasks in the plan, the plan needs to be detailed, covering the activities to solve the task. If this does not work, then re-planning or re-organizing is required (Table 9).

Table 9: The execution stage - managing the design process (keywords)

Managing:	**Information Flow:**
Team – performance and evaluation (P8 and P6), knowledge management (P8), learning barriers (P6), maturity of design (P4 and P10), audits (P8), and re-planning (P8, P4)	Performance evaluation: metrics, PPC, solutions, ICE, MA (P1, P6, and P8), BIM (P1, P2, P4, P9, and P10), Dialogue (P2 and P8)

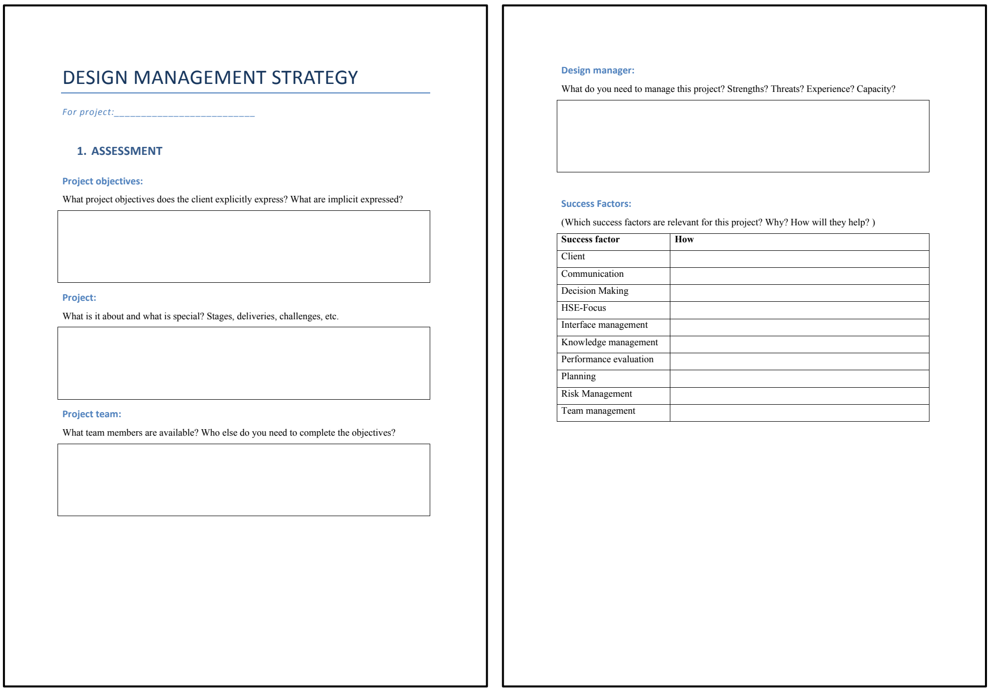
The team is, of course, another important part to follow up with and manage. As the team members start an onboarding process, it is important to align themselves to the project and its objectives. There will be issues concerning knowledge, performance, deliveries, capacity, etc., requiring the design manager to constantly evaluate the design team. There will also be a focus on the design development and how to ensure that the product meets the expectations of the client. This creates a need for a systematic performance evaluation of the team, its performance, and the product.

Summarizing the framework

Figure 12 illustrates a framework for building design management to assess and plan the design management strategy. This figure, along with Figure 13, Table 9, and Table 10, shows the framework and highlights the keywords that the design manager can use to prepare his/her design management. These illustrations are adequate for explaining the framework; however, they might not be easy to follow for the design managers in praxis. To adapt the content of the framework to praxis, this is presented in a document illustrated in Figure 14, and its full version is included in the appendix.

Figure 14 illustrates the first pages of a "design management strategy" document for the design manager to use as a support for the building design management process. The idea is for the design manager to analyze the different aspects of the project, its special context and fill out the frames with information concerning the project and its effect on design management handling of the project, as described in the framework. The idea is that the design manager alone or with other key project management personnel uses this chronologically to first assess the project, then plan the design management strategy, and finally, executes the management of it based on the actual project and the reflections on the key aspects of this project.

The document summarizes the main keywords based on this research and is not meant to be comprehensive. As presented, it is usable for a design manager with prior experience, understanding what the keywords might mean in a building design management setting. This is done deliberately so that it will not act as a checklist but as an aid to reflect on the project. A more comprehensive version could be made for training, if possible pitfalls and opportunities were also listed.



DESIGN MANAGEMENT STRATEGY

For project:_________________________

1. ASSESSMENT

Project objectives:

What project objectives does the client explicitly express? What are implicit expressed?

Project:

What is it about and what is special? Stages, deliveries, challenges, etc.

Project team:

What team members are available? Who else do you need to complete the objectives?

Design manager:

What do you need to manage this project? Strengths? Threats? Experience? Capacity?

Success Factors:

(Which success factors are relevant for this project? Why? How will they help?)

Success factor	How
Client	
Communication	
Decision Making	
HSE-Focus	
Interface management	
Knowledge management	
Performance evaluation	
Planning	
Risk Management	
Team management	

Figure 14: Building design management strategy document.

A possible hindrance for design managers using the framework could be lack of time. Design managers listed time as a scarce resource in design (P3). Since this framework asks the design managers to assess and plan their design management, instead of just starting and adapting, some might not find this new approach useful and fall back to old habits. This was an example from the AEC case where one of the design managers converted from CPD to traditional design management execution because the design team was not happy with the new way of working (P8). This is a learning barrier that needs to be overcome (Skinnarland & Yndesdal, 2014).

6.3 Concluding the Research

How should building design management handle the early stages of the design phase in building projects? Like in the design process, there is not only one solution to answer that. Building design management needs to understand the context of the project and adapt to a strategy. Thus, to adapt, the work of this thesis proposes a generic framework to handle building design management in the early stages, pursuing success factors, and proactively handling the challenges, resulting in a design management strategy. This strategy summarizes the planning of the building design management process adapted to the specific project.

The framework is generic and is independent of the specific design management tools; however, some are recommended in the framework. These are tools that encourage collaboration among the design team members and that utilize their competence and experience in planning. If the design manager is comfortable with the use of other design management tools and feels that they can help him/her obtain the objectives, this framework allows for that. However, the research has displayed the importance of transparency in organizing, planning, and managing the design work.

6.4 Research Contribution

The research of this PhD thesis examines building design management in the early stages of building projects. Compared to construction management research, this is an under-researched area which stills need attention and research to evolve. This PhD by publication contributes to the research on several levels.

First, the research has contributed to the general knowledge and attention of those in the research field of building design management by publishing research in journals and conferences. The publications concerning the challenges with organizational power in design (P3) and ethics in design (P7) are themes with even less previous attention in publications in the field of building design management. Second, this PhD work has researched and presented publications with tools to aid building design management (e.g., the use of simple metrics, the use of MA and the framework “Next Step”). Third, the PhD work has examined some of the challenges building design management can encounter when dealing with design processes in the early stages. It has highlighted ten success factors for building design management and compared the building design management with other comparable industries, proposing learning potentials. Finally, the PhD thesis presented a generic framework for building design management in the early stages. The framework will hopefully act as a support for design managers in devising a building design management strategy for their projects. Investing time in assessing what one is managing and how one aims to manage it contributes to not only improving the design managers´ work but also improving the project.

6.5 Recommendations for Further Research

The framework, presented in Figure 12, is based on the findings of this PhD thesis and is not validated through empirical research due to constraints of time. A recommendation for further research would be to test and verify the framework. This could be done along two axes:

The first approach is to present the framework for professional design managers to launch a discussion of the framework content and usability. The research project of which this PhD work is a part, has planned a workshop for professionals later this year (December 2017). A presentation of the framework and the following discussions will provide a view of what AEC professionals think of the framework and provide inputs for improvements.

The second approach is to verify the framework through empirical studies, where the design manager uses the framework adapted to the project. Preferably, the second approach should be done after the first verification by professionals.

Design management has a systematic managerial approach, and even though this thesis touches the interpersonal level of team members, by examining organizational power and ethics there is still a need to investigate how the personal behavior of the design manager influences the building design management process. In addition, MA addresses the behavior and improvement of the design team, but what happens if the problem is the behavior of the design manager? Therefore, further research concerning the personal and leadership qualities of a design manager would be interesting.

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