Doctoral theses at NTNU, 2018:49

Vegard Knotten

Building design management in the early stages

Doctoral thesis

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Norwegian University of Science and Technology
Thesis for the Degree of
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ISBN 978-82-326-2890-2 (printed ver.)
ISBN 978-82-326-2891-9 (electronic ver.)
ISSN 1503-8181

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Trondheim, February 2018

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Printed by NTNU Grafisk senter

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.

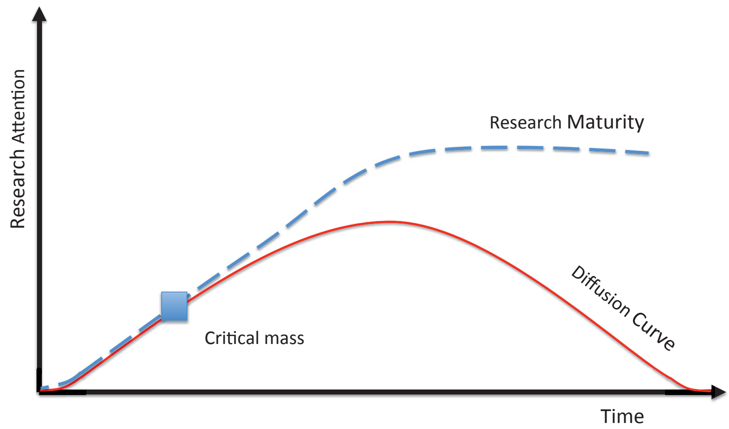


Figure 1: Building design management - research development (adapted from Rogers (2003)).

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.

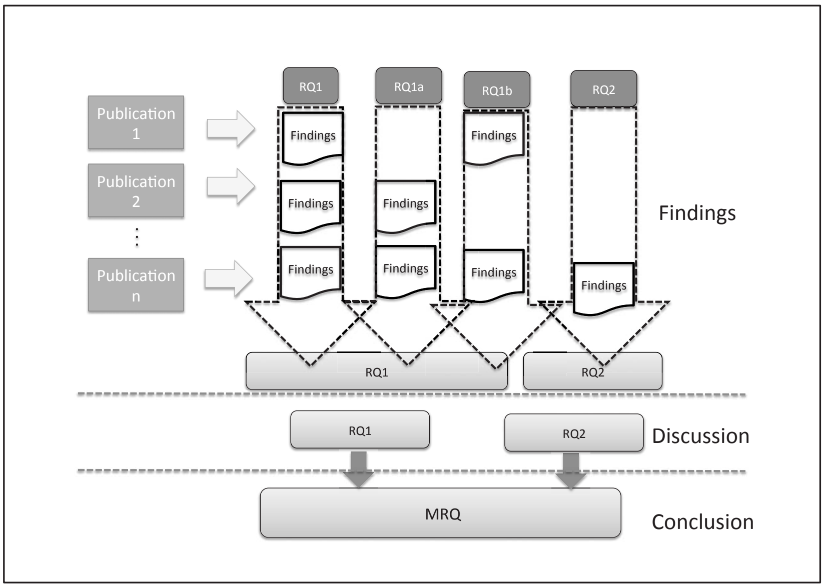


Figure 2: Answering the MRQ and RQs with the publications.

2 Research Design and Methods

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

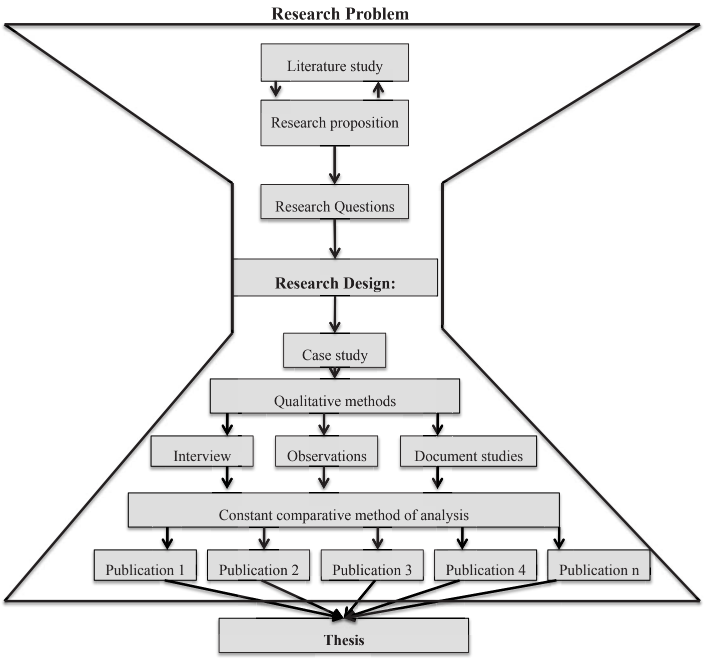


Figure 3: Research process of the PhD thesis based on Creswell (2012) .

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.

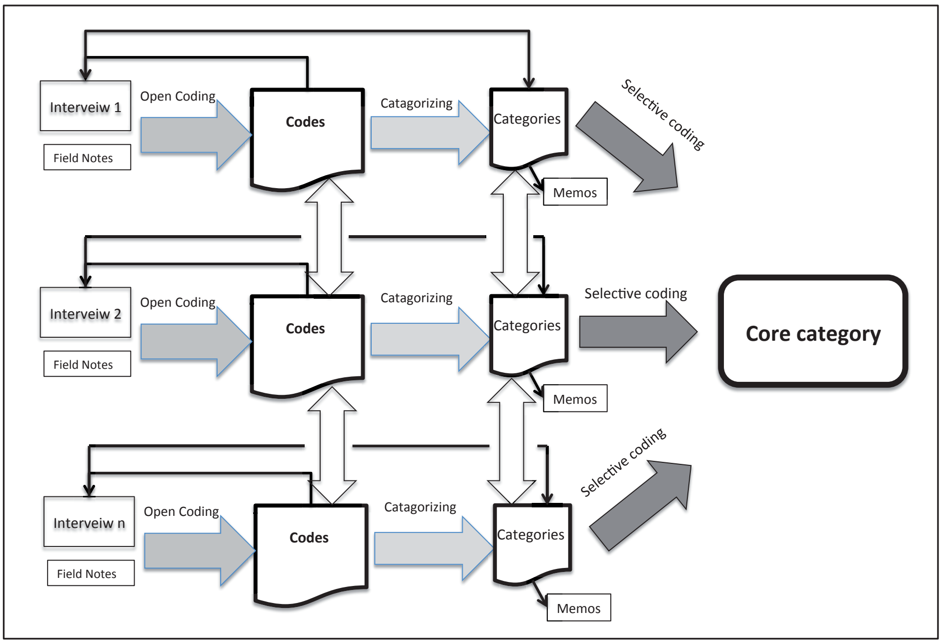


Figure 4: Constant comparative method of analysis.

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.

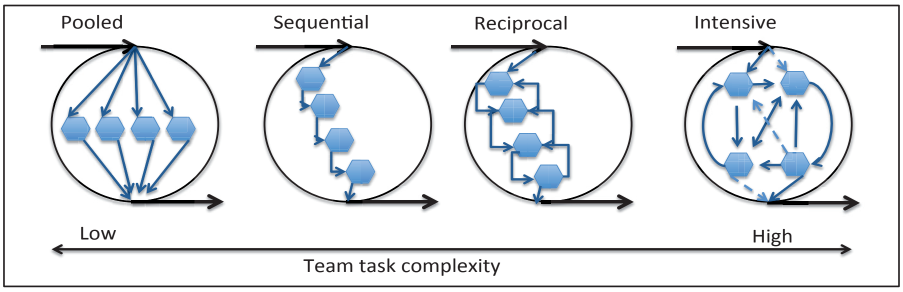


Figure 5: Different types of dependencies in team tasks (Bell & Kozlowski, 2002).

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.

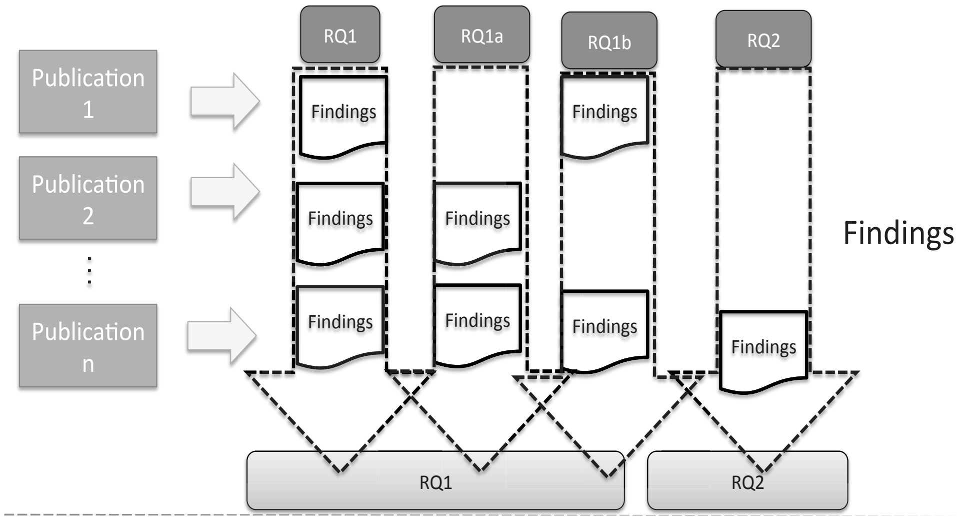


Figure 6: A model of the findings chapter layout.

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

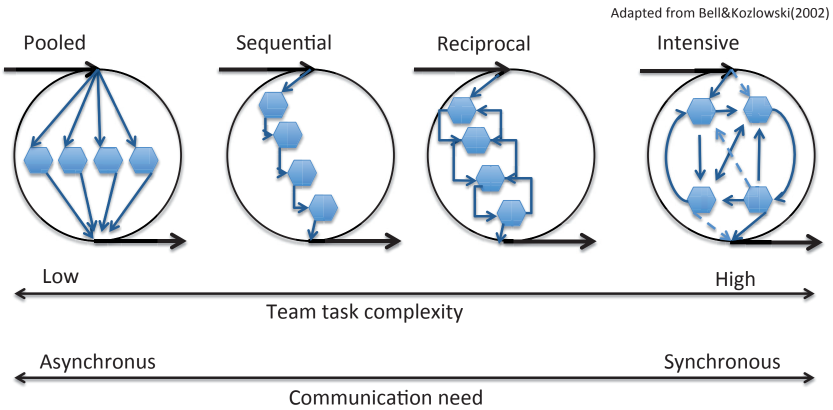
The aim of the paper was to report on a constructor's implementation effort of virtual design and construction (VDC). The VDC is primarily oriented around the use of models, and the

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.

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.

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

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.

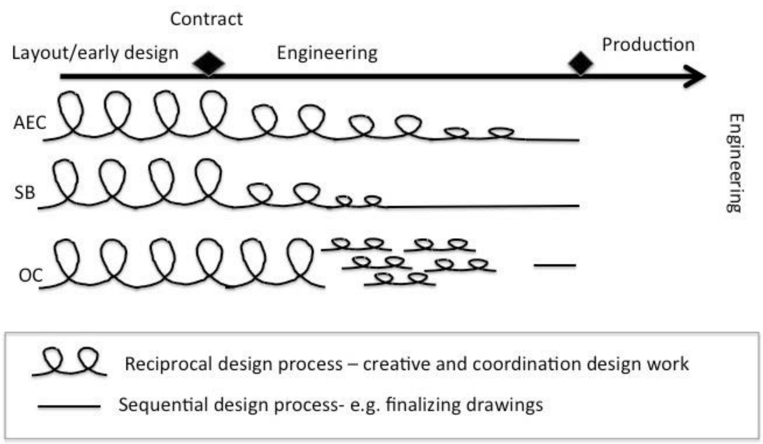


Figure 8: Design process in different trades (P4).

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).

Step	1 Strategic definition	2 Brief development	3 Concept development	4 Detailed designing	5 Production	6 Handover	7 In use	8 Termination
Core process	**Owner** perspective							
	User perspective							
	Supplier perspective							
	Public perspective							
Management process	Planning							
	Procurement							
	Communication							
	Sustainability - economics							
	Sustainability - environment							
	Sustainability - scocial							

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.

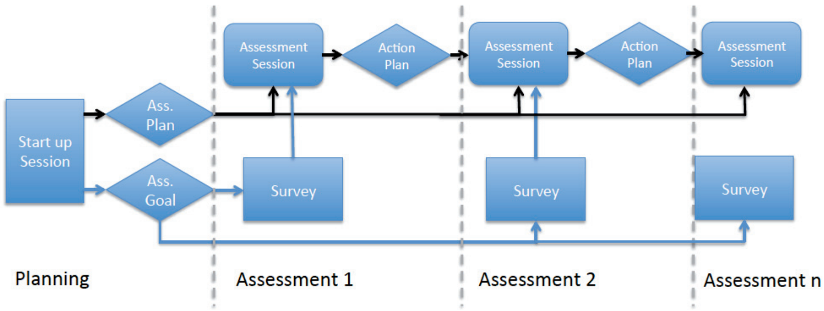


Figure 9: Mutual assessment (P6).

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.

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.

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

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.

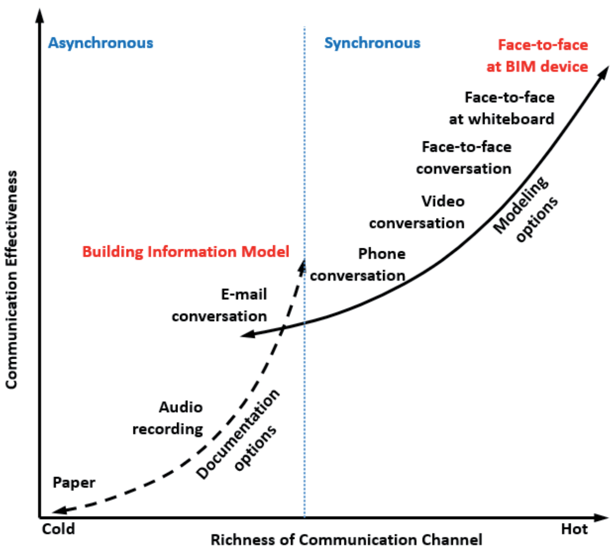


Figure 10: Communication channels (P9)

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.

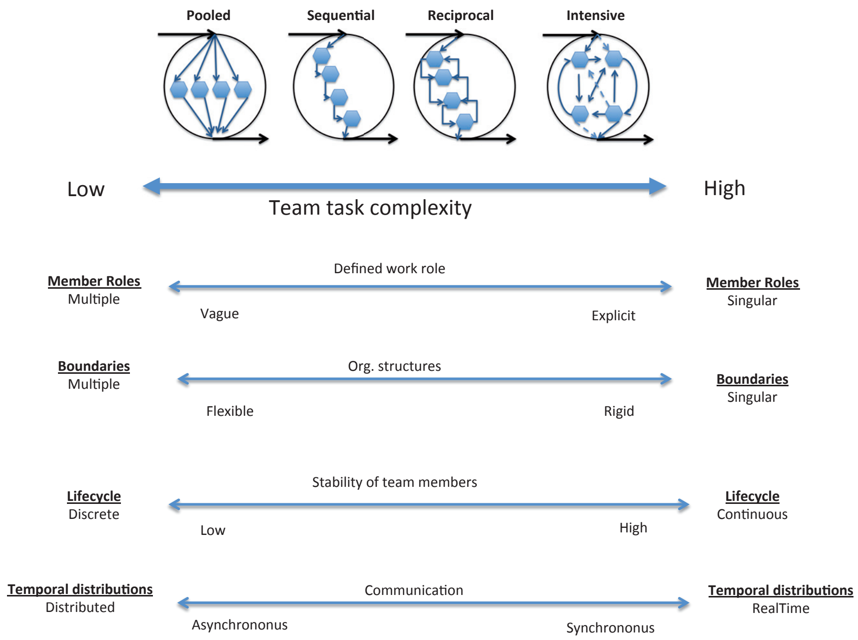


Figure 11: Team task complexity and characteristics (P10).

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.

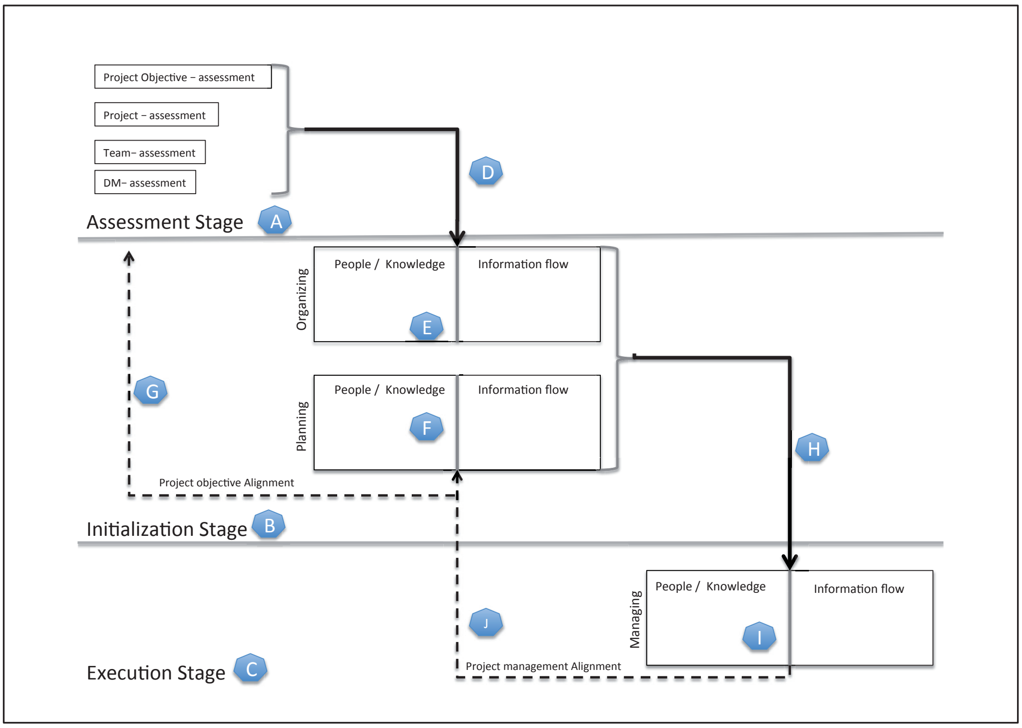


Figure 12: Framework for handling building design management in the early stages

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).

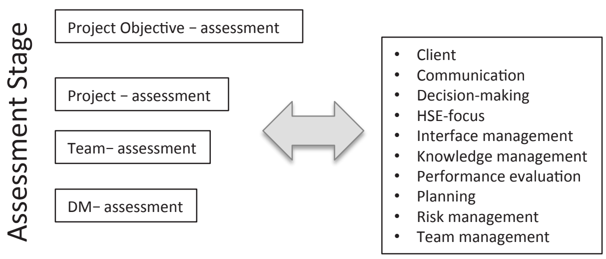


Figure 13: Assessment stage

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)

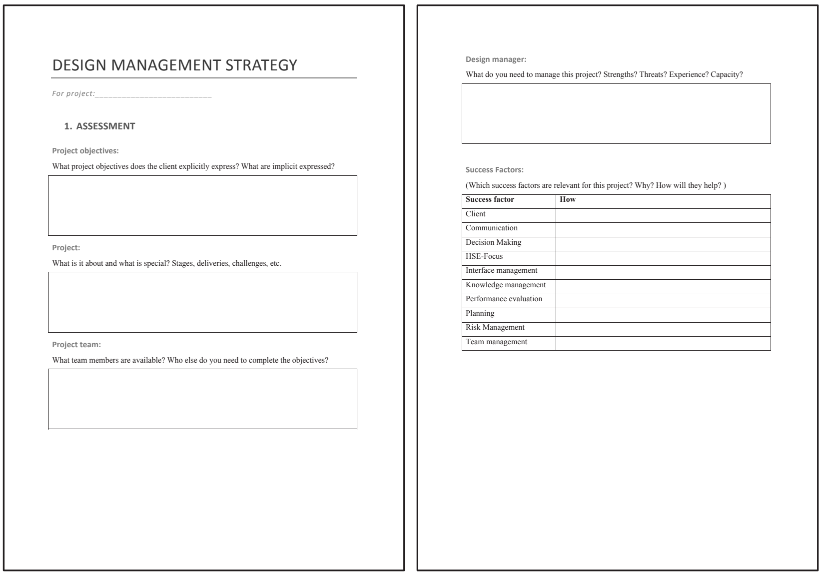
The team is, of course, another important part to follow up with and manage. As the team members start an onboarding process, it is important to align themselves to the project and its objectives. There will be issues concerning knowledge, performance, deliveries, capacity, etc., requiring the design 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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Appendix A: Design Management Strategy

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	

2. INITIALIZATION

Organizing the project:

How will you organize the project to achieve the objectives ? Keywords: Stakeholders, contract issues, experts, roles, responsibilities, stable team members. Team creation, team development and team mental model.

Planning the project:

How will you plan the project to achieve the objectives? Keywords: Milestones, stagegates, phases, steps, interdependencies, interfaces, sequential and reflexive logic, collaborative planning, and last planner.

Information flow:

How will you organize and plan the information flow ? Keywords: Asynchronous and synchronous communication, communication channels, co-location, removing bottle-necks, ICE, Knotworking, Scrum, meeting and coordination structure. The use of BIM and LoD.

3. EXECUTION

Managing:

How will you execute your design management strategy in order to achive the project objectives? Keywords: Team management, performace evaluation, knowledge management, progress handling of the plan, re-planning, product evaluation, audits, and maturity of design.

Information flow:

How will you manage the information flow ? Keywords: performance evaluation, process metrics (PPC), team evaluation, mutual assessment , reports, BIM and LOD.

Appendix B: Publications

No.	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.
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.
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.
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.
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.
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.
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.
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
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
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

PUBLICATION 1

IMPLEMENTING VIRTUAL DESIGN AND CONSTRUCTION (VDC) IN VEIDEKKE – USING SIMPLE METRICS TO IMPROVE THE DESIGN MANAGEMENT PROCESS.

Vegard Knotten[1] and Fredrik Svalestuen [2]

ABSTRACT

The productivity in the AEC industry in Norway has had a decline since the 80´íes and Veidekke has sought out new approaches to deal with the issue. One of the approaches has been to work with Stanford University and CIFE to improve efficiency of the design phase, by using Virtual Design and Construction (VDC).

Through a certificate course in VDC the participants got an introduction to the use of VDC and in the following year implemented VDC in their projects. Metrics is a key part of VDC, and by using simple metrics the participants discovered how to increase the efficiency of the design phase and how to improve the control of the design phase, including changing the processes that did not work well.

The aim of this paper is to present some of the course participants' experiences in implementing VDC in their projects and to show how simple metrics can document their efforts.

The following main findings were reported:

- The time spent with quantity take off (QTO) can be reduced dramatically.
- The PPC (Per cent Planned Complete) can be increased by using the 6 prerequisites of a healthy design process to determine the root cause of uncompleted tasks.

KEYWORDS

VDC, Metrics, Design management, Constraint analysis, Improvement

INTRODUCTION

Virtual Design and Construction (VDC) are defined by (Kunz and Fischer 2009)as: “The use of integrated multi-disciplinary performance model and design-construction projects to support explicit and public business objectives”

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This is further defined as ” The VDC project model emphasizes those aspects of the project that can be designed and managed, i.e., the product (typically a building or plant), the organization that will define, design, construct and operate it, and the process that the organization teams will follow” (Kunz and Fischer 2009)

So by using computer models of the project, integrated with the right organization and processes there is a big potential to increase the value of the project. (Khanzoode, Fischer et al. 2008)

Since the 1980-ies there has been a significant reduction of productivity in the AEC industry in Norway. By a comparison at productivity has fallen with 20% since year 2000, while other industries have gained productivity by 30%. (Source SSB - Statistics Norway). An internal survey in Veidekke from 2004 shows that one of the main reason for stop and delays in the production, is due to wrong or missing production material from the designers.

As a mean to improve the productivity and the quality of the work, Veidekke started collaboration with Center for Integrated Facility Engineering (CIFE) and Strategic Projects Solutions SPS at Stanford University.

CIFE/SPS has developed a VDC certificate program that teaches professionals within Architecture, Engineering, Construction (AEC) and Facility Management (FM) how to use VDC effectively and obtain high value for their projects and businesses.

The VDC certificate program consists of 3 different elements:

1. VDC introduction – a 5 day introduction course
2. VDC application – a 6-month period where the participants use their VDC knowledge in their organizations. This includes monthly reports and conference calls to discuss progress and issues with CIFE and the other participants.
3. VDC Integration Experience – a 2 day session to discuss what have been learned and how to implement VDC in their organization.

In March 2010 CIFE and SPS visited Veidekke in Stockholm and conducted the first VDC introduction Course for Veidekke. A new course was held in Sweden in 2012, and in January 2013 a course was held in Trondheim. This paper presents some of the results from the VDC implementation phase after the last course.

METHODS

This paper is based on studying the course participants’ reports and discussing the findings with the participants at the conference calls.

REPORTS AND RESULTS FROM THE VDC IMPLEMENTATION PHASE

The reports were submitted monthly and presented at a telephone conference. Since the course participants were new to the methods of VDC, it usually took some reports before they got useful metrics. All participants were employees of Veidekke, but they came from different field offices and had different positions in projects. There were design managers, project managers, foremen, and BIM engineers. Their position and current work situation set the framework for their VDC efforts.

METRICS

An important part of VDC is to collect metrics in order to evaluate the status of the agreed processes in the projects.

(Drucker 2008) argues for the term controls meaning measurement and information. "Controls deal with facts, that is with the events of the past" He also argues that "control deals with expectations, that is the future". In order to control the result of a process you need controls (metrics) to let you know how your process is doing.

The metrics presented in this paper are only a few of the metrics presented by the participants. The ones presented here are chosen because they demonstrate either an improvement from the way work is conducted today or they present a tool to change the way work is conducted today.

The metrics collected and shown here are referred to as simple metrics, since they are not difficult or time consuming to collect, yet they give valuable information about the processes.

The following metrics are presented in this paper:

- Comparison of time spent in Quantity Take Off (QTO) when using BIM vs. drawings and counting.
- Counting how many times the BIM can be used to review alternative solutions.
- Comparison of QTO from BIM vs spent materials.
- Per cent Planned Completed (PPC) of planned tasks in ICE session, action plans (between meetings), and drawings deliverance.
- Evaluation of ICE Sessions

THE USE OF BUILDING INFORMATION MODEL (BIM)

Since VDC is primarily oriented around the use of models, a Building Information Model (BIM) is essential. In this case, we define BIM as more than just a 3D model. BIM is a 3D model that enables the use of Quantity Take Off (QTO), 4D simulations and collision control. In our experience to achieve a good BIM, the key issue is to get a good file structure and a product breakdown structure (PBS) that concurs with the actual physical assembly of the project.

Figure 1 shows a metric of time spent with Quantity Take Off (QTO) in a tender phase of a project. The goal was to determine the amount of material to be able to give a most accurate price. The participant used two different approaches, in order to get the answers (Berg 2013). One has been preformed off the BIM using an automated QTO, and the other have been done by 2D drawings and a CAD program. This approach is done in two different tender projects. This metrics shows approximately a 45% reduction of time spent. In this case it is also interesting to view the hours reduced, since experience from Ole Morten Kvam (2013), revealed that as little as 5-10 hours spent at remodelling a BIM, can give an huge advantage in visualization and transparency for a tender team.

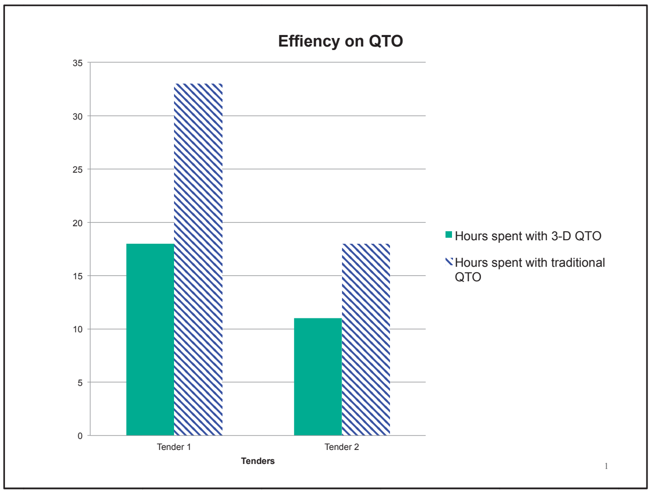

Figure 1: Efficiency of Quantity Take Off (Berg 2013)

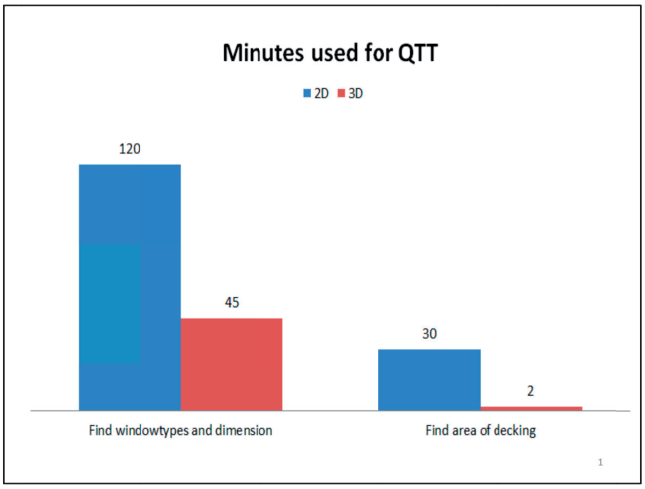

Figure 2: Time used for Quantity Take Off (Fluør 2013)

In a tender or design phase it is important to explore multiple solutions to achieve the best design. During this explorative phase the use of BIM is an effective tool. The model increases the transparency of the solution for the design team. During this phase it is important to keep an updated cost estimation of the project.

Figure 2 shows a time reduction of 63% at the QTO of windows and 93% of area of decking (slabs) by using BIM vs. manual QTO. This vast time reduction makes it easier to keep an updated cost estimation throughout the project.

The time saved by using BIM in QTO will vary depending on how good the BIM is and the scope of the QTO.

Figure 3 shows a metric comparing number of alternatives explored by using the BIM. Each alternative will bring the design team closer to an optimum design.

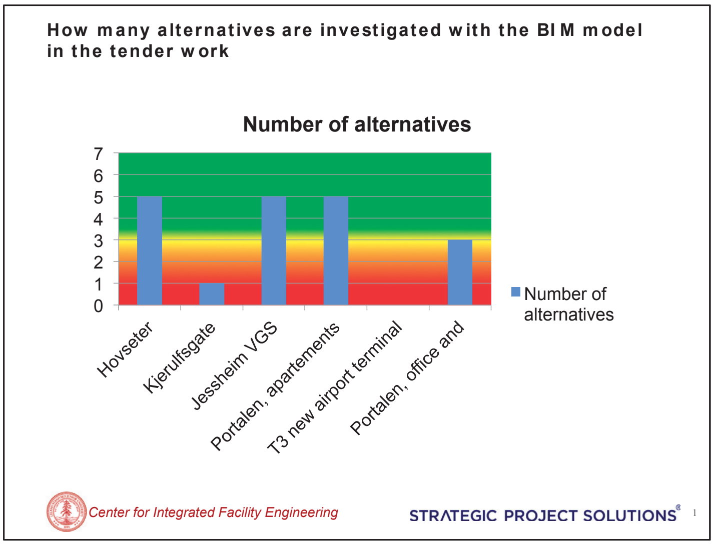

Figure 3: Number of alternatives investigated by using BIM (Borgen 2014)

The main goal of a QTO is to get the right amount of materials in order to make an accurate purchase or work planning. At a residential project, the foreman used the BIM QTO as a framework for his orders of drywall material (Braa 2014). Since the detail of the model was not 100% adjusted to the building of the apartments, he used his experience to make correcting factors to the result of the QTO, and then ordered the materials using the corrected QTO. Figure 4 shows variations of the ordered materials vs. the spent materials. As this metric shows there were some variations at used drywall material vs. the ordered material. Even though the largest discrepancy is 9,6 % between ordered vs. used, the metric is a success, since it enables the foreman to adjust his correcting factors, and to get a more accurate order the next time.

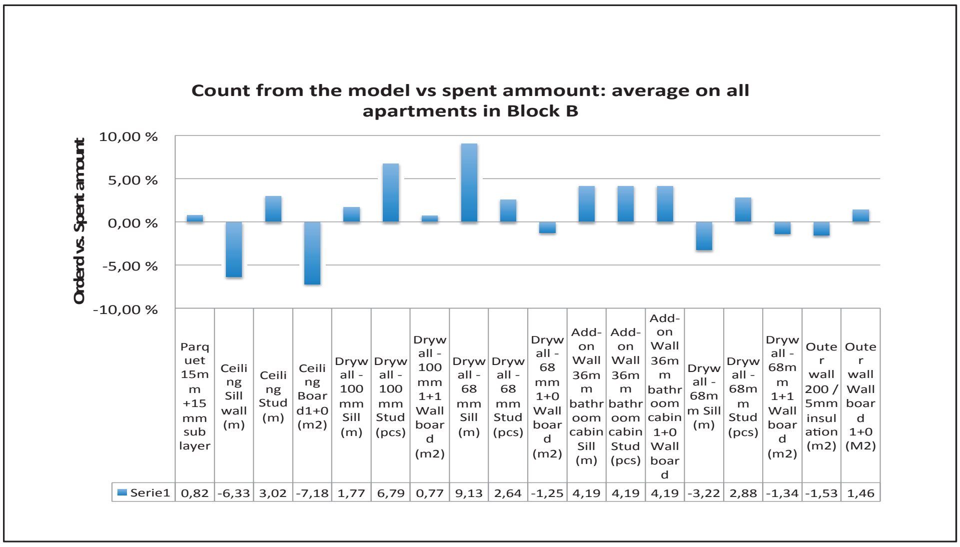

Figure 4: Quantity take-off from model vs. spent amount. (Braa 2013)

INTEGRATED CONCURRENT ENGINEERING (ICE) SESSIONS

Integrated Concurrent Engineering (ICE) was developed by NASA's Jet Propulsion Laboratory in the mid 90'ies. (Mark, G.) A design group called Team-X created an improved speed and quality of space mission planning, by creating environment of extreme collaboration. Similar setups made for AEC industries are referred to as ICE. Key success factors are good preplanning, clear agenda and objectives, productive environment (Kunz & Fischer 2009).

Being able to complete the task of a meeting is important in order to secure decisions and progress. Figure 5 shows measurements of completed issues in an ICE session. The first 3 sessions were conducted without a pre-set specific goal and without the agenda sent out in advance. The last 4 sessions was done with an agenda and a goal for the ICE issued in advance.

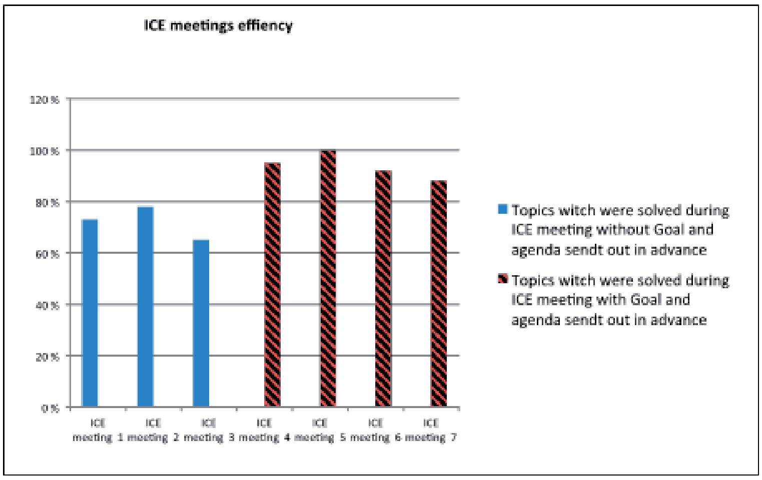

Figure 5: ICE meeting efficiency (Berg 2013)

The first sessions (blue bars in figure 5) had an average of 72% completion while the 4 last sessions (red-striped bars in figure 5) had an average of 94%. This clearly show the fact that a) preplanning is a success factor and b) with metric you can see what is broken / not working optimal and try to fix it.

Another way to try to determine the success of a meeting or an ICE session is to do measurements of the participants' perception of the meeting or the session. Content participants are more likely to engage and tribute to the process than those who feel it is a waste of time. Figure 6 shows measurements done by the ICE session's participants after each session. Each participant stated how content they were with the ICE session form a scale of 1 to 7, where 7 is extremely content and, 1 is very discontent. The measurement "Value for money" refers directly to if they experienced the session as a productive use of their time. This metric helps the ICE session leader to reflect on how to organize and arrange the next session.

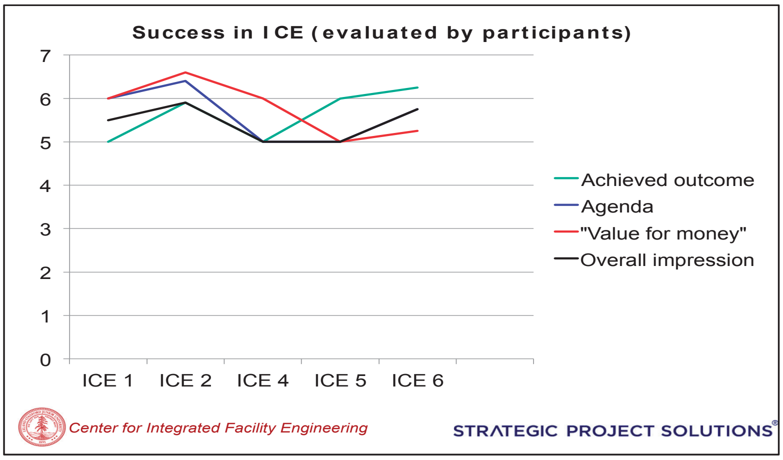

Figure 6: Success in ICE sessions (Haugen 2013)

PROCESS MANAGEMENT

In the design process the deliveries are decisions, solutions, clarifications or drawings. Each of these deliveries can be vital to the progress of the design process, and thus need a special attention. Measuring the Per cent Planned Completed (PPC) will give a good indication whether or not the process is on track. If the process fails to be on track, it is important to sort out the reason for a failing design process.

Figure 7 shows the measurement of how many drawings that were completed within agreed time. The measurement does not say anything about the numbers of drawings or the effect the delays had on the production. What the measurement is telling is that something in the process is not working and that this is not a “one time” error.

It is important to try to find the root cause of the delays in the production. This is shown in figure 8, representing the last week deliveries. The root cause was divided in the 6 prerequisite for design (Bølviken et al 2010). As figure 8 indicates, the main reason for the delays where lack of information, i.e. not enough information to complete the drawings. However according to the design manager, in the design meeting 2 weeks prior to completion none claimed the lack of information to complete their work.

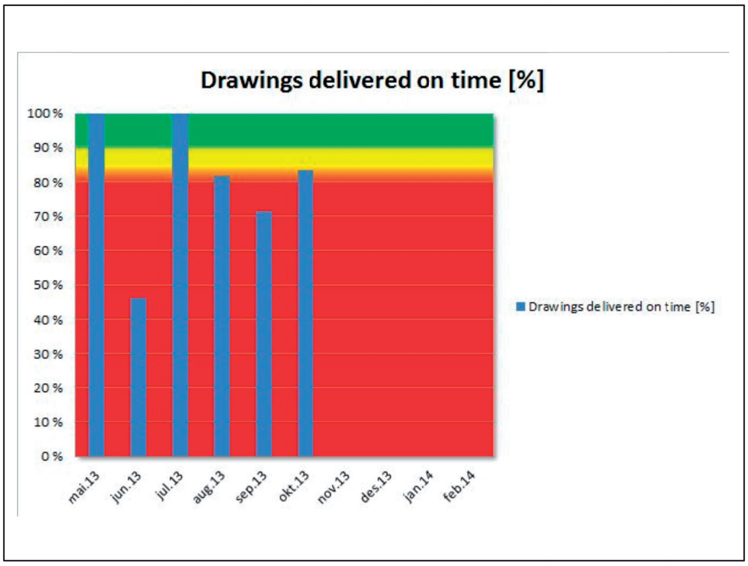

Figure 7: PPC of drawing deliveries (Olsen-Nauen 2013)

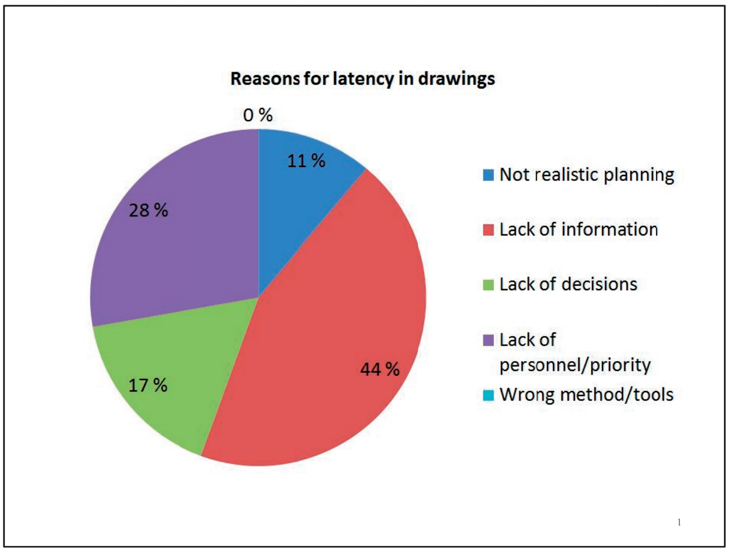

Figure 8: Reasons for latency in drawing deliveries (Olsen-Nauen 2013)

Similar measurements are presented in figure 9, showing the PPC of an action plan in the design phase of a project. The measurement was how many of the promised tasks were completed at the agreed time. This was then divided to show the status of members in the project.

From the metric it is easy to see which member of the design team does not deliver, and also the reason for the latency is displayed.

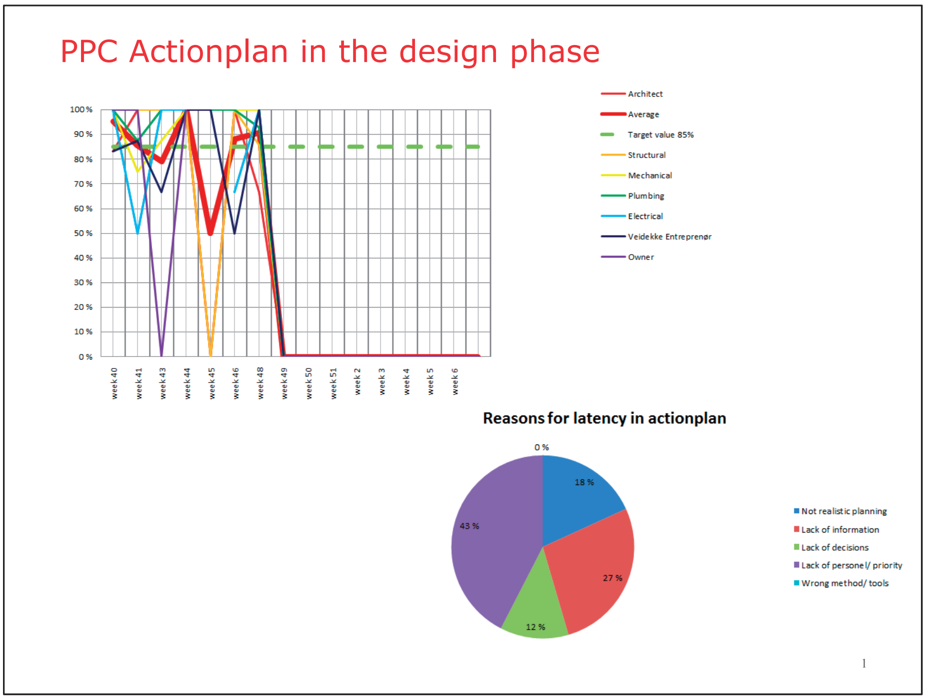

Figure 9: PPC of an action plan in the design phase (Duaas 2013)

Both Olsen-Nauen (2013), and Duaas (2013) displayed the metrics to their design teams and registered a change in performance and root cause in their teams.

CONCLUSIONS

The use of simple metrics in the design process is not a new tool, but it is an effective one to show the status of the process. As the examples given in this paper show, it is not difficult or time consuming to set up these metrics. They give a good description of what needs more attention, and where there can be made good investments.

This paper presents a collection of the course participants' experiences in implementing VDC in their work, and the benefits they experienced by using VDC.

The following main findings were reported:

- By using BIM the time spent in quantity take off (QTO) can be reduced by more than 90% when measuring areas of decking (slabs).

- BIM eases the possibility to explore different solutions in design and tender work.
- By using ICE and together with metrics the efficiency of the design team increases.
- Together with metrics and process management the PPC (Per cent Planned Complete) of the process can be increased. This works best when the metrics are transparent to the design teams.

In addition to improving the participants' own projects and work, their experiences are important for the management in evaluating the results of implementing VDC in Veidekke.

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PUBLICATION 2

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Procedia Economics and Finance 21 (2015) 120 – 127

Procedia Economics and Finance

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8th Nordic Conference on Construction Economics and Organization

Design management in the building process - A review of current literature

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Abstract

The architecture, engineering and construction (AEC) industry has experienced the declining productivity and some of this is due to deficiencies in building design. The focus on energy efficiency and sustainability makes it even more important to reduce such deficiencies. The managing of building design phases might be one of the most challenging forms of management in the AEC industry, i.e. it involves managing both outputs as drawings and creativity as minds. There must be enough room for creativity so that a building project can evolve to serve clients' needs. There are pooled, sequential, reciprocal and intensive interdependencies in building design that need to be handled or coordinated differently. A particular building design phase most likely consists of all the four types, yet dominance shifts between them through sub-phases. The logic of creative processes is difficult to understand and, therefore, to manage properly. In this paper, these four interdependencies and their coordination are described based on the literature review. The key findings indicate that the reliance on the same management approach to handle both reflective and sequential dependencies might be contra productive.

Selection and/ peer-review under responsibility of Tampere University of Technology, Department of Civil Engineering

Keywords: Building design management; interdependencies; review

1. Introduction

The architecture, engineering and construction industry (AEC) have a potential to increase productivity and increase the value of projects. There is a common apprehension that the overall performance of the AEC industry

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Selection and/ peer-review under responsibility of Tampere University of Technology, Department of Civil Engineering
doi:10.1016/S2212-5671(15)00158-6

has not evolved with other industries and that there still are too many quality errors, leading to rework (e.g. Love et al., 2003; Love & Li, 2000; Meland, 2000). A finger is pointed towards building design as a major factor of low performance (Ballard & Koskela, 1998). Especially, the poor management of early design phases has proven to be the cause for document deficiency and rework (El. Reifi & Emmitt, 2013; Tilley, 2005). Moreover, it has been proven that these problems influence building projects as a whole negatively in terms of increased costs or reduced productivity (Baldwin et al., 1999). Similarly failures to fully understand clients requirements and value influence the value of buildings negatively in a form of clients not getting what they really need and want (Thyssen et al., 2010).

The term value is arguable for many definitions (Salvatierra-Garrido et al., 2012), but in this paper it is regarded in the context of owners, clients and users. Value can be regarded as something that improves a project, either as a final product or a successful process (Eikeland, 2001). It is in the early stages of the design phase where the influences of stakeholders is largest and the costs of changes are lowest, making this the best stage for value realisation (Samset, 2008). This stage is also most complex to understand, carry out and manage.

Many projects are not able to realise their value potential and this is argued to be due to managerial problems in the design phase (e.g. Hamzeh et al., 2009; Hansen & Olsson, 2011). One of the reasons for this is the complexity of the design phase, and especially the early design phase where iterations are essential for value creation (Ballard, 2000). The management of a mass production factory can always be planned sequentially, where activity A must be completed before activity B can start. This is seldom the case for building design management, where you want several iterations to generate value, consequently making the early stages of the design phase a complex process to manage.

In this paper, the processes of building design, the complexity of those processes and the most current practice of building design management are described, based on the literature review, as follows.

2. Conduct of the literature review

Compared to project management, there are only a few books written about building design management describing specific challenges in design management (Blyth & Worthington, 2001; Emmitt & Ruikar, 2013; Eynon & Building, 2013; Gray & Hughes, 2001; Sinclair, 2011). The research is mainly presented in papers and articles. In order to describe complexity, building design management is linked to organisational management.

The literature review was done by applying the seven steps of Creswell (2003). The topic words were building design management. These were chosen to give understanding of the amount of literature with those keywords. The search of relevant literature has been using the search engine with a reference to the last 10 years. The search string was "Building near/0 Design near/1 management". The databases were AB/Inform (AB), Web of Science (WoS) and Scopus (Sco). The first search presented 289/6/192(AB/WoS/Sco) articles in the different bases and these were then reduced to 60/6/69 after discarding commercials and irrelevant journals (e.g. medical, chemistry etc.). Then the results were skimmed by reading the abstracts, keywords and titles, discarding those who were irrelevant. The review paper of Svalestuen et al. (2014) gives a good insight of the substantial amount of work done in the IGLC community concerning building design management, and this was added as well.

3. Results of the literature review

3.1. The building design process

In order to try to understand the difficulties of design management it is also important to understand the process in building design. The design process is often divided in several stages or phases. An example is the RIBA plan of work which has divided the construction process into the seven stages where stages 1 through 4 include design work (RIBA, 2013). The flow of information, focus points, planning and managing differ in these stages. A simplified definition is to say that design management is about managing people and information (Emmitt & Ruikar, 2013). People in this context are stakeholders in a building project and information being deliverables among stakeholders.

The final part of deliverables as drawings, models etc. are concrete and easier to manage than for instance ideas or evolving concepts from the creative minds of designers. “Design management is a complex social situation as value can be a socially constructed phenomenon and decision making to that end can be inherently unpredictable”(Kestle & London, 2002).

Brief stages and the implication that these can have on a project are attracting an increased focus hence they give inputs to the rest of a building process (Blyth & Worthington, 2001; El. Reifi et al., 2013; Gilbertson, 2006; Tilley, 2005). But this is an important and under researched area. The briefing period is also a complex stage to manage. If the management of the briefing phase is poorly conducted, it is likely that opportunities are missed out later in the design process (Tilley, 2005). On the other hand, Azlan-Shah and Cheong-Peng (2013) argue that good designers can improve the clients brief.

A briefing stage usually ends up in briefing documents, on which a project is based. In some projects, this process is short and very often only consists of a client and an architect. In this stage, the vast majorities of key decisions are made. Gilbertson (2006) argues that design cost is 20% of construction costs, yet maintenance and building operating costs are five times of construction costs and business operating costs can be as much a 200 times the construction costs. The research of El. Reifi and Emmitt (2013) revealed that the issues related to the design brief were responsible for almost 30% of the rework. Accordingly, they also discovered that the client brief was the largest hindering of the design value by over 60%. This highlights the importance of the briefing stage.

In the early stages of the design phase, such as preparation, brief, concept design etc., processes are creative, iterative and innovative. These are processes which many solutions, thoughts and ideas are shared between stakeholders. These processes need to be open and 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 the end value of a project.

Lawson (1997) defines design problems and design solutions as interdependent. Design problems cannot be comprehensively stated and there are no optimal solutions to design problems, and design solutions are unlimited in number. Thus, there is a need to control the design process, but also a major challenge. The design process can therefore be viewed as an endless reciprocal process versus the building production process is traditionally viewed as a strictly sequential process.

Bølviken et al. (2010) introduces the work of Thompson (1967) to describe the different processes of design and their interdependences. There are pooled interdependence, sequential interdependence and reciprocal interdependence. Bell and Kozolowski (2002) introduced a fourth dimension called intensive interdependence. Processes 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 standardisation, by plan and by mutual adjustment. “Design decision making is often negotiated amongst groups and teams, it is an iterative process” (Kestle & London, 2002). This was followed up by Kalsaas and Sacks (2011) and Andersen (2011) who used the same concept in the case study to explain the design process of a hospital project.

Kalsaas and Sacks (2011) argue that it is important to understand dependencies in the design process in order to handle them. Andersen (2011) describes the coordination as negotiations, mutual adjustment and opinion based communication. Relations in a process follow different logics. One of the logics describes an “everlasting movement”, where everything is connected to each other (see Fig. 1). To be able to proceed, you must make a decision, regarding an element or structure, if not the process stops or it will not start. A concrete decision of a solution might then start a sequential process, yet a decision turning down a solution, might just set of a new reciprocal process. A second logic is to pursue decisions so that they again set of a chain of solutions and new decisions. Knotten et al. (2014) introduce the term reflective logic and sequential logic describing the logics of design process. The sequential logic is based on a sequential, linear, closed process. Activity A must be finished before activity B can start. These are the typical processes displayed in a Gant schedule, and they can be planed and managed by the management planning tools (Pinto, 2013; PMI, 2013).

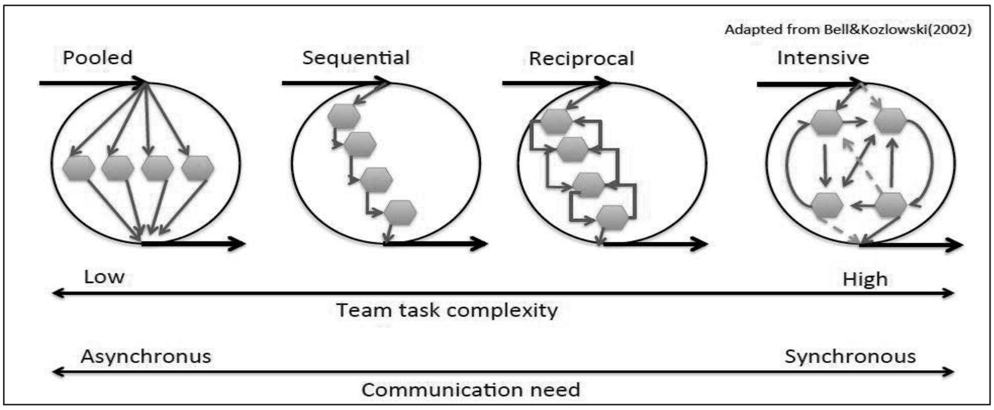

Fig. 1. Team task complexity.

The reflective logic is dealing with reciprocal, iterative and intensive processes. Activity A needs input from activity B, before it can finish, yet activity B needs input from A before it can deliver its output to A. The design phase typically starts with a high amount of interdependencies and team task complexity as a design team is looking for the best solutions. As design problems are solved, interdependencies are team task complexity are reduced and consist of singular tasks (e.g. drawing completion). In turn, Alvesson and Sköldberg (2009) describe reflective research to consist of two characteristics, i.e. careful interpretation and reflection. This is coherent with Lawson's (1997) description of the process as analysis, synthesis and evaluation. Therein, a logic looks at a problem, tries to generate a solution and then evaluate the solution, before this might lead to a final solution.

3.2. Managing the building design

A typical approach to project management is to gain control of a process in regard of time-cost-quality (Eynon & Building, 2013). In sequential planned processes, it is possible to see if an agreed drawing is delivered at the right time and how many hours were spent. Quality can be more challenging. This approach enables you to secure the scope of a design team but this may not necessarily deliver the most optimum value for a client. This is in line with many arguments for the importance of design in making value for a project (El. Reifi & Emmitt, 2013; Emmitt et al., 2005; Thyssen et al., 2008; Gilbertson, 2006). Value and waste are important for both the project as a whole and its design process. Likewise, processes and decisions are important vis-à-vis creating value (Koskela et al., 2013).

If the building design process consists of pooled, sequential, reciprocal and intensive processes, the managing of the process is complicated. A standard project management approach (Pinto, 2013; PMI, 2013) can help you manage pooled and intensive processes, but it is not an effective tool to manage a reciprocal or an intensive process. Mintzberg (1983) describes processes with reciprocal and intensive interdependencies as adhocracy. Adhocracy consists of a highly organic structure with little formalisation of behaviour, high job specialisation based on formal training and specialists in functional groups, i.e. a multidisciplinary design team. Managing involves chaos and unpredictability. The organisation of projects by hiring different consultants makes it relevant to compare challenges to design organizations with virtual teams (Bell and Kozolowski, 2002). Project culture, clear responsibilities, real time information and transparency become increasingly important as complexity increases in projects. Morgan (2006) suggests that we rethink the way we organize when we are at the edge of chaos. “Managers need to flow with the change rather than try to predesign and control in a traditional way.”

From the management perspective, the planning and the execution of plans have been debated. Many have agreed upon that design phases are not directly comparable with construction phases and, hence, you cannot use the same management tools (Bølviken et al., 2010; El. Reifi & Emmitt, 2013; Hansen & Olsson, 2011). The Lean Construction approach of using Last Planner as a principle of planning in building design management has been debated, too. Hamzeh et al. (2009) and Rosas (2013) argue for the use of Last planner. Hamzeh et al. (2009) report on the use of Last Planner at the Cathedral Hill Hospital (CHH) project and argue for a fact that "collaborative planning and continuous re-planning were the major constituents of the planning process at CHH during design where the iterations were ubiquitous, the tasks were complex and interdependent, and the constraints need to be removed in time for task execution". Thus, the planning of complex building designs processes is continuous process and it can in some extent be used for planning and executing design work. Hansen and Olsson (2011) argue for a layered process, where the Level of Detail (LOD) in the planning should be adapted to different needs for information in projects. Bølviken et al. (2010) criticise the shortcomings of the Last Planner method used in design. An approach to use LPS in design is the Collaborative Design Management (CDM). CDM looks at planning, teambuilding, coordinating (meeting) and constraints. The case study by Fundli and Drevland (2014) says " ...CDM enables positive changes in the design process compared to more traditional approaches". There has also been some attempts to automate planning processes. Rosas (2013) tries to integrate the Design Structure matrix and Last Planner in building design. Senescu et al. (2014) introduce a Design Process Communication Methodology. Cheng et al. (2013) argue for modelling resource management in building design process.

Interaction among design participants is important. The main purpose in a design phase is the exchange of information and the transformation of information to ideas and solutions to be presented to others. This exchange process is difficult to plan and follow up, and equally difficult to foresee interdependencies that each exchange might have. Azlan-Shah and Cheong-Peng (2013) argue that "coordination needs to be performed by a designer".

The way we communicate is therefore important. Otter and Emmitt (2008) describe the two ways of communicating, i.e. asynchronous and synchronous. Synchronous communication is described as an information flow between two or more directly using hearing, sight and talking (e.g. meetings, telephone etc.). Asynchronous communication is a remote flow of information, which is not directly in time (e.g. emails, drawings, models). The more complex processes are, the higher need is for synchronous communication. Flager et al. (2009) have shown that as much as 58% of the time is spent in managing the information in the design phase. With a more effective information management, some of this time can be reduced and used in more value creating activities.

Synchronous communication is an efficient design tool. This is supported by the approaches of Concurrent Engineering (CE) and Integrated Concurrent Engineering (ICE). The use of extreme collaboration by NASA (Mark, 2001) created a possibility for faster and more high quality design in the building industry (Chachere et al., 2004). When you are trying to manage a reciprocal or incentive process, ICE is a powerful tool. It needs a commitment among key stakeholders in order to make necessary decisions to keep a design process evolving and it works well with adhocracy.

The use of Building Information Model (BIM) in the construction industry is increasing and this is a powerful tool for asynchronous communication but also as a tool to use in synchronous communication as ICE. Moum (2008) has described the use of collaborative design and the participants' reflection of how a BIM could ease the difficulties to understand the complex problems and solutions. The benefits of communication is good (Clemente & Cachadinha, 2013) and possibilities to increase quality by an early clash detection can save much money in projects (Khanzoode et al., 2008).

In order to properly manage a design process, it is important to set up the metrics of processes. Drucker (2008) argues for the importance of measuring work in organisations and he elaborates that you need "controls" (different measurements) in order to get control of a process.

Kristensen (2013) identifies 14 key performance indicators (KPI) that are needed to control design processes. These KPIs are classified as the strategic, tactical and operational metrics. In addition to time-cost-quality, this metrics includes e.g. requests for information, participation and proofing. The need for metrics to improve design processes is also debated (Carvalho et al., 2008; Leong & Tilley, 2008; Succar et al., 2012). Even if it is important to measure the project outcome of time and cost, it is also important to set up metrics controlling the quality of design and the exchange of information. Using metrics to follow up the quality and efficiency, e.g. in ICE sessions, is important in order to improve design process (Knotten & Svalestuen, 2014).

Keeping the value perspective in mind, new ways of managing the earliest stages of the building design process might be considered. A comparison towards innovation and product design gives alternatives to conduct building design development, e.g. the Innovation Diamond (Darsø, 2011) and IDEO (Best, 2006)).

4. Discussion

Planning, coordinating, executing and controlling might be key tools of project management. As presented in this paper, it is not as straightforward for building design management. The understanding of the nature of processes is necessary to manage building design. The nature of processes is complex and consists of many types of interdependencies that need to be addressed differently in design phases. Allowing iterative processes to run as long as necessary can be beneficial to the value of a project, but if they run too long they can have serious implications on a project, concerning time and cost.

Acknowledging the fact how the logics influences the design process is the first step to improve the way we manage the process. The feeling of "chaos " or "ad-hocrazy" can somehow be reduced by planning, using CDM, but also the use of SCRUM can give benefits (Lia et al., 2014). SCRUM is adapted from the Software developers. It consists of small teams working with specifics tasks or problems in order to solve them within a short concrete time limit.

The efforts of Virtual Design and Construction (VDC) and the technics of the Last Planner seem to be the most current approaches to deal with building design management. "The VDC project model emphasises those aspects of the project that can be designed and managed, i.e., a product (typically a building or plant), an organisation to define, design, construct and operate it as well as a process that organisation teams follow" (Kunz & Fischer, 2009). VDC that focuses on using BIM as a tool of communication as well as ICE sessions as a tool to create agreements and solutions are both applicable for design processes with a sequential and reflective logic. Even if there is no consensus that the Last Planner is an adequate tool for planning building design processes, Hamzeh et al. (2009) have showed that the potential of the method in the planning and re-planning of tasks. This together with the measurement of a process and products enables a design manager to follow up the building design phase.

5. Conclusion

Even if there is much more research to be done concerning building design management, the last years have witnessed some new research and efforts in order to improve building design methods. This paper reports on the different interdependencies that occur in the design phase and how to coordinate them. The interdependencies vary throughout the design phase and sometimes the design phase consists of all the four types. It is important for a design manager to be aware of this, so the use of management tools can be managed properly. Even if new building design management approaches can be used for all dependencies, using the same approach to handle both reflective and sequential dependencies might be contra productive. By identifying which processes are sequential (and can be planned in detail) and which processes are reciprocal or intensive (and cannot be planned in detail), a design manager can prioritise and free a focus on the effective process. Hopefully, this paper gives some new insights to design managers and stimulates to further academic research in the field of building design management.

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PUBLICATION 3

Knotten, V., Svalestuen, F., Lædre, O. and Hansen, G.K. 2015. Organizational power in building design management .In: *Proc. 23rd Ann. Conf. of the Int'l. Group for Lean Construction*. Perth, Australia, July 29-31, pp. 763-772, available at www.iglc.net

ORGANIZATIONAL POWER IN BUILDING DESIGN MANAGEMENT

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ABSTRACT

In every new building project, there usually is a new organization assembled that needs to function as a team. The organization will vary through the project. This paper analyses the organizational sources of power in the design phase, using 14 main sources of power in organizations as described by Morgan (2006).

The methodical approach of this paper is a single case study, with interviews of participants in the building design phase who describe their experience with the sources of power in building design.

The aim of this pilot study is to learn more about how the sources of power appear in the building design process. Much has been written about how power works in static organizations but less in the context of building design teams and how this affects the design process. This paper contributes with new empirical research. The key finding is that the sources can be regarded as strength, a challenge or a threat to the design process. This knowledge can be used for the design manager to set up a design process. To enhance the sources that strengthen and to diminish the sources that threaten the process, a more efficient design process can be achieved, increasing value and reducing waste.

KEYWORDS

Design management, organizational power, value, process, last planner

INTRODUCTION

The building design process can be viewed in a simplified way as transforming ideas and thoughts to a practical solution for both the construction team and the client. The organization of the building design team will vary throughout the different stages of the design phase, in order to solve the different challenges in a best way possible, maximizing the value for the client. Value can be regarded as something that improves the project, either at the final product or in a successful process (Eikeland, 2001). Power (organizational) is recognized by some organizational and management

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theorists as an important factor to explain organizational affairs(Morgan, 2006). It is therefore likely to assume that power also has a great impact on the building design process and its management, yet there is done little previous research on the subject. The aim of this pilot study is to learn more about how the sources of power appear in the building design process.

BACKGROUND

Building design

In order to describe the process of building design it is important to start at the beginning. The process usually starts with a client having an idea, a need, a property or a combination(Blyth and Worthington, 2001).

Typically the client will engage an architect in order to help him explore the feasibility or options of his needs. During this process the client and the architect end up with a building program or definition for the project. The design phase is important in order to create value for the project (El. Reifi and Emmitt, 2013; Hansen and Olsson, 2011).

There are different approaches to manage the building design phase. This could be based on lean construction principles as e.g. Last Planner, were the designers plan and re plan their own work (Hamzeh, Ballard and Tommelein, 2009). This is also the basis of CDM (Collaborative design management), and CPD (Collaborative Planning in Design) (Bølviken, Gullbrekken and Nyseth, 2010; Veidekke, 2013; Fundli and Drevland, 2014). The use of VDC (Virtual Design and Construction) is another approach to improve the building design phase (Kunz and Fischer, 2009). With the use of ICE (Integrated Concurrent Engineering) you can reduce latency in the design process by involving the right stakeholders and working on specific issues together (Mark, 2001; McManus, Haggerty and Murman, 2005; Kunz and Fischer, 2009; Choo and Fischer, 2010) .

Typically new buildings are organized as projects. “A project is a temporary endeavour undertaken to create a unique product, service or result”(PMBOK, 2004). Regardless of contract form the most usual way to organize a project is trough agreements on a company level and not on a personal level. The professionals representing their company are then “teamed“ together with the other companies’ representatives. This means that the organization is often new and unfamiliar at each new project. The organization will also vary throughout the project. “Organizations are coalitions and are made up of coalitions, and coalition buildings is an important dimension of almost all organizational life.” (Morgan, 2006)

Organizational power

Killian and Pammer (2003) describes power as “one party´s attempt to impose an outcome on the other party”. Power can be exercised at an individual level or as a group (Killian and Pammer, 2003; Engelstad, 2005). In all organizations the power balance of the stakeholders will influence the work and processes. The design process, as an open, creative process is a difficult process to control for a design manager (Knotten, et al., 2015). Will the power imposed by stakeholders be more or less influential in a design process than in other processes? How will this affect management of the design process? Does it increase the design manager’s power or make him powerless? Powerlessness is if the manager lacks resources, information, and the decision making authority (Ivancevich, Matteson and Konopaske, 2013). Should the power be spread in the team? Empowerment is sharing power and authority with subordinates to increase their confidence and effectiveness (Ivancevich, Matteson and Konopaske, 2013).

There is written much about power in permanent organizations. Even though they address the same issues they seldom define the sources or interactions in exactly the same way (e.g. Daft, 1997; Engelstad, 2005; Morgan, 2006; Ivancevich, Matteson and Konopaske, 2013). This paper does not dwell directly on the different ways to describe power but looks at 14 different sources of power predefined by Morgan (2006). The definition of Morgan (2006) was chosen because of the more explicit definition of the sources makes it easier to compare with the building design context. The 14 sources of Morgan (2006) are listed and explained below;

1. Formal Authority; can consist of different types of authority, such as legitimate authority, charismatic authority, traditional authority or rule of law.
2. Control of scarce resources; means to have control of special competence, products or funding.
3. Use of organizational structure rules, regulations and procedures; is a structure to ensure the right power at the right actor, yet it also can be a source power if played right.
4. Control of the decision process is an important power source. Controlling the decision premises, process, issues and objectives can give someone a big influence.
5. Control of knowledge and information. The ability to gain knowledge and information and control it creates a power situation. Being able to control who gets the information and when, creates a dependency for the rest.
6. Control of boundaries. By creating and controlling boundaries you can control the information going between groups, which enables you to control the information. This can be done trough blocking some information and encourage some.
7. Ability to cope with uncertainty. The ability to cope with uncertainty has always been seen upon as a key managerial characteristic. Morgan (2006) describes uncertainty as an environmental uncertainty and operational uncertainty. The environmental uncertainty is the external influences that affects your organization, and the operational uncertainties are the once that's influences you directly. Ivancevich, Matteson and Konopaske (2013) lists 3 ways of dealing with uncertainty, coping by prevention, coping by information and coping by absorption. Coping by prevention means to reduce the probability of some difficult to happen, coping by information is the ability to use information to forecast what will happen and then be prepared. Coping by absorption is to deal with the uncertainty as it appears.
8. Control of technology. The rapid change of technology and our dependency of it make us both vulnerable and make technology a source of power. Technology influenced work placed in a sequential dependency, makes the whole process vulnerable to the function and operation of the technology

9. Interpersonal alliances, networks and control of informal organizations. Informal alliances and networks can be staged or coincidental. They can be developed in the organization or in spare time. The effect these informal alliances can have on the organization will vary. These informal networks can affect the organizations in different ways, both positively and negatively.
10. Control of counter organizations. Whenever a small group of people manages to build up a concentration of power, it is not uncommon for the opposing forces to organize themselves to rival power. This is typically how the unions were established, trying to establish a counterbalance
11. Symbolism and the management of meaning. An important source of power is how you can persuade the others to follow your lead and intentions.
12. Gender and the management of gender relations. “Many organizations are dominated by gender-related values that bias organizational life in favour of one sex over another” (Morgan, 2006).
13. Structural factors that define the stage of action. Even though you have a personal power trough e.g. legitimate authority the structure of your organization might limit your possibilities to do as you wish.
14. The power one already has. Power is a route to power and can help one to achieve more power either by using the power to manoeuvre yourself right or by others allowing you to lead them.

METHODICAL APPROACH

In order to study the sources of power in building design organizations the research was designed as a case study. The focus of the research was to learn more about how the sources of power appear in the building design process. This argued for a qualitative research approach. Qualitative research is focused to get an in-depth understanding of human behaviour and of the circumstance around (Creswell, 2003). This is best achieved with the perspectives from those who are studied (Crewell, 2003; Alvesson and Sköldberg, 2009).

The research was set up as a single case study, by using semi-structured interviews with participants of building design projects (Creswell, 2003; Yin, 2014). The interviews were audio recorded and transcribed over a period of a month giving the researcher an opportunity to reflect and improve the next session (Kvale and Brinkmann, 2009). The interviews were conducted in two different ways with 5 persons. The first way was to talk about the building design process in general with out mentioning any of the 14 sources and the second way was specifically to ask in reference to the 14 sources. Both approaches gave interesting information, but the latter was easier to code afterwards.

The five persons had different educational and working experience. There were 3 female and 2 male persons. All the Design managers (DM) were currently employed by the same Norwegian constructor, but working at different projects (see table 1). Even though 5 persons is not a large data sample both Flyvbjerg (2006) and Ragin and Becker (1992) argues that also a small number of cases will contribute to new and important learning.

The analysis of the interviews is based by on the six steps of Creswell (2012) as a variant of the constant comparative method as described by Corbin and Strauss

(2008). The coding ended up as a mix of using the 14 sources as codes and other codes that emerged through the analysis. For this paper the analysis is concentrated around the 14 sources of power. The findings were then arranged in a matrix to be able to compare the informants view towards the 14 sources.

Table 1: Case study subjects

Subject	Design Manager	Design Manager	Design Manager	Design Manager	Architect
Work Experience	7 years. As a consultant and constructor	17 years. As house builder, architect, and constructor.	23 years. As consultant and constructor	22 years. As consultant, governmental agencies, and constructor	10 years. As an architect

RESULTS

The key findings are presented in this chapter.

The informants identified the client as the formal authority in projects, acknowledging the legitimate authority. *"What the client wants he gets."* It is important to have a formal authority in order to be clear about who makes different decisions and that the role is executed dynamically throughout the project. The formal authority of the design managers was commented more as "*a source of power to influence the solutions*" than as a formal authority.

The informants emphasized the major scarce resource as time. Short time between contracts and the construction start could put the design period in a squeeze, yet this could also be interpreted as a lack of sufficient resources available. This makes it important to get a design team started as early as possible. Scarce resources in form of low budgets might lead to sub-cultures and sub teams.

The informants emphasize the important of a well functioning team. To be efficient the design organization needs a flat structure and to be transparent. The transparency regards to an open and clear understanding of everyone's responsibilities and tasks in the project. The organizational structures need to be formalized to have well functional teams.

Designing is very much about the decision process and the informants agreed on that fact. To ensure the right decisions at the right time the informants agreed this process needs to be planned and that the results of the decisions informed to the team members. As a design manager said: *"All client decisions were in the plan together with permit applications, and drawing deliveries. By a common run through of the plan every week, everyone was aware of what decisions that had to be made."* It is important for the design team to agree on what decisions can be made by team members and which needs to be addressed in common. The results of the different decisions need to be informed to the whole team.

The design manager needs to have the total knowledge to be able to manage the process, but also the designer need to have knowledge of what the others are doing. As an informant described the work as a junior engineer "*I just got handed a scope of my work (MEP) and a finish date. This was executed with little concern of other trades."* There is also a possibility that you withheld knowledge of new technology in order to reuse old solution in order to save your fee. *" I have the enough experience* *to solve this problem, but with the time and this scope I´d rather present something I´m comfortable with"*

Controlling boundaries and interfaces is a challenge in the design process. One of the design managers allocates responsibilities between the designers by making a matrix with the most common interfaces. *" It is important to balance and acknowledge the different interfaces in the project but also to keep an openness to cross the borders and to learn from each other. If you understand the challenges of the others then you better can solve them. "*

One of the most challenging boundaries is between the design team and the production team. To get the foreman's attention into the drawings process and be a proactive asset, instead of the latter complaining. As one design manager said: *"the production (team) don´t see how much better the design result could have been if they´d only participated a little in the design"*

Even though uncertainty in design cannot be removed all together, the informants agree that planning can reduce it considerably. The planning process needs to be collective. The more involved the team members are in the plan the better the plan is. As a design manager said about collaborative planning: *" It is not the mapping process, but the discussions that are important "*

Being able to use the new technology and tools of e.g. BIM might give you or your organization an advantage in a project. At the same time if your do not know how to use the technology you are obsolete and might miss out on opportunities. Investing in technology cost, but can give some crucial advantages. The aspects of technological challenges in a design process can vary. It can be from design tools as BIM, to process tools as collaborative planning and to actual construction tools as new materials, a new concept of structure etc.

By the informants there is an acceptance that the control of technology must be trusted to be with the different team members, all the time they are specialist. A poor or a low compliance solution with the project needs would result that they were not reengaged in other projects. Yet the informants came back to an open, common team culture so the knowledge and technology is spread.

Informal networks could work both ways. As an informant said *"Knowing people in the business, who to call, who is positive is important. Phoning the right clients representative is crucial to get the first meeting "*

Trying to pin down counter organizations in the design phase was one of the questions that were least coherent. It was recognized that there are a lot of actors in the process who have a sub-agenda of the project´s. This could e.g. be personal agendas, or a goal to make money for your employer on expense of the project.

The informants agreed that symbolism is not at typical sources in the Norwegian AEC industry. As one said, *" I think it is a pretty casual and democratic platform and structure"*

The AEC industry is male dominated but the female informants felt that they were almost never treated different because of their gender. Episodes that had happened were linked when they were newly educated and happened many years ago. Their opinion was that you are much more judged by your knowledge and attitude than by gender. Yet the male informants felt that there was discrimination in the Norwegian AEC industry. As a male design manager said; *"I´m a blue eyed middle-aged guy* *working as a design manager in a construction company. Do you think I´d this job if I were a middle-aged woman from the Middle East? "*

One of the most important structural factors is that the AEC industry is project based and the fact that members of the design team changes for each project. This makes the contracts structures important, but especially also the way clients are organized. E.g. a private real estate developer has a short distance between decisions and money, while most public companies have rigid structures and forms of decision-making. This can lead to a culture of " insecurity" and long decision time.

The power one already has will influence the design process in some degree. If you are the client or the formal leader this will enhance your power. Are you on the other hand an architect or consultant this might result in a poorer process and creation of a counter organization. As one informant had experienced: *"The architect was strong and forcing his solutions on the design team. He was able to do this since the team didn´t know each other well."* This didn´t contribute to the projects goal and wishes and created an extra challenge for the design manager.

DISCUSSION

It is difficult to clearly divide the influence of the power sources in the design phase into Morgan's 14 sources. One power source may have a direct or indirect influence on the other sources and the momentum of the sources varies as well with the stages of the design process.

Through the work with analysing the material, the main focus was how the organizational sources of power appear in the building design process. A natural step was to look at how they influence the design process. Through the analysis we found that the sources of power influenced the process in three major ways. They could contribute to strengthen the process. Several of the sources represented the main challenges in the design process and some also represented a threat to the design process.

There are sources that are important to empower the design manager. We could refer to these sources as strength. These sources need to be addressed and organized so they support the management process. These are typical: Formal authority, the use of organizational structures, symbolism and the management of meaning, structural factors and the power one already have. The informants felt that the structure and roles should be clear to everyone.

There are sources that directly influences the design processes and creates challenges to control. These are control of scarce resources, decisions, boundaries, technology, information, and to cope with uncertainties. From the informants it was emphasized the importance of transparency in the design process to diminish the sources negative effect on the process. By involving every team member in the planning process, by using e.g. Last Planner, CDM, CPD the informants felt that the transparency increased, everyone had agreed on critical decisions points, and the interfaces were discussed in advanced. In newer approaches such as ICE where all important stakeholders are present, the negative power of decisions processes are reduced.

A common opinion by the informants is that time is a scarce resource in the design phase. With parallel design and construction leading to "fast-tracks" initiative the time aspect influences the whole design team. This again influences decisions, knowledge transfer, uncertainty and boundaries.

There are also sources that can work against the management and the design process. These sources create a threat to the design manger and are; interpersonal alliances, counter organizations, gender issues, and powerful individuals. These can create sub-cultures, which are different of the project goals. The informants emphasized the importance of the design team. It is important to get the different members of the design group to function as a team and to establish common cultures, and goals. This is coinciding with the work of Bell and Kozolowski (2002) who emphasizes the team and common project culture in complex projects.

The establishment of the design team with a transparent organization and good communication is also identified as a way to diminish and clarify each team member's source of power. By having a good kick-off session the organization of the projects design team is discussed and presented making the formal roles open to all. By a common collaborative planning session like Last Planner everyone is involved in the process, and have to contribute to the process, reducing uncertainties (Fundli and Drevland, 2014). By including a decision plan in this plan everyone knows of and can influence on what decisions need to be taken and when. The transparency in the project organizations helps to keep everyone updated about what the project is about reducing the information "hub" as a source of power. There has been some efforts in trying to increase the information flow in projects (e.g. (Loría-Arcila and Vanegas, 2005; Thibelsky and Sacks, 2010) These have the focus of e.g. reducing bottle necks, which is a source of power. A bottleneck of information usually occurs when a lot of information has to go through one or a few people. A good tool to share information and knowledge is Integrated Concurrent Engineering (ICE). A strong coherent team will also be less side-tracked by informal or counter organizations.

CONCLUDING REMARKS

This paper describes the sources of power and the influence they can have on the design process. To the design process the sources can be viewed either as a: (See Table 2)

- Strength - where the sources contributes to empower the management
- Challenge –where the sources directly influences the design process
- Threat – where the sources contributes to create powerlessness

By investing time in building a good team and using tools as e.g. Last Planner and VDC you are able reduce the sources of power that can create problems for the design process. By enhancing the sources that empowers the management you strengthen the design process. If you reduce the sources that threaten the process you will 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 organize the design process. By focusing on how the sources of power influences the process a more efficient design process can be achieved increasing value and reducing waste for the project.

We acknowledge that this is a limited case study concerning the topic and that a future next step would be to compare the findings with other management literature.

Table 2: Summarizing the findings.

	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	Increase 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	Reduce 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

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PUBLICATION 4

Design Management – Learning across trades

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Abstract

The Architecture, Engineering and Construction industry (AEC) has a potential to increase its productivity and increase the value of its projects. There is a common apprehension that the overall performance of AEC industry has not evolved at the same pace as the performance of other comparable industries. The increasing complexity of AEC projects that follows the rising focus on energy efficiency and sustainability renders it even more important to reduce the deficiencies in building design. The AEC, shipbuilding, and offshore construction industry 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 interesting. In addition, the offshore construction industry and shipbuilding industry are typically both recognized to have a high level of complexity. As AEC-projects get more complex, this renders knowledge transfer between these industries pertinent. This paper reports on a pilot study, undertaken in order to identify main differences and possible similarities between the trades, specifically questions pertaining to the management of design. The methodological approach chosen consisted of a literature review, a document study, and interviews with key participants from an AEC contractor, a shipbuilder, and an offshore contractor. The interviews were carried out as group sessions with two or more participants at a total of 11 sessions. In this paper we highlight two key processes, planning and coordination, and furthermore, we present the learning potential between the different trades.

Keywords: Design Management, Planning, Coordination

1. Introduction

The AEC (Architecture, Engineering and Construction) industry has a potential to increase its productivity and to increase the value of its projects (Bråthen, 2015; El. Reifi & Emmitt, 2013; Mejlænder-Larsen, 2015). Different authors have criticized the AEC industry for its ability to evolve and increase its performance (El. Reifi & Emmitt, 2013; Hansen & Olsson, 2011; Pasquire et al., 2015; Rios et al., 2015). Industries such as the offshore construction (OC) and shipbuilding (SB) industries have evolved faster than the AEC industry (Grimsmo, 2008). As AEC projects increase in complexity, could the industry learn from other trades who are recognised as tackling such complexity? The OC and SB industry are typically both recognized as being characterised by a high level of complexity (Aslesen & Bertelsen, 2008; Lia et al., 2014). In addition, the AEC, SB, and OC industry 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 interesting.

This paper reports on a pilot study with three Norwegian companies from these industries. The main objective was to find the similarities and differences in order to identify potential improvements for design management in the AEC-industry, while the actual process of learning is beyond the scope of this paper. The research has revealed some specific areas – like planning, coordination and design management – where the potential for learning across the trades is especially high. At the same time it must be acknowledged that the contextual frameworks of the trades vary, making a direct replication challenging. The research was carried out according to the following three research questions:

- What characterize projects in the three different industries?
- What key process characteristics stand out as of particular importance?
- What learning potential lies in these key characteristics for the AEC-industry?

Typically, the AEC-industry is characterized by strong sequential mindset (Kestle & London, 2002). This influences both project and design management(Knotten et al., 2014). The potential value creation depends on reciprocal design processes, which are difficult to plan and manage (Hansen & Olsson, 2011). A potential value creation is well recognized in the theory, but only to a limited degree implemented in the industry. Our findings aim to analyze to what extent this gap can be addressed, using insights and practices from other industries

2. Theoretical Framework

The three different industries (AEC, SB and OC) can all be classified as engineering-to-order firms. This means that the firms in those industries know little to nothing about what specific to produce before the customer delivers a receipt i.e. all production is customer driven. Furthermore, engineering, design and production activities are all part of the customer order lead time (Bertrand & Muntslag, 1993). Although firms in the three industries described in this paper are all engineering-to-order firms, there are some areas those kind of firms usually differs (Bertrand & Muntslag, 1993): the complexity of the products, the degree of customer specificity of the product, the lay-out and complexity of the production process, and the characteristics of the market and competitors

The AEC industry is a fragmented industry, relying on many different actors from the start to finish of the project (Kerosuo, 2015; Zidane et al., 2015). This can cause problems with communication and teamwork within the construction projects. As Dainty, Moore, et al. (2007) describe, large project based organizations can experience communicational challenges between the temporary project and the permanent functional organization. Further, given that a construction project are organized in several phases and consists of several different actors from different organizations, 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 from i.e. refurbishment of a house to multi-billion-hospital project, differencing in both economical size and complexity. The scope also affects the organization of the projects in competence, size and culture (Dainty, Green, et al., 2007).

The OC industry is characterized by outsourcing services, relying on different vendors to do one or more of their activities. This is a strategy used by OC companies to cut costs and focus on their core competencies (Khan et al., 2003). E.g. a company producing housing rigs on an oil platform have their core competencies in producing those houses and might have less experience in IT services. A service necessary to administrate the production of those houses, but not a service that the company can compete with other pure IT company on. Therefore, outsourcing of this service might be a cost reduction for the company, as to the opposite of having an internal IT division. However, later years there has been little proof of cost savings with outsourcing (Olsen, 2006). Furthermore, there is evidence that the industry have started outsourcing high complexity engineering services in addition to services like IT-support (Olsen, 2006).

The SB industry is characterized as an industry with clusters of several different companies working together in alliances to form the whole supply chain (Wickham & Hall, 2006). The industry is competing in a global marked, which has changed the Norwegian industry over last two decades to work more multi-located and dispersed (Kjersem & Emblemsvåg, 2014). The increasing complexity of the vessels task leads to more complex products (Aslesen & Bertelsen, 2008). Kjersem and Emblemsvåg (2014) view the flexibility of the Norwegian industry as a competitive advantage, being able to produce complex vessels adapted to each client's needs. Dugnas and Oterhals (2008) list four key-production phases in SB, hull fabrication, primary outfitting, final outfitting and testing. The hull is typically produced in low-cost countries, whilst the outfitting is done at a Norwegian yard.

The characteristics of these three industries impose differences in the design process and management. Trying to achieve learning across the trades requires a deep understanding of these characteristics and their consequences.

Several theoreticians argue that there is a difference in managing a design project vs. a production project e.g. (Boyle, 2003; Jerrard & Hands, 2008). The design process is more challenging since it is not a purely linear process (Boyle, 2003; Knotten et al., 2014). The importance of design in order to create a successful project are commonly highlighted (e.g. (El. Reifi & Emmitt, 2013)), and the importance of a design management to ensure the value of the project (Hansen & Olsson, 2011).

The design phase is regarded as one of the most challenging parts of a project, and the management of the early design phase in particular. There is the general nature of the process, which varies from a creative reciprocal process to a straight sequential production process (Knotten et al., 2015).

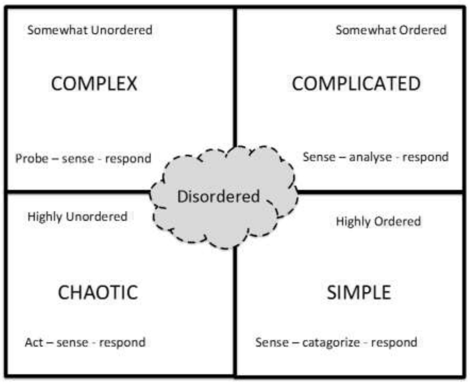

Figure 1: The Cynefyn framework adapted by Walker(2015)

Projects can be looked upon as complex, yet the complexity can be defined in many different ways. A complex system has many typical characteristics such as it involves a large number of non-linear interacting elements, in which a small change can produce large major consequences (Snowden & Boone, 2007). Snowden and Boone (2007) use the Cynefyn framework to describe the context of the situation. The framework describes five different domains, in order for a manager to make de appropriate choices. The domains are simple, complicated, complex, chaotic, and disordered. See Figure 1.

The Cynefyn framework of management is also relevant for understanding complex AEC projects (Klakegg et al., 2010; Walker, 2015). This is especially true regarding design and design management, where the processes themselves are complexly interdependent (Knotten et al., 2014; Knotten et al., 2015)

Kalsaas et al. (2014) argues for Scrum as a tool to work with complex design problems, thus trying to make complex system simpler, short-sighted and to capture critical activities. Scrum is an iterative and incremental project management approach, that delivers result in increments called sprints (usually a 2 – 4 week iterations, however, it's up to the management team to evaluate the needed sprint intervals). A sprint starts out with a planning session and ends up in a review. The planning session is a box meeting where the scrum team is dedicated to develop detailed plans for the sprint. The review meeting is where the scrum team meets the stakeholders and managers to assess and review the state of the business, market and technology. There is also a short daily sprint meeting where scrum team members address the questions: “what did I do yesterday?”, “what will I do today?” and “what impediments are in my way?” (E. Hossain et al., 2009; M. A. Hossain & Chua, 2009).

A major trend within the AEC-industry is to adapt VDC and Lean principles to the design management, but is also using elements from Scrum and Agile thinking. The OC and SB started with elements from Scrum and Agile thinking, but have also adapted Lean Principles.

A challenge of planning in design vs. standard management planning is that the design process consist of both sequential processes and reciprocal processes(Knotten et al., 2014). Typically the creative design process of problem solving as described by Lawson (1997), are viewed as reciprocal. The reciprocal interdependent process are thus difficult to plan since cutting them short they fail to discover the best solution and letting them run indefinite creates a progress problem for the whole project (Knotten et al., 2015). Olsson et al. (2015) suggests the use of agile methods in order to deal with reciprocal activities.

How to implement the new knowledge between the trades is not a part of the paper. It is noteworthy, however, to mention some of the research done in the AEC industry concerned with the question of barriers of learning. Skinnarland and Yndesdal (2014) points out problems with unlearning, organizational structures and norms as barriers of learning. Christensen and Christensen (2010) raise the question of the difficulties of learning because of syntax, semantics and motivation between the trades in AEC projects.

3. Methods

This paper compares characteristics of the AEC-industry with those of the SB- and OC industries respectively, by studying internal documents and interviewing key stakeholders. Primarily, this case study was carried out according to the recommendations of Yin (2014). According to Yin (2014) “a case study is an empirical inquiry that a) investigates a contemporary phenomenon within its real-life context, especially when b) the boundaries between phenomenon and context are not clearly evident. (…) In other words, you would use the case study method because you deliberately wanted to cover contextual conditions”.

The bounding of the case is to understand how different trades execute design and design management. Each of the companies represent a large actor in their trade and have invested in measures for integrated methodology for design management, in order to be a lead actor in their trades. The research has been done by interviews and presentation of their way to conduct business. The sessions are semi-structured interviews letting the informants present and placing follow up questions. There are conducted 11 group interviews, which are transcribes. Along this there is done a literature review concerning design management & engineering management according to the recommendation of Bloomberg et al. (2011).

4. Findings

The study shows that the AEC industry is usually set up with consultants and contractors apart. Few, if not none contractors have their own design crew. The designers and engineers are there procured at each project. A typical constellation would be a sub-contractor responsible for the function of his deliverance, i.e. responsible for the design as well. This means that the project team is new and there actually is an opportunity to gain new experience for the team. This seems not to be exploited; instead, a post-project evaluation is planed in order to learn the key-takeaways of the project.

The architect and consultants are often hired directly by the client at an early stage of the project to make a brief. If the contract is a design-build, the architect and/or the consultant might be transferred to the contractor. This might lead to a conflict of interest between the architect pursuing the goal of a perfect building and the contractors view to only build what is in the brief.

The ship builder (SB) differs in several major aspects. Firstly, is the project a customized or a standardized ship project? The standardized ship is a known design with a few options that can be chosen. Changes from that or completely new designs are viewed upon as a customized ship.

Secondly, if the project is to be built at the builders own yard or at a remote yard in e.g. Asia. Will the whole ship be built off-site or parts for an onsite assembly? This is solved in different ways depending on the complexity of the ship and the timeframe.

Very often, the designers take out a previous design as a starting point when they try to fulfill the client´s requirements of speed, handling and function. The function and the planned whereabouts of the ship is important since this affects critical design solutions as e.g. the power plant, hydro dynamics and the design. A ship operating in artic weather needs a different layout in order to minimalize the icing of the ship. The feasibility of the projects starts with the alignment of hydrodynamic capabilities, engine possibilities and propulsion, deeming these as the most important problems to solve. When this is solved, the design of the hull can finish and production starts. The engineering process is often parallel between design and production, narrowing the options of change as the parts are finished produced. The SB has an own department of engineers to develop the projects. When the project is realized, an engineering department takes over, very often with a complete new team. The transition is often made through a "kick-off" meeting and a common "audit" of the project. The engineering team consists of in-house personal, though they can be multi-located. The multi-located engineers have different cultures and this can be a challenge for the manager of the engineering.

The planning of engineering is based on deliveries to the production, as in drawings. This is monitored by a computerized planning system linking working hours to drawings. This does not monitor the value creating processes.

The offshore construction company (OC) delivers a part of a larger production system, and therefore has a lot of predefined interfaces both in space, weight, and technical requirements. All these are predefined before commencing the work. Even though the company deals with EPC (Engineering-Procurement-Construction) contracts, the company can be viewed as a supplier. The clients of the company are mainly large OC companies with long experience that knows what they need and what they want.

Like the SB, the OC has its own design team. However, the OC has a design team that consists of the same members through the whole design process. When the workload is high, they hire in extra crewmembers to the projects to help offload some of the work from the key members of the design team. Keeping the same design team thru the whole process ensures that the knowledge gathered from early design phase is brought thru the whole design process. To ensure that knowledge from construction is brought into design, key members from construction are brought into early design. However, if the construction members have a lot to do at the production site, they usually do not have time to participate in the design meetings.

Another clear advantage with having all the design trades in-house is the teamwork on each project. When the members know each other, they do not need a lot of team building exercise to get to know each other before the project starts. Further, they all have the same organizational culture. This ensures that they all work to achieve the same goal of the project and the company. The trust between the different design team members is already build before the project starts.

The design process at the OC follows a stage-gate model with clear deliveries at each stage. At the start of the project, key members of the design team collaborate and agree on a matureness level needed to proceed to next stage. The maturity level of each stage can typically be the Level of Detail (LoD) on a model and the placement of those elements in the model. The designers use BIM as a main tool for design. When an area in the model reach the correct maturity level for the given phase that area is frozen in the model. Not allowing the designer to do further changes within that area on the model. E.g., pipe-support needs the numbers and sizes of the pipes to be modeled correctly, when they are finished modeling the pipe support they freeze it and gives it a predefined color, which means that the option to add more pipes or alter the size is of the pipes is not gone.

When the BIM is considered finished and the client approves of the design, detail drawings are drawn in 2D. Designers in low cost countries sometimes handle the detail drawing process, to cut cost and to offload work from the company designer. Although, the design is complete and no new elements are brought in when this process starts, it requires a strict quality control system. Furthermore, it is very important that the decision to move to detail drawing phase is acknowledge by the client and that client understand that a change order after the detail drawing starts will be costly. Figure 2 shows a comparison of the design process in the different trades.

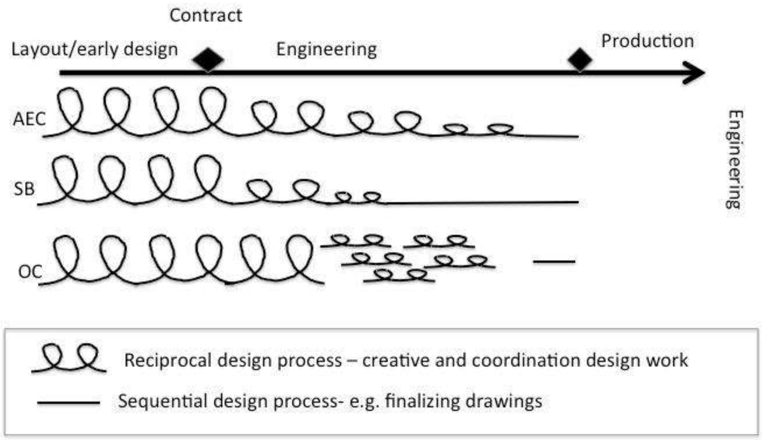

Figure 2: Design process in different trades

Before fabrication, the fabrication-engineering department takes the detailed 2D drawings and makes fabrication drawings. Those drawings are very detailed and focused on the information needed for fabrication. E.g. details of steel bolts and bends needed for the fabrication. The members of the engineering-fabrication department all have long experience from working in fabrication. They understand what is needed and how detailed the drawings and description needs to be.

The complexity of the products, processes and context varies from the different trades. There is a difference between an office building, Platform Supply Vessel (PSV) or an oil derrick. The complexity can differ in technical challenges, interconnections, time frame and other dependencies. Yet some of the tasks are similar. Design or engineering is about transforming the needs of the client and user to a finished product. In table 1 we present some of the key characteristics of the trades.

Table 1: Key characteristics of the trades

	AEC	OFFSHORE	SHIP-BUILDING
Project-based production	Yes	Yes	Yes
Unique products	Yes	Yes	Yes
Use of Sub contractors	Yes	Yes	Yes
Own design team	No	Mostly	Mostly
Common production site	No	Yes	Yes
Prefabriction	Some	Yes	Yes
Contracts	DB	EPC	EPC
Competition	Local	Global	Global
Professional Clients	Mostly	Yes	Yes

5. Discussion

The characteristics of the AEC-, Shipbuilding (SB) - and Offshore Construction (OC) industries are discussed previously in the paper and summarized in Table 1.

Through the results from our studies we ended up with two important key processes where we think the potential of improving is important, notably planning and coordination.

Planning is an important part of design management. The planning processes between the three industries are partly similar. Production methods usually set the framework for the design plan. This is usually carried out by an assumption of what production material (e.g. drawings) needs to be finished at what time in order to have an efficient production. However, using drawing as a measure of design creates some challenges. The drawings are the deliveries from the design process to the production process and just measuring according to that, do not say anything about the quality and value of the product, i.e. the design. Furthermore, the design process is inherently a creative reciprocal process (Knotten et al., 2015), creating challenges in coordination and planning of the design process (see Figure 2). Spending more time designing can increase the value of the product, by a better design. However, the project is time restricted and knowing when the correct point to stop the creative process is difficult. A focus on more than just deliveries of drawings is needed. The SB tried to estimate the workload by experience of making drawings. More drawings make more workload. For the AEC contractor, drawings were more a tool to check of finished work and measuring progress. The OC had a different approach and measuring maturity for the designed products. This meant that there was a focus on getting the product right in the BIM, rather than to just measure produced paper.

The use of coordination tools such as BIM differenced also in the studied cases. In the AEC industry, the use is still on a modest level of detail. The models main purpose is for coordination and visualization of solutions, and as the foundation of drawings. The SB used BIM in the detailed engineering, as at coordination tool. The OC had set a purpose for the use of BIM, and this was linked to stages of the design phase and to the development of the design. At certain level of the design-phase, the model would be at an agreed level of detailing (LoD). When this was coordinated, through model checks, the design was frozen and the elements marked in a particular color, letting everyone understand that these components were at certain stages. Components also evolved during the design phase, from placeholders to detailed models of the real thing.

What learning potential lies in the key characteristics for the different trades? The way OC uses BIM as coordination and planning tool is one of the key characteristics the other trades could learn from.

In planning for the design phase there is a focus on reaching the product, which are drawings for production. By using the amount of drawings, you get a timeframe for the design process. However, the OC focused more on the task and the objects in the model, and using that as milestones in planning the design. This is a planning method that both the AEC and SB can adapt and use. This would be more of a stage gate method(Klakegg et al., 2010), where maturity, objects, decisions, together with production and procurement would dictate the plan. This together with collaborative planning(Bølviken et al., 2010; Fundli & Drevland, 2014) would help to create better plans.

Using BIM in larger extent to coordinate the work would benefit the AEC. Still there is a hang to use drawings for coordination, but by using the model as the OC uses it would reduce the amount of drawings. This together with the plan would help to get a more efficient design phase. The OC uses sprints to address complex engineering issues; the AEC uses a variation of ICE. The use of sprints, by clearly defining objectives, stakeholders and a timeframe is an efficient way to deal with complex problems(Lia et al., 2014).

6. Conclusions

A comparison of the AEC, Shipbuilding (SB) and Offshore construction (OC) industry shows that there are a lot of similarities, but also some differences, as presented in table 1. The main differences are that the SB and OC, have in-house design teams, fixed production sites and are competing on a global 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 they have similar contracts forms. This makes the industries useful to learn across the trades.

In this paper, we highlighted two key processes, the planning and coordination of the design phase. These are equally important to all of the trades. The approach to plan and coordinate the design phase is different from each trade, but they are struggling with some of the same issues.

This pilot study shows that the AEC has learning potential by implementing planning and coordination methods used by the OC. The OC have implemented a new way of planning and executing the engineering, thus exploiting more of the benefits of BIM. 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. See figure 2. The OC has as the other trades a reciprocal design process before contract. After contract all designs processes are somewhat reciprocal, but the OC is divided in smaller concrete task. By using agile approaches such as sprints, OC can work through design challenges efficiently. After the reciprocal coordination work, the finalizing of the drawings is viewed as a sequential process.

In this paper we have compared the industries and identified the learning potential across trades. How the AEC industry should implement the methods of the OC industry is not discussed here Research carried out on learning within the AEC industry identifies, however, several barriers to learning. It would be safe to assume that these same barriers also would apply for learning across the trades.

As this is just a pilot study the next step is to try out the suggested improvements in AEC projects, and report of the findings there.

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PUBLICATION 5

“Next Step”: A New Systematic Approach to Plan and Execute AEC Projects

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Abstract

Planning and control of project execution is the core of project management. One key success factor is an adequate implementation strategy. The Architecture, Engineering and Construction industry (AEC) is portrayed as an industry with serious challenges ahead. Among observed problems that often happen in AEC project are the decisions, which are made in wrong time or at the wrong level of organization, as well as solutions executed in the project without being aligned with corporate strategies. This conceptual paper presents a new systematic approach introduced in Norway to fight the many difficult challenges in the AEC industry. The systematic approach is called “Next Step” and is a framework inspired by the RIBA plan of Work. The new framework presented in this paper identifies the key steps and tasks in a project lifecycle from the definition to the termination of the building. The framework focuses on project execution as well on the critical decisions on a corporate level, involvement of the proper stakeholder perspective, and a sustainable development of the AEC industry. The main purpose is to help the actors of the AEC industry. The intention is not to define a constraining recipe, but to give the industry a common language and collective reference for AEC projects. The framework also highlights important issues in the front end of projects concerning strategic alignment and project planning. This paper also reports on the adaptability of the new framework with different procurement forms. The new framework suggests examining the different phases in this systematic approach through different perspectives: by introducing 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.

Keywords: Project execution framework, perspectives, stage gates, project delivery methods, contracts

1. Introduction

Planning and control of project execution is the core of project management. One key success factor is an adequate implementation strategy. This is specifically true in the architecture, engineering and construction (AEC) industry. Implementation strategies refer to the systematic approach to planning and execution of a specific project within a corporation. Reasons for wanting systematic approaches are obviously the constant need for continuous improvement and learning from past experiences. These are difficult challenges, and given the wide array of different contexts (national-, financial-, industry etc.) and individual strategies of corporations (business models, markets, growth etc.) and technical solutions (elements, products, materials etc.) it is no surprise the approaches vary a lot. Focusing the AEC industry, the specific challenges are often identified as being increasingly fragmented and complex on one side (Pennanen et al., 2010) and reluctant to change and innovate on the other (Dale, 2007). These characteristics combined portray an industry with serious challenges ahead.

To summarize some observed problems that frequently occur in construction projects: strategic decision-making often rely on documents (Business Case, Project Plans etc.) that are incomplete, inconsistent and in some cases simply wrong by purpose or incident (Flyvbjerg et al., 2002). Decisions are not made in time, sometimes made on the wrong level of the organization (Berg, 1999) or by the wrong individuals. This may be indication of unclear roles in connection to the decision-making process, or ineffective organizations. It may also indicate errors and flaws in decision making on individual or group level as pointed out by many authors (e.g. (Kahneman, 2011; Lovallo & Kahneman, 2003; Raiffa et al., 2006). Another recurring problem is solutions planned and executed in projects, without being aligned with corporate strategies. Projects are often viewed as pure execution without responsibility for delivering the right product, the right result for users and owners. This is evident in the traditional definition of a project as a unique task (PMBOK, 2004). It is also well known that construction projects are tormented with errors and mistakes in planning, design and execution, costing unnecessary money and reputation (Love et al., 2003).

In sum all these challenges form a problem-complex that is too much to handle for each individual project owner, project sponsor or project manager. Allowing completely individual implementation strategies to be developed for each single project will not only be costly in terms of making the same development many times, but will also miss out the opportunity to improve and learn. This conceptual paper presents a new systematic approach introduced in Norway to fight the many difficult challenges identified above. The framework is presented in chapter 3. The main issues in this paper are addressed through three axes, each represented in a research question:

- How can the framework help to achieve the right result for owners and users?
- How can the framework help to secure that the right perspectives are considered?
- How can the framework deal with different procurement forms?

2. Theoretical Framework

2.1 Success and stakeholders

In project management literature there are many definitions of success, yet Oxford dictionary of English simply states, "Success is the accomplishment of an aim or purpose" and failure as "lack of success". Samset (2010) states "Projects are initiated to solve problems or satisfy needs". Thus, we can assume that a project success is actually connected to its ability to solve those problems or needs.

The identification of problems and needs and the process of solving them is an important step to be able to define the project, and to define the aim or purposes in order to achieve success. Samset (2010) also argues to look at AEC projects in a larger context than only to solve the immediate problem. He claims that monitoring of a project should be both on tactical and strategic level. The tactical level deal with what most regards 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 looks at indicators as effect, relevance and sustainability. Strategic success is associated with "project success" (Cooke-Davies, 2002).

The AEC industry is a fragmented industry and relies on many different stakeholders to complete a project (Kerosuo, 2015). Each stakeholder have a different perception of the aim 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. By displaying key stakeholders and together aligning their aims, can help to conquer some of the differences (Yang et al., 2009). Keeping the most important stakeholders in mind, it is important to look at the three major groups of stakeholders and their views. Samset (2010) refers to this as perspectives and list them as the owner perspective, the user perspective and the executing perspective.

The owner is the initiating and financing party, the one who normally has a long-term interest in the investment that the project represents. The user is the party who is going to utilize the result of the project for operating their business. The executing party (-parties) is the architects, engineers and contractors who are executing the project on behalf of the owner – the project organization. The owner typically has, or at least should have, interest in the strategically performance of the project, while the executing parties typically limit their interest to the tactical performance (Slevin & Pinto, 1987). Bertelsen and Emmitt (2005) identify the owner, user and society as important groups that a "client" should represent: "These three groups of interest each value different things at different times in the life of the building." Identifying the perspectives early might help to change and understand the focus of the stakeholders.

2.2 Project delivery methods

Project Delivery Method (PDM) - a system for organizing and financing design, construction, operations and maintenance activities that facilitates the delivery of a goods or service (Miller et al., 2000). Choosing different PDM will affect the project cost, schedule, success and influence the efficiency of running the project. This makes it a challenging issue for stakeholders and decision makers (Al Khalil, 2002; Chan et al., 2001; Kumaraswamy & Dissanayaka, 2001). The suitability of the selected PDM can improve the project performance to a great extent (Al Khalil, 2002; Han□Kuk et al., 2008; Kumaraswamy & Dissanayaka, 2001; Oyetunji & Anderson, 2006; Udechukwu et al., 2008).

There are large numbers of different PDMs available in AEC industry to overcome the shortcomings of traditional procurement (Alhazmi & McCaffer, 2000). Numerous authors have categorized the range of procurements forms in the literature. However, in this paper we try a new classification of procurement forms, to make it more practical for alignment with the framework. This classification is inspired by a very recent PMI book (Walker & Lloyd-Walker, 2015).The procurement forms could be fitted in three groups:

Segregated procurement forms: A key feature of procurement forms in this group is a trend to separate design and construction/delivery. Segregated forms include well-known traditional approaches. The dominant segregated form of procurement, which is operating in most countries, is Design Bid Build (DBB). In DBB the owner will receive the bid and award construction contract based on the finished designer's construction document. In this procurement approach, it is assumed that the project design is complete enough to enable a bidding process to establish the cheapest and/or the quickest tender cost. It also assumes that the price of design variations encountered throughout the delivery process will not be excessive (Masterman, 1992; T. Rizk & Fouad, 2007; Sanvido & Konchar, 1998).

The advantage of segregated forms, which is the key cause to select this procurement form in many organizations, theoretically lies with market contestability for the lowest cost (bid) in combination with shortest time. Other example of forms in this group is Cost reimbursement (Cost-Plus).

Integrated procurement forms: Integrated procurement forms are to some extent either physically or contractually integrated design and delivery process. A key character of this collection of procurement forms is that there is a planning and control logic driving the project and a confidence that integration is mainly accomplished through planning and control systems. Some of the procurement forms in this group are: Design and Construct (D&C), Management contracting (MC/CM), Joint venture consortia, and BOOT family procurement approaches (PFI, PPP). The most recognized procurement form in this cluster is Design and Construct (D&C) where one entity is contractually responsible to produce design and perform the construction service, typically called design-builder. It integrates the design and delivery functions either through an integrated firm mechanism, which has an in-house design team, as well as a delivery team or by the delivery organization outsourcing the design to another team that becomes its design services provider (Molenaar & Songer, 1998; Molenaar et al., 1999; T. F. Rizk, Nancy, 2007).

In all integrated procurement forms the main focus is on integrating design and delivery processes by emphasizing on planning and control, however, this does not eradicate the importance of collaboration aspect and the people management but it indicates the weight on systems integration through planning and control.

Collective procurement forms: In this cluster the focus is on integrating the project design and delivery teams rather than the process by highlighting collaboration and coordination. Some might claim that this group of procurement forms could be the most mature forms for best outcome and value for money. Collaborative procurement forms like *Partnering*, *Integrated Project Delivery (IPD)*, *Delivery Consortia/Partner (DC/P), Competitive Dialogue (CD)* and *Alliancing* are fitted in this collection. However, the authors believe that some of the forms in this cluster (partnering, competitive dialog, etc.) are naturally represented as a cultural state or formal/informal contract arrangements rather than procurement choice. They have characteristics, features, and cultural elements that can be applied to other forms.

Collective procurement forms provide a framework for establishing mutual objectives among all parties involved. This normally also lead to developing an agreed dispute resolution system. Collective forms need strong team building skills among participant. Compared to other traditional forms it also needs a different paradigm from highly commercial winner-gets-all and adversarial relation between parties involved. In collective forms, the project owner does not only engage/collaborate with the designers but also collaborate from the very initiate stage of the project with contractors and possibly with significant subcontractors. Collective forms mainly characterized by covering collaboration, transparency, innovation and accountability.

2.3 Phases and decision gates

The governing of projects is a major challenge for project management. With the increased focus on governance over the last decade, phases and decision gates became more in focus and hence have received increasing attention (O.J. Klakegg et al., 2009; Müller, 2009). A fundamental logic in this perspective is that for each step of the development, one should stop and check the status before moving on, that is; one should proceed only if everything is in order. This approach is maybe best summarized in the concept of gateways: a formal control of documents and assumptions before making a decision to accept a project, or to close one phase and enter into the next. The source of this thinking seems to stem back to the term “stage gate” introduced by Cooper (1993). We choose to use the term “decision gate” as a reminder that in a governance perspective, we hold the decision to be the main issue connected with these gates.

The gateway is a key element in an adequate implementation strategy: Seen from an owner’s perspective a decision point (a point for looking forward), whereas seen from the constructor´s perspective it may be a milestone (a point for celebration, following accumulated results), as pointed out by Lereim (2009). The purpose of a decision gate, as seen from a project owner’s perspective, is to make sure the formal decision-making is successful in supporting the success of the organization, business-corporation or public entity. Broadly speaking, this depends on making the right decisions. The logical way of making sure the right decisions may be achieved is to choose the right people to make the decisions, and make sure they have the best possible basis for making the decisions.

Having the best possible basis for making key decisions is a question of extracting the right information. The right information is a question of what is available (known at the time of decision) balanced against the cost of obtaining more/better information and the risk associated with making the decision on less than perfect basis. Decision gates are often characterized by having defined procedures for assessments/control and decision making, defined roles and responsibilities, criteria for acceptance, and a gatekeeper (owner of the gateway process) who decides whether the project is allowed to enter the gateway or not.

The cost of attaining perfect information means it is rational to divide the development in steps and not produce more than needed at each step. Making sure the relevant information is available at the right time and in adequate detail is paramount. Consequently, phases and decision gates are key elements of an information flow framework. Examples from phases given below are meant to illustrate some selected decisive moments in this development:

The first phase is the initial process where the problem or need is acknowledged. This could be due to an owner having a site he wants to realize, or a company looking for other facilities to do their business. This indicates a reason to invest and is often referred to as the business case. Acknowledging that a reason to invest exists is a decisive moment because it drives the decision-making and planning process forward and raises expectations among users.

The next logic step is to view the feasibility of the business case; can it be developed, what are the best alternative concepts, what should the project include. This should now end up in a brief, specifying the contents of a project. Particularly the brief is viewed as a crucial document to achieve a successful project (El. Reifi et al., 2013). The brief is the foundation for a good design and production process. Approving the brief is another decisive moment because this is the point in time where you decide what the users are going to get in the end.

Another key milestone is the handover from the contractors to the owner. This decisive moment represents responsibility shifting from executing party to owner. At this point it is crucial to compare the actual delivery against what was decided in the final brief. For some projects this is when the owners and users for the first time are able to consider to what degree the project fits his or her needs. Traditionally this was where the focus of the project organization ended, but today there is strong focus in the use of the project, looking at how the users of the project succeed in their business and in the management of the facility.

Having a long-term perspective that includes sustainability of the investment is today required, even expected for all parties, despite traditional short-sighted execution perspective. Sustainability has to be considered in in terms of the investment's economical-, social- and environmental consequences. Only when the truth is known about the investment's long-term consequences can its true value be assessed. This makes the decision to terminate, decommission or sell the facility into another decisive moment. This is where the initial intention meets the hard reality of the end and the circle is completed.

3. Result

In January 2015 Bygg21 and The Norwegian Property Federation took an initiative to make a common phase model for the Norwegian AEC industry. The project was undertaken by a research group from the Norwegian University of Technology and Science (Ole Jonny Klakegg et al., 2015). Figure 1 presents an outline of the resulting framework, which was released in December 2015 (www.bygg21.no).

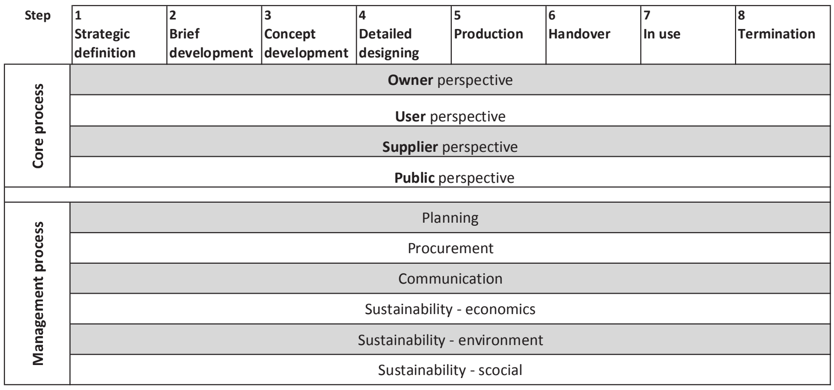

Figure 1: Outline of the framework called "Neste Steg" (Next Step)

The framework “Next Step” is generic and based on a similar set-up as the RIBA Plan of Work (RIBA, 2013). The AEC industry can use the framework with any form of contracts and is open for future development of new PDMs as well. The main purpose is to help the actors of the AEC industry with defining key tasks that need to be fulfilled in the different stages of a project, and to help coordinate their involvement. The intention with this framework is not to define a recipe that needs to be followed to the letter, but to give the industry a common language and collective reference to execute projects.

The different steps of the project are indicated on the top of Figure 1. Each step has a clear purpose and together they all the different phases of a project. In this framework there are 8 steps, including the last important step of termination. Termination can refer to the termination of ownership; i.e. the owner sells the property or the demolishment of the building in order to utilize the site in a different way. The logic of the steps is based on a systems thinking approach with input, process, and output logic, creating decisions gates after each step. The output can be input to the next step or leading to a termination of the project. The process is the actual tasks that need to be completed in order advance the project (Ole Jonny Klakegg et al., 2010).

Inspired by Eikeland (2001) the framework divides the processes into two major categories: Core processes and Management processes. Core processes are main tasks and supporting tasks that develop the professional contents of the project. Management processes are planning, coordination and control tasks that need to be performed professionally to make the core processes work well.

In the core processes, the activities are separated into four different perspectives, allowing the stakeholders to easier identify their major activities and tasks and understand the purpose of the tasks at hand. The fundamental perspectives are described by Samset (2010), consisting of owner- user- and executing perspectives. In addition, the new framework includes a public perspective to put focus on how projects need to work actively with their context. The core processes are described with recommended activities that needs to be addressed, in what perspective they need to be performed, and summarizes necessary start-up conditions (input) and deliveries (output) from each step. The idea is that all parties in the project need to know that these are the main activities and issues to be addressed. The framework does not prescribe who should address each task – it is up to the project management to organize the project. The framework prescribes what perspective, or mindset, each task should be performed in.

The management processes includes several categories of tasks that are of the utmost importance for the project process. Planning, procurement and communication are three vital examples. These processes run continuously over time across all steps, but also include separate tasks for each step. Another category of management processes deals with the sustainability of the projects. To secure a wide perspective all three dimensions of the triple bottom line is explicitly addressed. To secure a long time perspective the 8th step focus termination of the project result (the infrastructure, building etc.). There shall be no excuse for not making sustainability considerations in construction projects.

The planning tasks are linked to making plans for the execution of the tasks, adding details to the plan through each step. Examples of important planning tasks include planning the handover strategies from the contractor to the owner and for the user. The procurement tasks will vary along the steps and have to be adjusted to the execution strategies of the project. A typical question is at what step you procure consultants and contractors: This can vary from step three to step five depending on how early involvement is optimal for the development of the project. Some execution strategies require involvement of all parties on an early stage; other strategies develop a detailed design before procuring the construction companies and suppliers. The framework holds that it is important not only to plan but also to control that the plans are followed. The framework is a powerful tool for project management.

Communication in a project is important and challenging; given that the construction industry tends to be fragmented with many different parties specialized in different areas. The framework explicitly addresses the digitalization of the project process, especially the use of integrated communication tools, such as building information models (BIM) as a communication platform. Developing digital project execution strategies early in the project is important to make sure the parties are all “on the same page”.

Sustainability is necessary for future projects – both in execution and with regards to the result. The AEC industry will not be allowed to continue using energy and producing waste like they used to. The framework differentiates the sustainability in three dimensions: economic, environmental and social. The economic sustainability includes securing the right choices in investment and for the full lifecycle cost of the project result. The environmental sustainability is regarding the use of materials, emission, heating, cooling etc. – both the climate effect and the energy use. The social sustainability is how the project affects the life of the team members, users of the result and people around the project, including ethical dimensions and fairness in distribution of effects.

4. Discussion

Planning and control of project activities is still a challenge in the AEC-industry. As seen in the introduction, this is a serious threat to tactical or project management success (doing it right). However, as argued in the introduction, there is a bigger issue – the strategic or project success (doing the right thing). More systematic planning and execution in every step of the development, from problem to solution to effect to termination, can improve both. Doing this one by one (each company by themselves) will necessarily create non-conformance and miscommunication. It will also require a lot of unnecessary effort in repeatedly inventing the wheel. It will waste time and resources and at the same time create limited results.

Trying to change this situation require major steps. Designing a new framework like described above is only a first step. Whether it is good or bad, suggesting it as a general standard will inevitably spark resistance in a traditional industry. To have effect many actors will have to adapt their systems and management practice to the new framework.

First of all, the time is right. There is a growing attention to the importance of good governance in solving major challenges in the industry, companies and projects. All leading actors in the industry accept sustainability as the standard – at least on paper and in speeches. There is a highly developed understanding that projects are about value creation and that everything that represents wasting time and money or "gold plating" is improper. This is helped by the current slow-down in the economy due to reduced activity in the oil and gas sector. Finally there is a wide range of different new standards being developed for PDMs and information exchange that paves the way for integrated delivery strategies. These strategies obviously need some sort of common framework.

The new framework itself is made as flexible and future oriented as possible. The generic framework is valid for different projects delivery methods (PDM) including future innovations. The framework is scalable in the sense that roles and activities can be adapted to small and big, simple and complex projects. Finally the framework is not a strait jacket that requires everyone to become the same or use the same words. On the contrary, it is designed acknowledging the need for companies to be able to develop their profile and competitive edge. The framework is supposed to be a common reference and "language" that all parties refer to in order to clarify concepts and better coordination. In order to achieve this, the framework should highlight the most important issues in each step, and help to create a platform for timing the right decisions and securing relevant basis for these decisions.

The framework is constructed from well-known principles and international best practice. It has a solid basis. For most actors the changes needed to implement it will be small to moderate. A comparison between the project-models of major companies in the industry reveals that most of the major decision making points are identified in most models(Ole Jonny Klakegg et al., 2015). The level of detail in models varies and the choice of words and graphic presentation is different, but the fundamental structures are remarkably compatible.

Leading organizations in the Norwegian AEC-industry are behind the new framework, including major public clients. The response from the industry has been positive. Other major actors are ready to start using it, and this is the main force that will be able to influence the industry. By January 2016 it is already clear that three different committees in Standards Norway are using Next step as a part of their working basis in developing new standards for the AEC industry. When major clients require it used as a reference, and major executing parties also say they will comply, this has the potential to grow into a strong wave with the force to change a conservative industry. In the long run, the observed improvements will be the best selling points for the model. This of course still remains to be seen.

5. Conclusions

This paper presents a new Norwegian framework for the AEC industry. The framework is not a detailed recipe for project execution, but tries to define the key tasks and steps in a project from the definition to the termination of a building. To sum up we conclude the proposed research questions:

How can the framework help to achieve the right result for owners and users? By defining the decisive moments and the necessary steps on the way from problem to solution until the investment is terminated. By forcing the parties to consider the long-term issues, and assess holistically the relevance and sustainability of alternative concepts, the right choice comes forward and becomes the natural decision.

How can the framework help to secure that the right perspectives are considered? A key feature of this framework is the focus on the key stakeholders and their perspectives. To help the owner make good business decisions, the actors need to think like an owner when they perform their tasks in planning and execution. To create the right solution for the users, the actors need to think like a user and consider how the project can best support the user’s business and facility management. To perform an efficient execution process the actors need to think about project delivery models early and make conscious choices about constructability. To secure that society’s perspective is considered, the model puts emphasis on requirements, approvals and other aspects of context that the project has to work with.

How can the framework deal with different procurement forms? One challenge in delivering a project is at what stage you procure consultants and contractors. The framework helps to deal with this challenge by explicitly state on what stages different procurement strategies has to be considered to be valid alternatives. Collective and integrated procurement forms needs to be considered early – from step three to five – depending on how early involvement of parties is optimal for the development of the project. Segregated procurement forms could be fitted in step five. A typical problem today is that some strategies are constantly considered too late in the process and thus remain unexploited. Other actors choose strategy from tradition and lack of awareness more than a conscious choice. If they are confronted with the new framework there will be no room for such neglect anymore.

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PUBLICATION 6

Knotten, V., Svalestuen, F., Lædre, O., and Hansen, G. (2016.) "Improving Design Management with Mutual Assessment." In*: Proc. 24th Ann. Conf. of the Int'l. Group for Lean Construction,* Boston, MA, USA, sect.4 pp. 173-182. Available at: <www.iglc.net>.

IMPROVING DESIGN MANAGEMENT WITH MUTUAL ASSESSMENT

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ABSTRACT

The Architecture, Engineering and Construction (AEC) industry recognizes the understanding of the design process as a key to successful projects. With the background of Lean Construction efforts such as the Last Planner, Collaborative Planning in Design etc. the planning of the design process has improved significantly. A key part of Lean Construction is to involve the team in the planning and use metrics to check the results. Metrics and measurements in the AEC industry have traditionally focused on the performance of the project and not so much on the interpersonal relations of in the design team itself.

In this paper, we elaborate on how the Mutual Assessment (MA) can help to improve the design process, by aligning the MA with experience and current relevant literature.

Mutual Assessment (MA) is an approach for continuous improvement of the design team in a pre-planned setting. MA was developed by a Scandinavian contractor in order to improve client satisfaction. Through the use of a survey the design team evaluate each other, creating a common understanding of needed improvements. MA gives all major participants a chance to systematically assess the team, and creates room for dialogue and improvement. Improving the design teams helps align design and construction, and thereby to achieve success.

The methodical approach of the research is a single case study, based on studied documents and semi-structured interviews with a large Scandinavian contractor. In addition, a literature review of metrics, design management and teams was carried out. The research is a qualitative study focusing on MA as an important tool for continuous improvement of the design team.

The experiences from the case show that MA is an easy and accessible method to systematically improve the design team thus improving the design management process.

KEYWORDS

Lean construction, continuous improvement, collaboration, mutual assessment

INTRODUCTION

The Architectural Engineering and Construction (AEC) has a potential to increase its productivity and to increase the value of its projects (Bråthen, 2015; El. Reifi &

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Emmitt, 2013; Mejlænder-Larsen, 2015). The industry recognizes the understanding of the design process as a key to successful projects (Aquino & Melhado, 2002). With the background of Lean Construction efforts such as the Last Planner, Collaborative Planning in Design etc. the planning of the design process has improved significantly (Fundli & Drevland, 2014; Hamzeh et al., 2009). A key part of Lean Construction is to involve the team in the planning and use metrics to check the results. Metrics and measurements in the AEC industry have traditionally focused on the performance of the project and not so much on the interpersonal relations of the design team itself.

The design team or the people doing the design are important for the result. Dainty et al. (2007) points out the industry´s ability to improve are limited by how the people are managed. ”Buildings require the combined efforts of many individuals, working and designing collaboratively to provide value to their clients” (Emmitt & Ruikar, 2013). Boyle (2003) states that a key factor for achieving success in AEC projects is directly linked with the personnel involved, i.e. the team.

Mutual Assessment (MA) is an approach for continuous improvement of the design team in a pre-planned setting. MA is an experience-based approach developed by a Scandinavian Contractor in order to increase the client satisfaction in projects. Through the use of a survey the design team evaluate each other, creating a common understanding of what issues that needs to be improved. MA gives all major participants a chance to assess the team in a systematic manor, creating a room for dialogue and improvement. Improving the design teams helps to close the gap of misalignment between design and construction, and helps to achieve success.

The Lean Project Delivery System (LPDS) have implemented a learning loop that runs thru all the phases of a building project, from start to finish and back to start again on a new project. This implicates that there is a need for a planned learning thru the whole lifecycle of a building project. The authors did not find a consistent description of how this is executed, but we believe that MA could contribute to this.

In this paper, we elaborate on how Mutual Assessment (MA) can help to improve the design process, by aligning MA with experience and current relevant literature.

The paper is organized by first presenting a relevant theoretical framework, then in the findings chapter presenting how MA is carried out, and at last a discussion and conclusion chapter linking MA to the theoretical framework.

METHODS

The method of this research has the approach of a qualitative case study. A case study does not need to control behavioural events and the focus is on contemporary events(Yin, 2014). The research consisted of a review of relevant literature linked to the main parts of MA, based on the recommendations of Creswell (2003). The literature is presented in the theoretical framework chapter and its link to MA is presented in the discussion and conclusion chapter. The literature on MA seemed to be quite limited, so the authors selected to expand the scope to also include for example Balanced Scorecard and Lean Project Delivery System. The case studied is from a Scandinavian contractor chosen of their experience with MA. The study consisted of two open–ended interviews and a document study concentrating on internal descriptions of MA.

THEORETICAL FRAMEWORK

Success can be defined in many contexts but Oxford dictionary of English simply states, "Success is the accomplishment of an aim or purpose" and failure as "lack of success". Samset (2010) states "Projects are initiated to solve problems or satisfy needs". Thus we can assume that a project success is actually connected to its ability to solve those problems or needs. From the same definition it is apparent that we need an aim or purpose to be successful, i.e. we need a goal. So how do we know that we have reached our goal? We need a way to assess that the goals are achieved. The next question is of course when do we assess? The time of the assessment is linked to the goal we have set. If a goal is linked to the total time or economy of a project, a post-project evaluation is ok (Samset, 2010). On the other hand if you want to assess goals concerning the process of the project then a interim evaluation is more suitable. The timing of the assessment is closely linked to the learning potential, if you want to change the process then the assessment must be made so its possible to try out the changes. Jerrard and Hands (2008) point 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 consist of quantitative economic measures.

Even though a failure can be explained as the lack of success Meland (2000) points out important failure predictors in the design process of AEC projects. Important predictors were lack of support from the client, but also design manager´s lack of managerial skills, especially regarding communication, goal setting and planning.

The learning potential of the AEC industry has been debated by several authors and also in the Lean community (e.g. (Christensen & Christensen, 2010; Lantelme & Formoso, 2000; Skinnarland & Yndesdal, 2014). Learning barriers has been mentioned as a challenge for change. Skinnarland and Yndesdal (2014) points out problems with unlearning, organizational structures and norms as barriers of learning. Christensen and Christensen (2010) raise the question of the difficulties of learning because of syntax, semantics and motivation between the trades in AEC projects. Addressing these barriers is important to achieve learning and improvement of the industry.

The AEC industry is a fragmented industry relying on many different actors from the start to finish of the project, creating challenges with communication and teamwork within the AEC projects (Kerosuo, 2015). Bølviken (2012) characterizes the industry´s production as a project production of unique products and temporary organizations. "Temporary teams function under constraints off high uncertainty and interdependence during a limited time. The functionality of the teams is dependent on their members' sets of diversely skills and knowledge sets"(Kerosuo, 2015). Emmitt and Ruikar (2013) states "Building design is rarely the product of one persons thinking process; rather it is the result of many different disciplines collective knowledge." The performance of the design team is thus dependent on the group members' skills and knowledge, and their ability to work as a team. Svalestuen et al. (2015) list 12 key elements that influence the performance of a building design team. As table 1 shows, the survey indicates that trust between team members and commitment to the project is the most important element for an effective team. However, a team is not build on trust and commitment alone. The other elements are also important in order to create an efficient building design team. Having a team building exercise is important in the design phase were team members are unfamiliar with each other, and even a short exercise to commit them to the goal is always a good investment. Furthermore, focus on team development throughout the process is important as it takes time to form a team (Svalestuen et al., 2015).

Table 1: Key elements of a good design team (Svalestuen et. al., 2015)

Elements	Average score	Short explanation
Trust between the team members	1.34	Honesty, transparency, consistency and respect
Commitment to the project	1.34	Involving team members in planning
Involvement in the goal setting process	1.56	Commits the members to the goal
Good collaboration between all project leaders	1.56	Increase collaboration in the whole project
Cohesion	1.72	Commitment to the team
Contract models	1.78	Needs to encourage collaboration
Elite feeling	1.88	Create a unique and challenging project
Team building	1.94	Getting to know each other and the project
Former relation between team members	2.03	Speed up the team building process
Identifying the design team members' roles	2.06	Team composition
Focus on team development	2.22	Takes time and effort to form a team
How difficult the goal is to reach	2.66	Effects the elite feeling

Managing the design process is challenging due to the nature of design (Knotten et al., 2015). The design management can be divided in two parts, the management of the process and leading the design. The management is trying to keep the process on time, at budget and with the right quality. The design leader is trying to get the most of knowledge and creativity of the team. The high flow of information, and the need of decisions call for a strong collaborative environment. There have been some efforts to describe ways of collaborative design management (e.g. (Emmitt & Ruikar, 2013; Fundli & Drevland, 2014)). Fundli and Drevland (2014) highlighted the importance of a start-up meeting in the project. A start-up meeting with the project team had positive effect on cooperation, communication and commitment of the team members.

The Balanced Scorecard (BSC) is a common method to align strategic, operational and tactical goals. "The BSC should translate a business units mission strategy into tangible objectives and measures" (Kaplan & Norton, 1996). There are four focus areas in the BSC approach, the financial focus, the customer focus, the internal business processes focus and the learning and growth focus. "The measures are balanced between the outcome measures – the results from past efforts and the measures that drive future performance"(Kaplan & Norton, 1996). The BSC looks at measurements of what has been e.g cost, time, but also at what to come. It also balances between external and internal focus (see Figure 1). The BSC can also be use to set the strategic goals. The focus here is; Clarifying and translating the vision and strategy. Next is communicating and linking these. After that planning and setting the targets, and finally giving strategic feedback and learning.

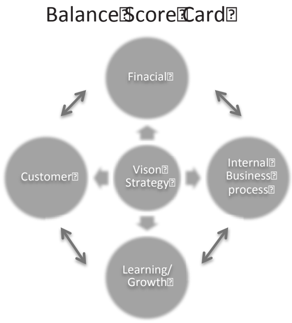

Figure 7: Balanced Score Card

Construction industry has developed a large number of KPI`s (Key performance indicators) and despite the claims about their usefulness they received a fair amount of criticism from many researcher (e.g.(Beatham et al., 2004; El-Mashaleh et al., 2007)). The KPI`s are designed not to give insight into the means of improving performance and therefore have limited use for internal management decision-making (Bassioni et al., 2004). KPI`s are `lagging` measures (Haponava & Al-Jibouri, 2012). They are used for review purposes after a completion of the project and do not provide the opportunity during the project development and execution stages.

FINDINGS

When introducing Mutual Assessment (MA), the contractor primarily aimed to increase the client satisfaction of projects by addressing issues raised by the client (and others) during the project instead of post project evaluations. This works because if the client does not raise any issues during the project, how can the client then raise issues at the end of the project. Hereby, the contractor can avoid client dissatisfaction.

MA consists of two major parts, the planning of MA and the execution of MA. The planning of MA needs a consensus from the team members and the client to use this method. The planning is done collaborative in a start up session. In the planning one needs to agree on the use of metrics, how often to asses, who will evaluate on behalf of who, and of course to agree on the common goals of the project. The start-up session has many agendas to cover, but in regard of MA the most important is to agree on when the team wants to carry out an assessment session, who will answer on behalf of who, and agree and what goals are important for our project. The start-up session has two outputs, an assessment plan and the assessment goals. (See Figure 2)

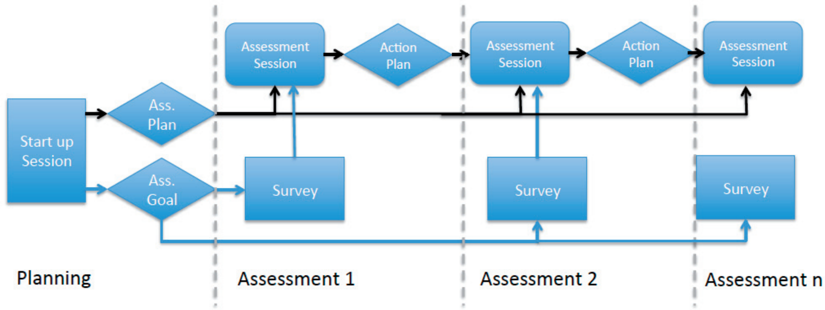

Figure 8: Mutual assessment

The assessment plan consists of two major parts. The first part is to decide who of the team is answering and participating in the survey and the second part is to plan when the assessments should take place. One of the key points of MA is that all of the main parties are to be heard in the assessments. There will of course be a limitation to how many of the involved parties (consultants, suppliers, sub-contractors etc.) should be included, but a rule of thumb here could be to ask yourself how dependent you are of these parties. If a party could be the success or failure of the project, then they should be involved. Together the project should agree on who are the parties to assess each other and who of the projects members should the represent their party. For instance this could mean that the main contractor would point out who of his team would assess the other. The same would apply for the client, architect and the other consultants. A key here is to make a representative voice. For the purpose of not letting the project history cloud the teamwork, it is important that the facilitator of the MA- process have no direct connection to the project. The facilitator leads the start-up session and runs the assessments sessions.

The second part of the assessment plan is to decide when the assessments should take place. Consequently, creating fixed interval between each assessments and assuring that the team members actually reserve time in their busy schedule to improve during the process. This could be a milestone or just fixed intervals in the design phases.

Figure 9 shows an example of a plan for a project. The red lines show the planned assessments sessions. The sessions are placed so the team can benefit from the session and prepare for the next phase. The number of assessment sessions will vary according to what is decided in the assessment plan.

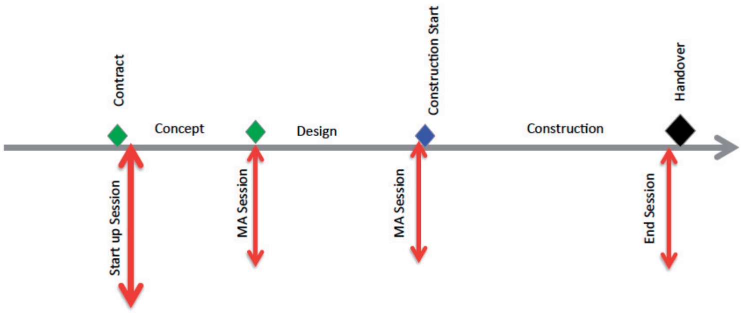

Figure 9: Assessments sessions

The assessment goals are worked out together through the start-up session. The goals are set by the team in collaboration, and are important for this project and this team. The goals will typically be related to cost, time and quality, but also to cooperation, client satisfaction etc. The goals will then be formulated so they can be assessed in a survey. *Figure 10* shows an example of goals from a project, translated into questions. In the survey the questions will be answered as e.g. "how is company N.N. helping to keep the project on plan?"

Questions:

Is the project on plan?
Is the project on cost?
Is the quality as ordererd?
Are flaws and errors taken care of?
Are the responsibilites in the team clear and accepted?
Is the cooperation based on honesty and openness?
Is teh communication open and constructive?
Is the cooperation positive and focused on results?

Figure 10: Example of Survey questions

The second part of MA is the execution of the assessment sessions. The execution should be according to what the team members planned in the start-up session (see figure 2). First, the team members representing the project receive the survey with the pre-agreed questions. The team members will rank the other team members after their ability to fulfil the goals. A low score on several of the survey questions from many team members indicates that there is an issue that deserves attention from the team. Second, the appointed facilitator will go through these surveys and pick the topics that need attention from the team. In the assessment session all the team members should be present, including the client. The facilitator runs through the topics, creating a dialogue for the best way to improve the team. The result of the session is a unified action plan that describes who is responsible for what action and when it should be done.

At the next session the completion of last session's action plan is addressed, and the next MA starts. In the end of the project, the actors arrange an end assessment session that sums up the project.

DISCUSSION AND CONCLUSION

Mutual assessment (MA) is an experienced based approach developed by a Scandinavian contractor in order to improve the client satisfaction with project execution. The contractor works primarily with negotiated contracts and have a yearly turnover of approximately USD 204 million. By increasing the client satisfaction one can assume that the client gets a better product. This is done by focusing on the team and letting the key team members assess each other with interim evaluations throughout the project.

The contractor's experiences from using MA are very good. Since they started using MA, all their projects had a positive financial outcome. They also reported of no conflicts with clients or other cooperating parties.

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. The collaborative setting – ,established through the start-up session, the planning of common goals and execution – makes the grounds for continuous improvement. All this helps to achieve good design teams(Svalestuen et al., 2015). Second, MA addresses the performance and improves the performance through a collaborative dialogue, which can replace KPIs. Third, MA creates an opportunity for learning during the project, instead hoping that something is learned when the project is finished. By agreeing on MA the actors remove an organizational barrier of learning (Skinnarland & Yndesdal, 2014), and by letting all key team members set goals and evaluate them one removes the barriers between the trades (Christensen & Christensen, 2010).

Involving the team participants is important (see table 1), and the team participants get involved when practicing MA. Tillmann et al. (2014) highlights the importance of a collaborative environment when creating a learning team. This together with a collaborative design management (Emmitt & Ruikar, 2013) or collaborative planning in design (Fundli & Drevland, 2014; Veidekke, 2013), the management of the process is helped.

Lantelme and Formoso (2000) state that one of the most cited approaches to measurement is the Balanced Scorecard Method, introduced by Kaplan and Norton (1996). The MA has some similarities with the BSC, by looking at important goals, both hard and tangible goals, and also to look at more soft measurements of team evolvement and cooperation. By using BSC as a frame for goals and measurement it is easier to make this transparent for everyone.

Even though the BSC was developed for corporate structures, BSC could be aligned to AEC projects (See figure 1). Clarifying and translating the vision and strategy for the project should be done by the key stakeholders, representing goals for the project and how this affects the corporates strategies. Communicating and linking is ensuring that all project members are aware of the common goals of the project. Planning and setting target are the goals the project wants to achieve, made tangible so one can assess them. The goals should represent all the four focus areas of finance, customer (time, cost, quality), the working processes of the project and learning processes of the projects members. This should finally be organized in such a way that the feedback from the process could be assessed and aligned with the strategy. The goals of the projects could be e.g. project finance, the client focus, team process, and learning / development. Kaplan and Norton (1996) highlight the important of linking the goals both in the organizations and at the companies CEO level.

MA fills a gap in design management by letting the whole team assess how they work together, thus contributing to a more thorough continuous improvement of the design team. Getting a good team needs collaboration and good assessment. MA is a versatile approach, which can adapt to different project executions and sizes as long as there is a mutual agreement on the need of assessment.

MA is based on the fact that the project participants are truthfully in the survey and in the assessment sessions. There is a need of trust to make MA work. In small projects with a low number of team participants it might be transparent on a personal level who is assessing who, risking to shift the focus away from the continuous improvement process.

MA was primarily set up to increase client satisfaction and the authors see some room of improvements. By structuring the goals of the project through a framework based on BSC one can better align project goals with the team. Because of the fragmented nature of the AEC industry, MA is an important tool of continues improvement of teams, even if a client does not want to be a part of MA.

The involvement, collaboration and the aid of process control makes MA an approach well suited for Lean Construction approaches, and the learning loop of LPDS.

For the contractor MA has proved to work well in the design phase. The authors believe that the approach could work equally well in all the phases of an AEC project, and in fast track projects in particular. Further research would be to test the MA approach in more projects, and also to expand on the number of interviewees. It would also be interesting to map other construction companies' experiences from using MA approach.

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PUBLICATION 9

ITcon

www.itcon.org - Journal of Information Technology in Construction - ISSN 1874-4753

USING BUILDING INFORMATION MODEL (BIM) DEVICES TO IMPROVE INFORMATION FLOW AND COLLABORATION ON CONSTRUCTION SITES

SUBMITTED: February 2017
REVISED: July 2017
PUBLISHED: October 2017 at http://www.itcon.org/2017/11
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SUMMARY: *The AEC (Architectural Engineering and Construction) industry has been successfully using BIMs (Building Information Models) as a tool for improving the design process for some time now. Lately we have seen an increase in use of BIMs in the construction process with BIM devices like BIM stations and tablets. The research presented studied the advantages and challenges with BIM devices on a construction site and used communication theory to explain why these tools are more effective than traditional approaches. A survey with 82 respondents employed by a large Norwegian contractor revealed the most prominent challenges in the interface between design and construction to be both deficiencies and errors in the design. To further investigate these challenges and how BIM can help mitigate these challenges, mixed-method research plan with a case study approach was undertaken. In total, 24 semi-structured interviews with key actors from both the design and construction sides, a study of over 400 different documents from three cases implementing BIM devices, and a survey of craftsmen using BIM devices, with a total of 73 respondents, were carried out. The analyses indicate that reaping the full benefits of BIM devices demands insight in communication theory. The main finding is that BIMs used as a mediating artefact in synchronous communication provide far more effective communication than other types of synchronous communication. BIMs as a documentation option in the construction process are superior to all other media because it has a higher bandwidth and is self-documenting at the same time. Any new system or tool that is implemented will require some sort of training, and this study shows how proper training of all the involved practitioners will be necessary when implementing a BIM device. This study can help practitioners to focus on the right strategy when implementing BIMs and the use of BIM devices in AEC projects.*

KEYWORDS: *Tablets on site, BIM-stations, BIM on site, Design Management, Communication*

REFERENCE: *Fredrik Svalestuen, Vegard Knotten, Ola Lædre, Frode Drevland, Jardar Lohne (2017). Using building information model (BIM) devices to improve information flow and collaboration on construction sites. Journal of Information Technology in Construction (ITcon), Vol. 22, pg. 204-219, http://www.itcon.org/2017/11*

1. INTRODUCTION

Over the last decade, studying the procedural and human aspects of realising projects within the Norwegian Architectural Engineering and Construction (AEC) industry has gained increased interest. This includes exploration of Building Information Models (BIMs) and other Information and Communications Technology (ICT) tools for enhancing on-site communication.

Even if BIMs and other ICT tools typically have been seen as most pertinent to the design phase, the technology equally represents a great potential during the construction phase. Over the last decade, BIMs have in fact gone from being a design tool to being an important part of the production process. Technological solutions such as so-called BIM stations render BIMs available for everyone, including all the workers onsite (Murvold et al., 2016).

A current trend in construction is that projects are getting more complex and require ever more detailed drawings. Van Berlo and Natrop (2015) question if the information presented by the drawings really constitutes all of the information needed on the construction site. They even claim that most drawings are not specific enough for specialised tasks. With BIMs, much more information is available than with traditional paper drawings. To develop the use of BIMs in the construction phase further – that is, to provide information with a quality high enough to enable such specialised tasks – it consequently seems desirable to move BIMs from the design office to the construction site, where the physical work is actually carried out; this introduction of BIMs to the workplace makes information available when and wherever it is needed (Van Berlo and Natrop, 2015).

BIMs, today, are mostly used inside the construction office. In this paper, we examine pathways to bringing them out to the construction site.

Norwegian AEC industry actors now commonly use ICT tools, such as project intranets and BIMs. Project intranets provide all team members immediate access to project information, thus speeding up information flows. Videoconferences make communication with other participants easier, even over long distances. Yet, the use of these tools can create problems; in some cases, they even reduce the overall comprehension of the project if not implemented adequately (Harstad et al., 2015). For example, when all participants have access to all information at any time, it is hard to control who receives what and when. In the worst cases reported, this resulted in actors making their own 'image' of the project, which sometimes was not in line with overall project objectives. In general, the potential of such tools does not seem to be used to its full degree.

It is in fact essential to acknowledge that in contemporary construction projects, actors interact in an environment in which different barriers combine to prevent straightforward production of the physical artefact. On the basis of this insight, one general lesson stemming from experiences within the Norwegian context is that it seems important to proceed with informed attention when adopting new methods and technologies. This proves particularly true if the advantages that these entail for the project team are not immediately clear. As can be learnt from Norwegian industry, an uncritical implementation of such tools can, in the worst cases, reduce the overall performance of project teams.

Internationally, the implementation of BIMs on worksites through specific methodologies have been examined by several authors, e.g. Sacks et al. (2013), Ruwanpura et al. (2012). The ambition of this paper is to explore what we consider usages of ICT solutions that are in the forefront of AEC practice within the Norwegian context today, from a communication perspective. More specifically, we examine the use of so-called BIM stations and tablets onsite with the ambition of improving the two-way communication between design and construction.

To address this general concern, we in this paper address the following research questions:

- How can BIM enhance communication between design and construction practitioners?
- What are the advantages and challenges of using BIM to communicate between design and construction practitioners on site?
- What practical measures can lead to BIM enhancing communication between design and construction practitioners?

The first question will be addressed in the theoretical framework section. The second question is presented in the findings section and is mainly empirical based. The last question will be addressed in the discussion section.

2. THEORETICAL FRAMEWORK

In the following, we describe why it is important to study further the information flow between design and construction, and how BIM devices like tablets and BIM stations can help improve information flow.

2.1 Information flow at the construction site

A study carried out by Tenah (1986) shows that a manager or supervisor cannot perform his or her functions efficiently without accurate, timely and relevant information on which to base decisions. The flow of information significantly affects all other resource flows, and is therefore important to manage (Dave et al., 2010; Sacks et al., 2010). The control of information is viewed as a source of power and therefore poses a challenge to management processes (Knotten et al., 2015b)

Waste in construction includes delays, quality costs, rework, unnecessary transportation trips, long distances, improper choice of management, methods or equipment, and poor constructability (Koskela, 1992; Alarcon, 1997). Studies show that waste often occurs due to poor information management. The research of Love and Li (2000) demonstrates that during construction, rework often arises out of incomplete and incorrect information. Their work indicates that rework results in inactivity and inefficiency in several activities at the construction site.

To solve site problems, production management personnel typically have to run back and forth between the construction site and their computers at the site office. According to Lofgren (2007), documentation of building activities, production meetings and various inspections often have to be carried out twice; once when they are actually occurring and then once again in a computer document. This leads to inefficient use of managerial resources due to unnecessary transportation and a production management team that is occupied with their computers for a large part of their working hours. Samuelson (2003) claims that the fact that information needs and communication behaviours at construction sites are not adequately met explains the low productivity figures in the construction industry.

According to Lofgren (2007), the quantity of information that is passed to the construction site can be overwhelming, and it often generates a poor quality of information in the field. As a result, construction personnel are forced to deal with slow problem solving and construction rework.

2.2 Richness and effectiveness of communication

The notion that communication can have different degrees of richness is based on how much understanding different types of communicated information provide. Daft and Lengel (1983) explain that rich information provides substantial new understanding; information with low richness, on the other hand, provides little new understanding. Furthermore, the different types of channel/media used for communication will have a direct effect on its richness. Lengel and Daft (1989) acknowledge that communication media differ in their capacity to convey information; they consider that the more information that can be ‘pumped through a media, the richer the media is. Furthermore, they define three important characteristics for a rich communication medium, notably 1) the ability to handle multiple information cues simultaneously, 2) the ability to facilitate rapid feedback and 3) the ability to establish a personal focus. Based on an analysis of the different types of media usually available to a manager, Lengel and Daft (1989) classified the different types hierarchically on a ‘richness scale’, shown in Figure 1.

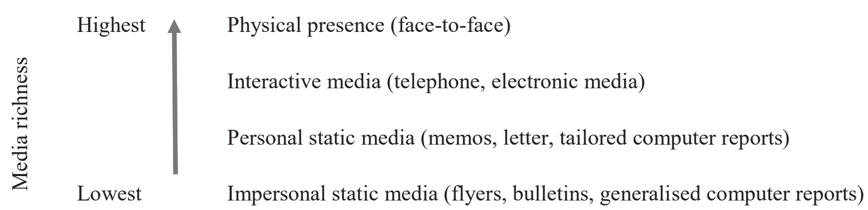

Figure 1: Different types of media and their richness (Lengel and Daft, 1989).

Lengel and Daft (1989) also examined the different types of communication that take place in an organisation and categorised them into routine and non-routine communication. The routine communications within this categorisation typically include straightforward day-to-day messages, with an established common frame of reference and with high degree of objectivity (e.g. a work order from management). The non-routine communications on the other hand typically concern communication novelties, which are events with no common framework between sender and receiver. Feelings and subjective beliefs may influence the non-routine communication. For such reasons, a communication media with higher richness is therefore preferred in such circumstances.

Table 1 shows the different types of communication media Reinertsen (1997) studied (which he called systems), and what types of attributes they were characterised by.

Table 1: Different type of communication media and their attributes (Reinertsen, 1997).

System	Real time	Self -documenting	Leveraged	High bandwidth
Meetings	X			X
Telephone	X			
Voice Mail		X	X	
E-mail		X	X	
Paper Documents		X	X	
Web sites		X	X	
Video tapes		X	X	X
Video conference	X			X
Chance Encounters	X			X

Real-time are communication media that can send and receive information in real time. *Self-documenting* are communication media that can store the sent information without requiring a second source for storage (e.g. information from a face-to-face meeting could be stored with a recording device). *Leverage* is the relative time spent by sender to encode the information vs. the receivers to decode the information (e.g. it takes just seconds to send an e-mail with a link to a 100-page document, which of course takes longer time to read). *Bandwidth* refers to how much information the communication media can convey at a given time (e.g., a face-to-face meeting can communicate both facial expression, vocal tone and the message at the same time, furthermore the receiver can ask questions in real-time. This is opposed to communication based on paper documents, which take a long time to read and reply to).

Cockburn (2006) made a visual presentation of different communication media and how they relate to richness and effectiveness. As shown in Figure 2, the richer the communication media, the more effective it is.

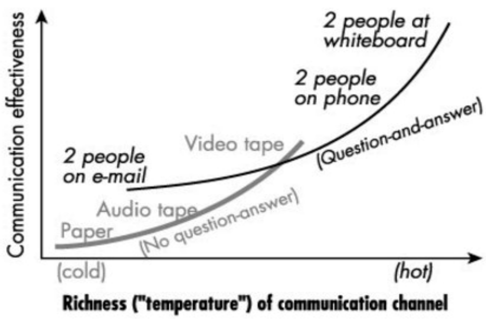

Figure 2: Illustration of richness and effectiveness of different communication channels (from Cockburn, 2002; 2006).

Cockburn (2006) also divided the different media into two categories, “question-and-answer” and “no question-answer”, based on the media’s capability to handle direct two-way communication. The question-and-answer category consists of all two-way, real-time media. An exception from this is the use of e-mails, which is clearly capable of a two-way communication but lacking the real-time attribute that Reinertsen (1997) identified. The no question-answer category consists of all media that do not allow the receiver to answer the sender without using another of the same or other type of media.

Ambler (2002) and added some new media to Cockburn’s figure, such as face-to-face without whiteboard and video conversation (Figure 3).

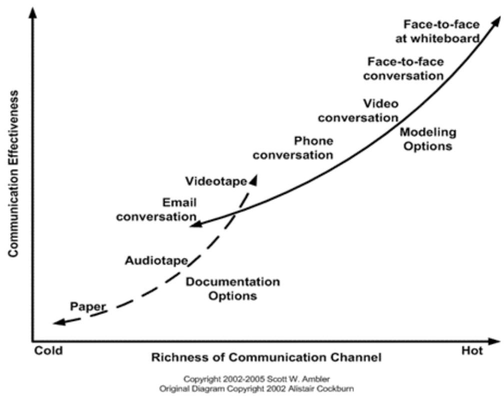

Figure 3: Illustration of richness and effectiveness of different communication channels (from Ambler, 2002; after Cockburn, 2006)

Ambler (2002) has not significantly modified the Cockburn (2006) model, other than add some new communication media and rename the categorisation of different communication media. The new categories *modelling options* and *documentation options* seem to be the same as those used by Cockburn (2006), without giving any explanation other than it seems to better fit the theme of his book.

Otter and Emmitt (2008) describe two ways of communicating, asynchronous and synchronous. Synchronous communication is described as information flow between two or more persons directly, using hearing, sight and speech (e.g. meetings, telephone etc.) Asynchronous communication is a remote flow of information, which is not directly in time (e.g. emails, drawings, models). The more complex the processes, the higher the need for synchronous communication (Bell and Kozolowski, 2002; Knotten et al., 2015a). Emmitt (2009) states that it is vital for a building design team to use synchronous communication when the team task complexity is high.

Communication can typically be divided into three categories, verbal, non-verbal and symbolic (Granér, 2003). Verbal communication is spoken or written words. Written words do not contain any more meaning than the literal one. Oral communications on the other hand, can have different emotional value to the receiver, as it allows the sender to use feeling in the spoken words (e.g. screaming a message will have a different meaning than whispering it). Non-verbal communication includes using body language and gestures, which can further help enhance the communication. Symbolic communication is the use of different objects like drawings and models, and even the clothes you wear to a meeting will have a symbolic meaning (Granér, 2003).

Communication media that can transmit information that is verbal, non-verbal and symbolic will always be richer and more effective. For instance, a phone call can transmit just verbal communications, but a videoconference where the sender and receiver can see each other can transmit both verbally and non-verbally. Using a whiteboard in the conversation as well can further enhance communication and work as a common ground for the sender and receiver. Koskela et al. (2016) define such tools to be *mediating artefacts* that, among other things, allow for exploration of sematic differences and help the joint transformation of knowledge between actors from different practices (architects, structural engineers, project managers etc.). In fact, the cognitive process may involve distributed cognition states, where a cognitive process can be shared among members of a group, and external processes like materials or the environment. Furthermore, the process may be distributed through time, allowing previous experience to transform later events (Hollan et al., 2000). This means that a group of people using a mediating artefact will be able to share the cognitive process across the group members. Busby (2001) studied errors and distributed cognitions in design work, and found that the design team could benefit from thinking of their task in terms of distributed cognition.

3. THE USE OF BIM ON SITE

Over the last years, different methods have been developed to bring BIMs to the workers on site, enabling access to the model wherever they are. With BIMs on site, it is possible to find and solve problems early. This is a relatively new approach to on-site production control for contractors. Van Berlo and Natrop (2015) state that paper drawings typically dominate information in the workplace. Furthermore, they claim that BIMs on site can realise a great potential during the construction phase and that construction workers get the benefit of visualising when communicating using a BIM on site. The different tools that are being used can be divided into three categories. 1) Computer terminals on site (hereafter called BIM stations), 2) mobile devices such as tablets and 3) specialised environments (e.g., BIM caves).

Hewage and Ruwanpura (2006) found that there was a need for a mobile, real-time information source on site. Workers wanted an opportunity to view 3D and 4D (3D with timeline) drawings, technical information, safety information, weather updates, and other information related to the project. Following this research, Ruwanpura et al. (2012) developed an information booth to give workers onsite access to material management, work demonstrations and updated drawings. This led to positive results in productivity, efficiency and worker satisfaction.

Davies and Harty (2013) found that there was only limited research on how BIM has been used on site. They studied the implementation process of “Site-BIM” in a case study of a large hospital project in the UK. Mobile tablets were used to access the project’s BIMs. Tablets onsite combined with in-house document management systems resulted in positive effects, like waste reduction and a lower than usual cost growth for service installations. Harstad et al. (2015) have also documented positive effects from their research on tablets on the construction site. Based on research carried out, we can maintain that tablets provide easy access to information, are easy to carry around, and can increase the understanding of the project while creating a new line of communication.

The contractor Skanska developed a prototype in 2014 of what they called a “BIM computer kiosk” (Bråthen and Moum, 2015). They placed a computer connected to a 50-inch TV-screen on each floor of the building site. These computer kiosks allowed workers to access the 3D-model on site. The equipment was placed inside a protective wooden cabinet with an internet connection (Bråthen and Moum, 2015). The BIM kiosks were widely used on the project and resulted in better productivity, especially for MEP (Mechanical, Electrical and Plumbing) workers. Vestermo et al. (2016) showed that a device like a BIM-station could help reduce the volume of non–value-adding activities on a project and that the use of BIM-stations in a production phase could enhance lean outcomes.

Van Berlo and Natrop (2015) analysed a concept using BIMs to generate drawings adapted to the task of workers onsite. The idea behind this was to “[...] provide site workers with all the information they need for the task, but nothing more”. They found that this approach created a very good communication tool between the site office management and construction workers. According to Chen and Kamara (2008), the most effective way for workers to acquire information onsite is to collect or capture information at the point where they are, when they need it.

Sacks et al. (2013) have developed a system for workflow control on site, called KanBIM™. The system visualises the workflow of both process- and product information on a ‘live’ BIM to the workers on site. A field test of the system revealed two desired results: 1) a reduction of time spent ‘looking for work’ and 2) the system could potentially enable site superintendents to double the scope of work they could supervise.

BIMs can result in a leaner construction process with a greater degree of utilisation of prefabrication, improved workflow stability, reduced inventories and enhanced teamwork (Alarcon et al., 2013). When BIMs are implemented in the design phase, there could be some challenges to carry it forward to the construction phase. Some of the most common barriers are: software and hardware issues, cultural barriers, contractual and legal aspects, lack of commitment, lack of training and lack of a client request for it (Alarcon et al., 2013). Compared to the positive aspects of implementing BIMs in the construction phase, however, the challenges must be said to be of a relatively limited nature.

4. METHODOLOGY

The research questions addressed in this paper cover a wide spectrum of interrogation. This approach has been chosen to include as large a variety of elements in the analysis as possible, through triangulation of different research methodologies. In order to respond to challenges possibly entailing from this methodological approach, data collection has been done according to the recommendations of Creswell (2009) about using mixed-methods approaches. The different approaches used are explained in the following.

The starting point for this study was a literature study, following the five basic steps described by Blumberg et al. (2011). Relevant literature was identified and collected. Then this literature was reviewed and analysed. After synthesising the literature, the theoretical framework presented in this paper was developed.

Next, a survey was sent to 602 potential respondents working for the largest contractor in Norway in order to map the challenges between design and construction and their general experiences with BIM devices such as tablets and BIM-kiosks on construction sites. Out of these, 82 answered the survey. The results are reported in Section 5.1.

In order to find out how tablets influence communication – that is, what advantages and disadvantages follow their use, and what measures can lead to tablets enhancing communication – nine semi-structured interviews with both design and construction personnel were conducted. The respondents were mainly project managers and foremen from contractors and design consultants working close to construction sites. One representative from an application developer was interviewed in order to reveal aspects of interest related to using tablets to communicate BIMs. The nine initial interviews were followed by interviews with five persons holding key positions in some of the largest contractor firms in Norway. These five contractors have adopted, to a varying degree, tablets in their projects. All fourteen respondents answered on a general basis, i.e. they didn't use case-specific experiences. A general study of documents from different, randomly selected projects where tablets were used to communicate the BIMs supplemented the findings from the interviews.

In order to find out how BIM stations influence communication, three different cases were then selected in order to collect experiences from practitioners. These cases were selected based on criteria suggested by Yin (2013). Attention was paid to find out how BIM stations influence communication, that is, identifying what disadvantages follow their use and what measures lead to them enhancing communication. Ten case-specific interviews with contractor representatives – seven BIM specialists and three project managers – were carried out. A study of more than 400 different documents from the three cases was carried out in order to supplement the case-specific interviews, following the general prescriptions of Krippendorf (2013). A second survey asking about the specific experiences from each of the three cases was carried out with 48, 15 and 10 respondents, respectively. The purpose of the case-specific survey was to map the use of the BIM stations in addition to user attitudes and behaviour. The questions were both multiple choice and open-ended questions. Multiple choice responses gave the ability to compare the answers and obtain a statistical representation. These results are reported in Section 5.2.

Both the general and the case-specific interviews were based on interview guides structured after this paper's three research questions. The respondents answered – almost word-for-word (small adaptions were made) – the same questions. The document study followed the guidelines proposed by Krippendorf (2013). The surveys, both the general and the case-specific ones, were inspired by the informative how-to-do description proposed by Fink (2013).

5. FINDINGS

The findings chapter is divided into two parts. The first part, Section 5.1, presents findings from the general survey undertaken of employees of a large Norwegian contractor. The survey presents the AEC professional view of the industry's major challenges. The second part, presented in Section 5.2, is based on a case-study approach, using interviews, study of documents and case-specific surveys. The case studies present the advantages and challenges with using BIM devices in construction projects, mainly from a practitioner perspective.

5.1 Challenges between design and construction

Figure 4 shows the general challenges found in the interface between design and construction. Major findings here are a lack of design in a particular area and errors in design, collisions between the different trades, delayed drawings and poor communication.

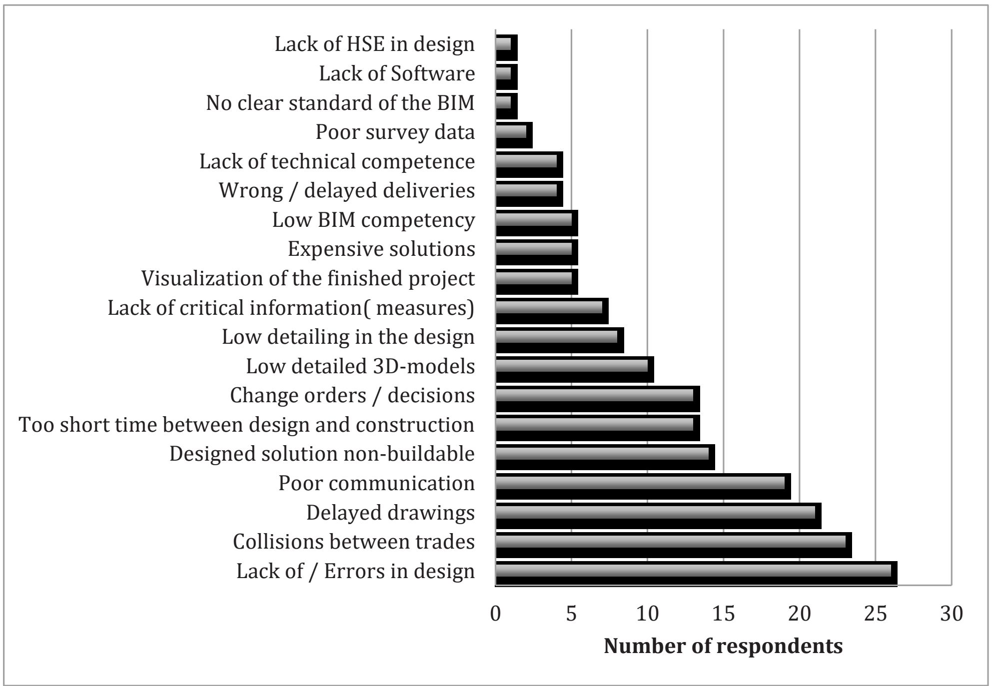

Figure 4: general challenges found in the interface between design and construction.

The survey also posted a question of which challenges the use of BIMs on construction projects can help solve. All respondent agreed that the use of BIMs could mitigate some of the challenges between design and construction. The main answers were:

- Fewer change orders and faster decisions
- Details of the project more visible and increases client knowledge of the final product
- Collision between trades can be mitigated by using collision control tools in BIM viewers like Solibri.
- A model can easier show the proposed solutions and simulate the construction process to increase knowledge of constructability.
- Better coordination among trades.
- Better control of quantities, can reduce the time spent on quantity take off in the construction process.
- The use of BIMs forces the design ahead and deficiencies are more obvious.
- A good tool to assess constructability of the designed solutions before drawings arrive at the construction site.

5.2 Experiences with the use of BIM devices on the construction site

The BIM devices discussed here are BIM stations and BIM tablets. BIM stations are computers with large screens made available for the workers at site. The BIM station, as its name implicates, includes software for using BIM.

However, there could be several other functions linked to the BIM station as well, such as progress plans, information from management, QA systems etc.

Tablets are small mobile personal computers with a touch screen, including software for using BIMs, CAD and other Project manager tools. Primarily a tablet is used by people with typical control responsibilities, like project managers, construction managers, superintendents and foremen. Design consultants and client representatives also use them. Most of the respondents primarily use tablets as a tool to obtain information in design meetings, site meetings and out in the field. However, there are a number of other applications related to the use of tablets.

First, we present the advantages of a BIM devices. Second, we present some challenges and improvements to increase the benefit of BIM devices. The findings presented here are based on the cases studied.

5.2.1 Advantages with BIM devices

It is not only the use of BIMs that contribute to more effective construction projects. Equally important is the fact that it is a tool with continuously updated production descriptions (drawings, models, descriptions, plans etc.) onsite. Furthermore, the tool can contribute to increased collaboration between the different trades. As shown in

Table 2, there are some advantages that are common for both BIM stations and tablets; advantages that are more specific either to BIM stations or tablets are shown at the bottom of the table.

Table 2: Advantages with BIM devices as reported by the interviewees and identified through the case-specific survey.

Advantages of BIM devices	
Common	
• Helps the workers get a better understanding of the project through the 3D visualisation • Helps to provide updated production information (drawings, specifications BIMs, progress plans) at the site at all times • Can provide quantitative take-off on-site for the workers • Can provide tools for the reporting of task completion, quality control and errors to the designers. • Obtaining direct measurements from the blueprints and BIMs onsite. • Live communication through video chat between site and office • Reduce the risk of errors due to old drawings • Less printing and distributing drawings	
BIM Stations	**Tablets**
• Provide a meeting place and the BIM is a great communication enhancer	• Access to BIM and drawings (Pdf/dwg) everywhere • Operation and maintenance management

The primary function of the BIM station is to present an updated version of the BIMs to the workers onsite. The BIMs give the workers a better understanding of the project, sequence of trades, details etc. The BIM station creates an artefact for better communication between the trades on site.

As for the positive effects of BIM stations on the project, opinions were divided in the first survey. Some of the carpenters considered the BIM stations an unnecessary cost, with no positive effects whatsoever. However, this was not the general opinion. A large percentage of workers experienced saving time with BIM-stations. They reported higher productivity due to having the necessary information available at all times. The overall impression from both the survey and interviews is unanimity that the MEP workers had the greatest benefit of the BIM-stations. This is also reflected in the answers for the last question the workers were asked: we wanted to know if

BIM stations were something the workers would like to have access to on their next projects. A total of 96% of the MEP workers wanted this, while only 50% of the carpenters did.

A reason as to why some of the carpenters thought that the BIM station was an unnecessary cost for the project was that the information they could get from the BIMs was too vague. The model lacked information they needed to do their work, e.g. measurements of the door openings relative to the axis system of the building. Consequently, the carpenters had to check the drawings to get that kind of information. The superintendent on one of the projects did also comment that a lack of excitement about the BIMs among some of the carpenters could be because they lacked the proper tutoring and training in the use of the BIM station.

As shown in

Table 2, one specific advantage of having a BIM station is that it provides a good arena for meeting on the construction site. All the interviewed workers had an impression that it gave them more insight into the weekly production plan and how their work was related to others. The BIM model was a great tool for showing the workflow of different areas in the building and how the work of different crews were interrelated. Furthermore, the crew leaders felt that members of their work team was more involved in the planning when they had a meeting around the BIM station as opposed to the normal meeting without the BIM station.

Tablets provide easy access to up-to-date PDF/DWG drawings and BIMs at meetings, in the office and out on the construction site. This reduces the risk of errors and rework due to old drawings. As one of the interviewed superintendents said: ‘we spend less time on controlling that drawings on site are up to date since tablets and BIM-stations provide workers with an up-to-date drawing’.

Less time is consumed obtaining necessary information like heights and measurements in the field through drawings and BIMs on the tablet, instead of walking back to the site office and searching through stacks of paper to find the required information. Tablets also provide access to information about the progression of tasks and distribution of responsibilities. Much time is spent on delegating, follow up and ensuring that things have been done. Through tablets, the workers at the site can receive personal tasks and responsibilities, which they mark as finished when the task is done. This is an easy way to keep track of progress and reduce time spent on monitoring tasks and responsibilities. Furthermore, using tablets for quality control in the handover phase gives the client a better way to point out where the quality is not up to the given standards. With the tablet, he can just take a picture of it and link it up to the model with a short description of errors. This makes it easier for the workers to find the specific quality error and correct it. When it is corrected the workers can use the tablet to take a picture of the corrected error and check it off on the tablet as completed.

5.2.2 Challenges of using BIM devices

Even though the BIM devices had a lot of positive advantages and contributed to mitigating some of the challenges presented by the professionals in Figure 4, some additional challenges were also revealed in this study. The challenges are presented in Table 3.

The results stem from three different case studies, yet they bear similarities and sum up the same challenges; mistrust of this new tool, scepticism towards protecting the devices against harsh environment (dust, moisture, etc.) and lack of tutoring to access all the benefits of the device.

Table 3: Challenges with BIM devices onsite as reported by the interviewees and identified through the case-specific survey.

Challenges of using Tablets on site	Challenges of using BIM stations
• Cost/benefit ratio	• If the distance to the BIM station is far from the work site, there is a lot of lost time
• Poor motivation amongst craftsmen	• Training of the workers to use the BIM station efficiently
• Poor usability of the BIM	• Knowledge of the BIM stations’ potential
• Lack of trust in the BIM	• Obtaining sufficient resilience in the hardware to cope with tough conditions.

• Dependent on network	• Needs stable internet access to remain updated.
• Reduced data security	
• Vulnerable to moisture and dust	
• Lack of support of operating systems	

The cost/benefit ratio was a challenge that some of the respondent on the survey voiced as an important challenge. However, the cases studied that used tablets did not see the huge cost in procuring tablets for those who needed it, the benefits where superior to the cost. The other challenges that is presented in Table 3 will be further discussed in Section 6.1.

5.2.3 Initiatives to better utilise BIM devices

Initiatives to better utilise the devices were discussed with practitioners in the three studied cases are presented in Table 4. An important factor was the need for better tutoring and training to use the devices. More than 60% of the workers highlighted more training as the most important factor to increase the benefit of BIMs on site. Furthermore, one of the cases had just one BIM station placed rather close to the construction office, so the walking distance from the work site was just about the same. The workers would like to have more stations and the ability to move the stations closer to their work if needed. Another initiative to improve the use of both tablets and BIM stations was to have applications that could handle more than one function. When the workers needed specific measurements, they used one application, for progress reports they used another and a third one for viewing the 3D model. The workers felt like this was unnecessary and required training in more than one application.

Table 4: Initiatives to better use BIM devices as reported by the interviewees and identified through the case-specific surveys.

Initiatives which can lead to better utilisation of BIM devices	
• Better training in use of the devices	• Promote success stories
• More details in the BIMs	• Pilot projects
• Change the attitude of users	• WLAN at the site
• Better location of BIM stations	• Assess usability throughout the development of the BIM
• Better protected devices	• Several functions in one application

6. DISCUSSION

Figure 4 shows the general challenges in the interface between design and construction on AEC projects. The four most prominent challenges are quite typical for a fragmented industry like the AEC industry. Especially, the challenges with collisions between trades are directly caused by the fragmentation between the trades.

The fragmentation of the industry is hard to change as it stems from many factors, like contract models and tendering processes. Such deep structures are inherently challenging to alter significantly. A more practical solution to the challenges the industry faces is richer and more effective communication between the trades on a construction project. BIMs could be a good tool for increased understanding of the information communicated between the trades, as the model itself works as a mediating artefact, increasing knowledge transfer between the trades, as Koskela et al. (2016) described. A BIM could work well (and even better than a drawing) as a mediating artefact. For instance, using BIMs on screen in a meeting will allow the different trades to visualise the whole project in several dimensions at the same time. Like the use of drawings between persons without a common language, the BIM can enable trades to understand each other, by moulding different jargons into a common form so they can see their respective interpretations of the model.

As the findings show, most of the challenges presented in Figure 4 can be mitigated with BIM. However, implementing IT-tools like BIMs poses new challenges, like the need for proper training in the use of the tool. The advantages and the challenges of using BIMs are further discussed in the next section.

6.1 Advantages and challenges of using BIMs to communicate between design and construction practitioners on site

There are many advantages with using BIMs on a construction site, as opposed to the traditional way of using drawings and written descriptions. BIMs can solve some of the general challenges in the interface between design and construction. The findings chapter presents some of the advantages with using BIM devices like BIM stations or BIM on tablets in the construction phase. One of the common advantages was better understanding of the project through 3D visualisation. The visualisation of the project helps the workers understand the whole project and the design of certain elements in the building. As Wileman (1993) describes, visual communication can be more effective than verbal communication. A BIM device also has the possibility to further increase the effectiveness of the communication, as the workers are able to interact with the model. Furthermore, the BIM devices used on construction sites have the possibility for two-way communication. Such two-way communication channels enable the easy reporting by the workers of errors, progress, etc., directly to the design team. Two-way communication is, as described in the theory section above, more effective than a simple one-way communication media such as a drawing.

Having a BIM device onsite opens up another communication channel between design and construction. This permits the addressing of problems involving, for instance, poor communication and delayed drawings. Traditionally, phone calls, e-mails, drawing and meetings between superintendents and design managers have been the commonly used communication channels. These are not, however, very efficient means for communicating concerning progress, error, etc. as the information has a long route before it reaches its destination (e.g. a construction worker reports an error to the superintendent who then talks to the design manager who then informs the proper designer). In such long chains of communication, errors and misunderstandings typically occur, making it even harder to address the experienced challenges. With a BIM device, the workers can easily mark up an error on the BIM and send a direct error report to the design team. To make the information even richer, workers can take a photo of the building site with the tablet and attach it to the error report, so the designers can see exactly what the problem might be. Such direct communication between construction workers and designers could evidently decrease the perceived need for control and traceability of all information for a manager. In the view of the authors, such challenges ought not to be overestimated. A BIM device is a documentation option, meaning all the information that is sent from such a device is stored in a database accessible to a manager. Furthermore, using a system like KanBIM™, process information and product information can be traced through the project (Sacks et al., 2013).

Traditionally, the means of communicating a design to a construction site has been drawings and descriptions. When there is a revision of those drawings, the designer will print out new ones and send them to the construction site. This creates the need for on-site control of those drawings, to secure that every worker uses the newest revision. With a BIM device, a printed drawing is rendered obsolete, as the workers have access to all drawings, descriptions and models on the device. Furthermore, connecting the device to a wireless network, will secure an automatic upload of the newest revisions. In addition, it will reduce the risk of errors due to workers using old drawings.

Having access to 3D models with a 4D presentation of the workflow enables the workers to better understand project information and the workflow of the project. This can lead to a positive effect on the productivity and efficiency of the workers. Ruwanpura et al. (2012) demonstrated the same result with the use of an information booth, which is essentially the same as BIM station.

There are some challenges with the implementation of BIM devices on a construction site. For instance, there is the cost of buying the equipment, like tablets and computers, for use on site. Buying the equipment could be a substantial cost for a small project and something that could be difficult to defend in a project budget. However, the benefit of using BIM devices in most cases should exceed the cost. As has been previously discussed, the traditional way of communicating is ineffective and the cost of rebuilding because workers accidentally use old drawings could easily exceed the one-time cost of BIM devices.

Another challenge discovered is that workers do not know how to use BIM devices and therefore do not see the benefit of using them. However, this is not unique to BIM devices. Every implementation of a new system, tool, method, etc. will be met with scepticism if the workers do not get the proper training to use the tool. In fact, the tool will not provide any benefit at all if the workers do not know how to use it.

A more specific challenge that arose under the implementation of BIM devices was hardware and network connectivity. On a construction site, there is a lot of dust and moisture, so the hardware used must be resistant enough to withstand such a tough environment. Today such devices exist so it is not a challenge, but it is important not to buy the cheapest equipment and also to know what kind of environment the equipment can tolerate. The construction site also needs to have a good and stable internet connection to get the full benefit of BIM devices. This is not a huge challenge either; it is more a question of investing in enough wireless access points around the construction site.

Of course, open access to documents and having wireless access on the construction site can become a security risk. If for instance, someone loses the tablet without having a good password protection it could give someone unauthorised access. However, this is easily solvable by having good security routines and using a protected network on site. Furthermore, the access to the documentation database could be restricted with a virtual private network (VPN) using a secure ID for logging.

Finally, the findings showed that there is some operating software (OS) out there that does not support all the different BIM software. However, the software industry is continuously developing and it is not a question of if it is supported, but rather when it will be supported. Nevertheless, it is something that should be taken into consideration before investing in the equipment – check what type of OS supports the BIM software used on the project and invest in that.

6.2 What practical measures can lead to BIMs providing better communication between design and construction practitioners?

There are several practical measures to better utilise BIM devices. An important step is to set up a training program for users, so they learn how to use the new tool. Although it is important to know how to use a new tool, there is not a direct link between knowing how to use it and seeing the benefit of using it. Therefore, it could be beneficial to have a good implementation strategy with clear goals for the implementation, perhaps also running a pilot project that gets extra attention to secure a success. To get people to see the benefit in implementing new tools like BIM devices, it is important to promote success stories among co-workers. Most people want to be the best or do their best, if they see that one project has a tool that makes them more efficient, it is normal that other people want to try out the same tool.

6.3 How can BIMs enhance the communication between design and construction practitioners?

Based on the insight from the analysis presented in the theoretical framework section, and experience from the case studies, the theoretical model found in the literature lacks the new communication channels that BIM has introduced.

Coming back to the Ambler (2002) model and the relative effectiveness of communication channels, it is clear that the most effective form of communication will be face-to-face at a whiteboard. Everything else being equal, a BIM device is clearly a much richer artefact than a whiteboard, thus better enabling communication.

If we consider BIM as a documentation option, the situation becomes a bit fuzzier. Although a BIM will normally be far superior in information richness and ease of retrieval, it cannot serve as a carrier of non-verbal information the same way audio and video documentation options can. We would say, however, in the communication context that we are considering, the value of this information is negligible; e.g., knowing that the architect is happy with the building he drew is normally not pertinent to executing the construction correctly.

Another potential weakness of BIM compared to other documentation options is the possibility of 'false' information. When modelling, software packages will supply, in many cases, default values for attributes like ceiling height or wall thickness if the user does not specify them. This could lead to a communication error down the line if people who access the model assume that the designers have actually decided upon these values.

In practice, the solution to this is to have an Information Delivery Manual (IDM) that specifies what information is supposed to be in the model at different stages of a project. Thus, the designers will know what information they have to put in, and builders and others that access the model will know what information can be expected to be relied upon and what is just 'placeholder' information.

Although using BIM as a documentation option has some issues, we consider BIM to be a documentation option far superior to other options, if it is used correctly.

Figure 5 shows how BIM and BIM devices fit in to Ambler's model. In addition, we have added Emmitt's definition of communication as either asynchronous or synchronous. This makes the model richer as it gives a clearer picture into what kind of communication channel has the capabilities for real-time communication.

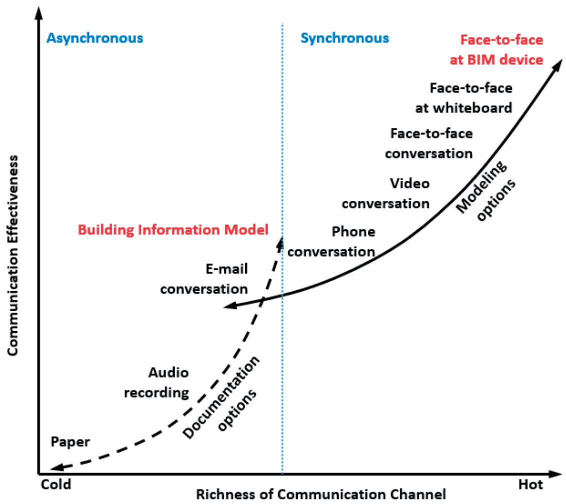

Figure 5: different types of communication channels and how rich and effective they are compare to each other (after Ambler, 2002; Cockburn, 2006).

Knowing when to use synchronous and when to use asynchronous communication is important on a construction project with a high degree of complexity. Clearly, it is not efficient to use synchronous communication on topics that Lengel et al. (1989) call routine, e.g. calling into a meeting just to say when the materials will arrive on site is not very effective. Synchronous communication should only be used on non-routine topics, where the outcome is unknown and requires collaboration.

7. CONCLUSIONS

This article has studied the advantages and challenges with the use of BIM devices on a construction site and has explained with communication theory why these tools are more effective than the traditional approach. Most of the advantages and challenges presented here have been presented earlier in previous studies by the authors themselves and by others. However, to the best knowledge of the authors, there is no study that has used communication theory to explain why it is an advantage to use BIM devices on a construction project.

Reaping the full benefits of its potential demands insight into communication theory. The main finding is that BIMs, used as a mediating artefact in a synchronous communication option, provide far more effective communication than other types of synchronous communication. BIMs as a documentation option are superior to all other media, because they have a higher bandwidth and are self-documenting at the same time. We have found some challenges with communication in general and more specifically with BIM devices. The most prominent challenges with BIM devices are connected with the implementation process and are not necessarily unique to them. 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.

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 will be counterproductive.

8. ACKNOWLEDGMENTS

We would like to thank Erle Harstad, Vegard Murvold, Aleksander Vestermo and Martin Salmon for their support in gathering primary data.

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PUBLICATION 10

Svalestuen et.al (2017) Using trans-industrial knowledge to manage the Building Design Process according to Level of Development: LCJ Format Readme & Template. *Lean Construction Journal* 2017 pp 00-00 www.leanconstructionjournal.org

Planning the building design process according to Level of Development

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Abstract

Question: Q1: What characterizes planning of the building design process in the different industries today? Q2: How do the challenges with planning in the building design process stand out from the other industries? Q3: How to improve planning in the building design process?

Purpose: The purpose of this paper is to compare the design process in three different industries: 1) Architecture, Engineering and Construction (AEC), 2) Offshore Construction (OC) and 3) Ship Building (SB), and from that learn how the AEC-industry can improve building design management.

Research Method: A comparative case study with one case from each industry (AEC, OC and SB) with interviews and a case specific document study were carried out. In total, thirty-two semi-structured in-depth interviews were used to collect the analysed data from the three cases. Finally, a focus group interview with ten participants were carried out to test and develop a conceptual model.

Findings: This paper presents an analysis of differences between design processes in the three industries and proposes a conceptual model for how building design management can be planned according to Level of Development (LOD).

Limitations: The study is limited to single case studies in companies in three different industries.

Implications: The use of the proposed conceptual model with LOD could improve planning of the building design process.

Value for authors: This paper will help project practitioners to use LOD to, as a result of planning, improve the design process.

Keywords: Level of Development, Collaborative planning, Design maturity, Building design management.

Paper type: Full paper

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Introduction

A current trend in the Architecture, Engineering and Construction (AEC) industry is that projects are getting more complex and require more detailed drawings. Van Berlo and Natrop (2015) question if the information presented by drawings really constitutes the information needed on the construction site. They even claim that most drawings are not specific enough for specialized tasks. In Norway, Building Information Models (BIM) and other Information and Communication Technology (ICT) tools have been investigated as measures for improving communication throughout the whole life-cycle of a building, from early design to operations and termination (Harstad et al. 2015, Murvold et al. 2016, Vestermo et al. 2016). With BIM, much more information can be available than on traditional drawings on paper. Therefore, increased use of BIM in projects poses new challenges in the planning of the design process. With the use of drawings, it is easy to set status and plan for delivery of a certain drawing. The objects in a BIM can have different status, causing challenges for the planning of the process (Hooper 2015). Different approaches have been tried to address these challenges. Among the most promising is the so called Level of Development (LOD) (AIA 2013). However, experience in construction industry have shown that the introduction of LOD have not been as straightforward as wished for (Borrmann et al. 2014).

Other industries have implemented BIM in a more convincing manner than what is the case with AEC-industry. Consequently, there seems to be a potential for learning. Of particular interest are the Shipbuilding (SB) and Offshore Construction (OC) industries (Knotten et al. 2016). The OC and SB industry are typically recognized as being characterised by a high level of complexity (Aslesen and Bertelsen 2008, Lia, Ringerike, and Kalsaas 2014, Gaspar et al. 2012), a complexity which especially over the later decades has reached the AEC-industry in general (Forbes and Ahmed 2011). These similarities make a trans-industrial comparison of these three industries interesting, and to identify the potential for learning the following research questions are addressed:

1. What characterizes planning of the design process in the different industries today?
2. How do the challenges with planning in the building design process stand out from the other industries?
3. How to improve planning in the building design process?

The first of these questions will be addressed in the theoretical framework section of this paper, whilst the two latter will be addressed in the findings and discussion sections.

Methodology

The comparative case study presented in this article is based on three cases. A case study is, according to Flyvbjerg (2006), an appropriate method for gaining context-dependent knowledge about complex issues. The research included a literature review following the procedure described by Blumberg, Cooper, and Schindler (2011).

The three cases were found in three different industries; at an AEC contractor, an offshore contractor and at a shipbuilder. Interviews, observations and a document study was used for data collection.

In these case studies 23 semi-structured in-depth individual interviews were carried out according to the procedures outlined by Brinkmann and Kvale (2015). In addition to the case specific interviews, eight non-case specific unstructured in-depth interviews with senior level participants from OC and SB was carried out.

The semi-structured in-depth interviews were carried out using a common interview guide. They were recorded, transcribed and analysed based on the concept of constant comparative method (Knotten et al. 2017), meeting the rigour of qualitative research as highlighted by Gioia, Corley, and Hamilton (2012).

The observations done in the cases were made as a peripheral member/researcher with a focused observation approach based on the recommendations of Adler and Adler (1994), Gold (1958), Postholm and Jacobsen (2011). The pre-defined focus of the observations was the behaviour of the design manager and the team participants in meetings.

The document study concentrated on schedules, contracts, organization charts and other project documents. It was carried out to find background information that could supplement the picture obtained during the interviews.

Yin (2013) suggests member checking as a way to strengthen the results of case studies. The case study results were discussed with representatives from the three industries in workshops. The conceptual model of the work flow presented in the discussion chapter were presented and developed in a workshop with 10 design managers.

Theoretical Background

The theoretical chapter consists of two parts. The first part describes the different types of dependencies occurring in the design process and how the process could be managed to handle those interdependencies. This is recognized as valid for all the three industries. The last part sums up a previous study on how the reciprocal and sequential process develops in the different industries.

Different types of dependencies in the design process

According to Knotten, Svalestuen, Hansen, et al. (2015), there is four different interdependencies occurring in the design process, notably pooled-, sequential-, reciprocal- and intensive interdependencies. Kalsaas and Sacks (2011) maintain the importance of understanding the dependencies in the design process in order to handle them. Figure 1 shows the team task complexity and important characteristics that can occur in a design process.

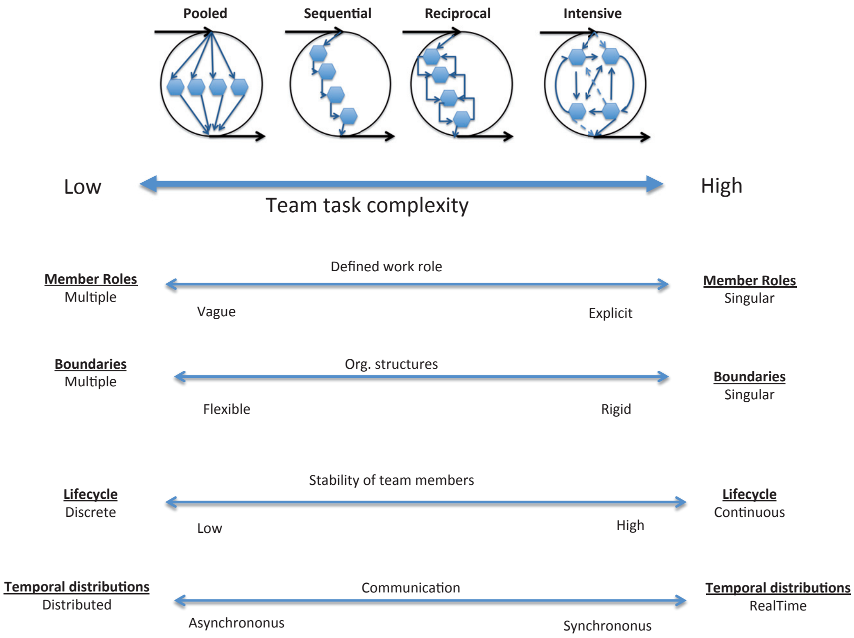

Figure 1: Team task complexity and characteristics based on Bell and Kozlowski (2002), Knotten, Svalestuen, Hansen, et al. (2015).

As shown in Figure 1, different team tasks encounter different types of dependencies. This will require different definition of work roles, organisation structures, stability of team members and communication. Intensive dependencies between design tasks will require more teamwork, with a high degree of synchronous communication as opposed to pooled dependencies between design tasks that require asynchronous communication. The challenge is according to Knotten, Svalestuen, Hansen, et al. (2015) that the different types of interdependencies can happen at the same. In a design process, there will be several activities, some might be pooled others might be either sequential, reciprocal or intensive. A tool like Design Structure Matrix (DSM) can be helpful to identify the different interdependencies in a design process (Browning 2001). However, according to Rosas (2013), DSM is not adequate alone to define the optimal design sequence. A tool like Last Planner System™ (LPS) needs to be implemented in addition to DSM to control the planning process.

A specific challenge for the AEC industry is the fragmented nature of the industry. The building process is relying on different actors from different companies to complete the project. Consequently, this causes challenges with the teamwork and communication on the projects (Kerosuo 2015).The performance of a building design team is dependent of the team members' ability to work together as a team, their skills and knowledge (Emmitt and Ruikar 2013). Svalestuen et al. (2015) found 12 elements that were important to effective building design teams. Out of those twelve, trust between team members and commitment to the project was the most important. However, other elements were also found to be important (e.g., a team building exercise at the beginning of the project is important to be able to gain trust and commitment between project participants). One way of ensuring an effective team in the building design process is to use a method called Collaborative Planning in Design (CPD) (Knotten and Svalestuen 2016, Fundli and Drevland 2014). CPD is based around four elements: 1) the start-up process, 2) the scheduling system, 3) the constraint analysis and 4) the meeting structure. The start-up process is where the team gets to know the project and each other. The goal with this is to ensure that all participants commit to the project and work towards completing the same goal. The scheduling system of CPD is an adaptation of Last Planner System™ to design (Bølviken 2010). Together with the meeting structure and the constraint analysis, the system endorses teamwork and team development. A key tool in CPD is the dialogue matrix, consisting of design activities as well as new tasks needed to complete the work. The design team uses this tool collaboratively in each meeting to tell each other what they promise to do, what they need from others and when they need it to accomplish their own work on time (Knotten and Svalestuen 2016). Fundli and Drevland (2014) found that using a method like CPD led to better communication and cooperation within the design team and a better understating of and commitment to the project.

Level of Development (LOD) is discussed as a possible tool to improve communication between actors (Hooper, 2015). With a shared BIM-model capable of showing 4D and 5D information, the quality of communication between designers and construction practitioners can increase (Svalestuen et al. 2017). Furthermore, a transparent information flow is vital for an efficient project team, as it fosters trust between participants (Svalestuen et al. 2015) and reduces sub optimisations (Knotten, Svalestuen, Lædre, et al. 2015).

LOD is used to describe how developed a BIM is. The idea is that you attach a LOD status attribute to objects in conjunction with standardized reusable checklists. Thus you can, with increased certainty, guarantee a certain quality of information at a given point (Hooper, 2015). American Institute of Architects (AIA) have developed a LOD definition, describing how the BIM-elements evolve through the project. Their definition range from the low LOD level 100 to the highest level 500. Abou-Ibrahim and Hamzeh (2016) have developed a framework for LOD that relates the LOD value of a model element to its actual design context. The framework divides the definition into three variables: 1) Graphical Detail level, 2) Information Richness and 3) Confidence Index. The sum of all three variables will define what LOD-level the different elements have. Although the concept of LOD was pioneered in 2004 by Vico software, there is still a lack of cases where LOD is successfully implemented. One of the reason for the lack of successful implementation is the lack of practical understanding for what LOD can be used for (Hooper 2015). Furthermore, what is required as a minimum level of detail will vary form project to project as building projects vary in size and complexity. The pre-set values of LOD from AIA might be too detailed for some projects and to vague for others (Borrmann et al. 2014).

Trans-industrial comparison

The AEC-, OC- and SB-industries all have different approaches to handle reciprocal and sequential interdependencies in the design process. As shown in Figure 2, all industries have a creative reciprocal design process in the early design phase. However, the AEC industry continues the reciprocal process longer than the SB- and OC-industry.

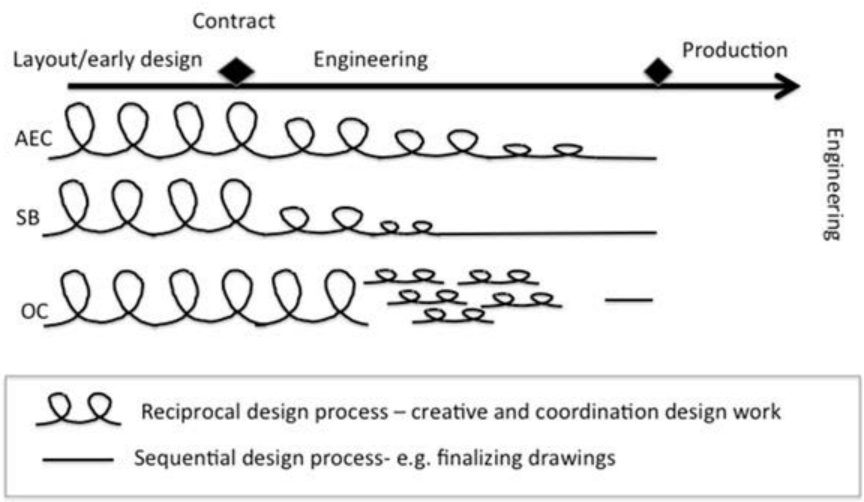

Figure 2: Illustration of reciprocal and sequential design processes in the different trades (Knotten et al. 2016).

According to a study by Knotten et al. (2016), the SB-industry have a state-gate model with quite clear decision points that allow them to end the creative reciprocal design process before the AEC-industry does. In the case from the OC-industry the company had implemented a new agile method for the engineering process. By pushing the production of drawings to the last responsible moment and controlling the design process with BIM maturity levels they allow the creative reciprocal design process to continue longer for each area of design. The planning method of the OC was described as a stage-gate method where the maturity of objects, together with production and procurement, dictate the plan. The research of Knotten et al. (2016) concluded that the AEC industry could learn from the way the OC-industry planned the design process and how they used BIM. Mejlænder-Larsen (2017) describes the use of Project Execution Models (PEM) in offshore engineering as something the AEC can adapt to. PEM is a highly structured and systematic description of the process. SB is complex and Killaars, van Bruinessen, and Hopman (2015) emphasises the importance of a holistic view of the final vessel, as the function is not only depended on the function of the components, but their holistic interaction. This is valid for OC as well and influence the planning and design.

Findings and discussion

This chapter contains the main findings in this article and discusses how the AEC-industry can improve planning of the design process. First we present how the different industries plan their design phase in the three cases. Then we discuss how the AEC-industry can improve planning of the design process.

Main characteristics of planning in the different industries

This study follows up the study of Knotten et al. (2016) and investigates the planning in these industries further. The OC- and AEC-projects investigated were dealing with the early phases of detailed design, while the SB-project were dealing with basic design. The typical approach of the OC-industry and SB-industry is to look at the function of the major systems in a holistic manor. They look at the function, the overall systems to support this and then the detailed layout (area). The typical approach of the AEC-industry is to look at the function of the building, how the detailed layout supports this and then look at the overall systems. Together with external designers (sub-optimising their systems) the holistic view is not as dominant as in the other industries.

The planning process in the three different industries have a similar approach in the way that they all have a production that sets the framework for the design plan. Usually the design plan is made by an assumption of what and when the immaterial product (drawings etc.) is needed in order to have an efficient production process. The design process is inherently a creative reciprocal process, and how that process is planned differs from industry to industry.

The AEC-industry

The AEC–project was a design-build project. The contractor organized the design management. The architect and structural consultant were procured by the contractor, while the rest of the main designers were procured by subcontractors.

The design plan was collaboratively made. This plan was the guidance for the design activities, but little attention was paid to this plan throughout the project and it was not revised. They used the dialogue matrix from CPD as a tool to map activities that needed to be completed in the next period.

The design team of the AEC project was exclusive for the project. The client had already procured the architect when procuring the contractor. The subcontractors were procured based on lowest price. The subcontractors provided their own designers. As a result, the team was not organised by the design manager. Despite this, the design team functioned fairly well.

The main communication and coordination between the design team members took place in the project's ICE sessions. The frequency of these sessions was one day a week. The rest of the week the design team was dispersed.

The OC-industry

The OC-industry also used Lean planning techniques to make the master schedule. There was an enormous attention on the "schedule" and important milestones. The work was aligned around the "schedule". The OC-industry used BIM for design, but also for registration of design status according to the schedule. The OC-company investigated was sub-contractor with a responsibility of a DES (drilling equipment set), while the main contractor was responsible for the remaining (DSM, MFS).

The design team in the OC-project primarily consisted of own employees. At the time of study there was a resession in the industry, making it possible for the DM to hand pick the team members based on competence and previous work experience from collaborative environments.

The whole project was full time co-located in the same building. This included the client, users, constructors and designers. This made for short informal communication routes, which were clearly visible when visiting the office.

The SB-industry

The design process in the SB-industry changes between pre-contract and post-contract. The Pre-contract design process is challenging with a high degree of innovation and a constant change in specifications from client. Planning of this process is therefore considered as useless among the team members. During post-contract design (engineering design) the project had a well-functioning plan for the design process, linking production and drawings together.

Despite lack of planning and highly unpredictable workload, the project delivered design and innovative solutions. A key to this was the design team members. Even though there belonged to different ship segments, the designers and design leads could be said to work almost in an autonomous way, handling complex tasks and dependencies together. The actors were aware of each other’s needs, shared inventive solutions across segments and offered previously developed design solutions.

The line of communication was very informal, yet the formal procedure was to run all design issues through the Naval Architect, who had the role as a design manager. The Naval Architect also was responsible for the totality of the ship called the General Arrangement.

Main challenges with planning of the design process

The most prominent challenge for SB-industry in the basic design phase is the general belief among team members that the phase is “un-plannable”. The constant change in the specification from clients and constant drive for innovation made planning seem useless. Another challenge is that the projects are dependent on the Naval Architect, as all the formal communication was routed through this key actor. This created an information hub around the Naval Architect with the possibility of information overload, yet the autonomous informal communication solved these challenges. The routing of the formal communication increased information loss, leading to possibility of flaws in the design.

The OC-projects had a very good autonomous team that where co-located during the whole project. This made for short informal communication routes, which were obvious when visiting the office. However, the formal communication procedures set up by the client were not adapted to rapid informal communication and created challenges causing frustration among the designers. The DM said his main task was “chasing” decisions for his team, so they could carry on.

The AEC-project had difficulties with following the schedule and making adjustments to the schedule when needed. They had a collaborative planning session where they created the design schedule, but they did not use or update the schedule accordingly. While the schedule looked like a good plan for the project, it was quite clear that the different disciplines had difficulties to communicate what they really needed from each other to complete their own work. Another challenge for the AEC project was the fragmented team and the fact that the contractor was not involved in the early design phase. The fragmentation did cause some issues threatening the trust between the different disciplines. This was made quite clear when the engineer did not want to share his model with the contractor, because it was not finished and he was afraid that the contractor would use it as if it was ready for construction. Table 1 summarizes the challenges with planning of the design process in the different industries.

Table 1: The main challenges with planning in the design process

	AEC	OC	SB
Communication	▪ Different disciplines have difficult to communicate actual information needs between each other	▪ Long lead time on formal communication channels	▪ Focused around Naval Architect
Team	▪ Fragmented teams ▪ Trust between different disciplines	Decisions across the different teams (DES, DSM, MSF)	▪ Culture with high degree of specialisation ▪ Autonomous culture
Planning	▪ Follow the schedule and reschedule when needed ▪ Decisions	▪ “Chasing” decisions ▪ Lagging planning between the parts (DSM,DES, MSF)	▪ General belief that the project is too complex for planning

As shown in Table 1, the main challenges with planning in the building design process are related to difficulties to communicate actual information needs, fragmented teams and problems with following the schedule. From what we have observed in this project it is almost as there exist a resistance to detailed planning of the building design process. The different disciplines in a building design team have a reluctance to actually plan their work, and that they prefer to handle tasks ad hoc.

Initiatives to improve planning in building design management

There are three elements that we think could benefit planning of the building design process in AEC-projects.

First, we suggest to increase the importance of the schedule during the design process. The OC-project had a tighter follow-up of the schedule and managed to better utilise resources than the AEC-project did. Second, the BIM should be used collaboratively as a communication and development tool. BIM increases the understanding between disciplines and displays solutions for decisions. Third, we suggest to use LOD in the planning of the design process. By setting the maturity of an object at a given date, it is easier to know if the designers are on plan, and also what valid information that can be extracted from the BIM at that given time.

In addition to this we see that both the SB- and OC-project participants were more autonomous than in the AEC-project, with clearly defined roles, which (Bell & Kozlowski, 2002) highlight as important to successfully deal with complex tasks.

We propose that the AEC industries uses CPD and adapts the LOD definition in every projects. As stated by Borrmann et al. (2014), a pre-set definition of LOD might not work for each project. Consequently, each project needs to define their own values for LOD. One way of doing this is to utilize the “start-up meeting” in CPD, where each team member gets to know each other and the project, before making a plan for the design phase collaboratively. Before they make the plan in the “start-up meeting”, they could agree upon what the different LOD values should be and develop a plan showing the development of the BIM. As we learned form how the OC-project focused their design plan on maturity levels on the model. Where they color-coded the different areas on the model according to their maturity, the AEC-industry could do the same with LOD values.

With a color-coded system on the model we hope to eliminate problems of misinterpretation of the BIM by design team members. It should be easy to see on the model how mature each element is. Figure 3 shows a conceptual model of the design workflow in a LOD-decision plan.

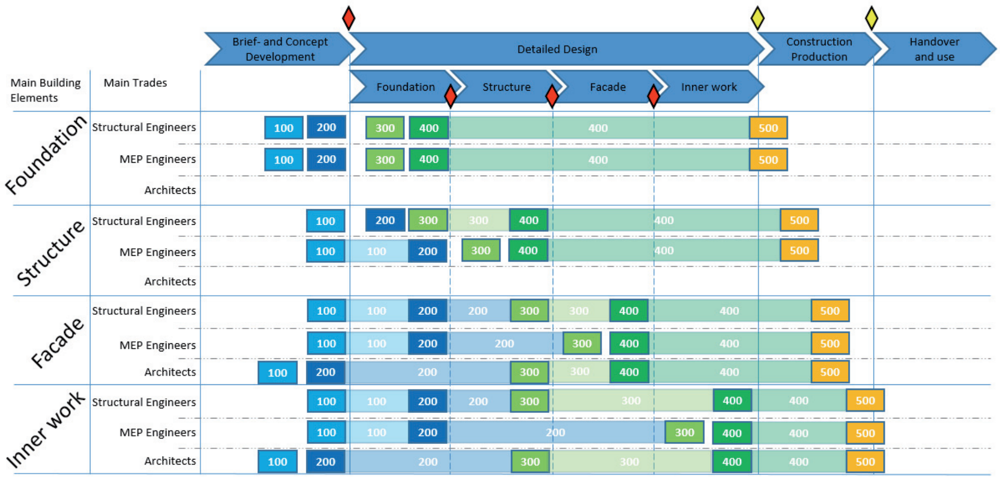

Figure 3: Conceptual model of the workflow in a LOD-decision plan

In Figure 3, the workflow is represented by LOD-values, where LOD 100 represents a draft and LOD 500 represents the final “as-build” element in the model. On the y-axis the process is divided into the most common trades in a building process and the main building elements. On the x-axis those elements are also represented as stages in the building process, where the design process is divided into a phase for each trade. The order of the trades follow the natural way of constructing a building, which is to start with the ground work and foundation before the structure, facade and finally the inner work. The diamonds on top of the phase’s marks up important decision gates and the LOD-values shows the progression of the workflow for each building elements and trades. If construction of one of the main building elements starts before the design process is finished, the LOD-decision plan makes a good mark for the delivery of a certain sets of final blueprints for production.

The model shown in Figure 3 is supposed to be used as a tool for planning decisions and workflow in the design. The precondition for the LOD decision plan is that each delivery into the plan is a promise of work to be done or binding decision to be made. For example, if we look at the end of foundation phase, the structural- and MEP (Mechanical, Electrical and Plumbing) engineers needs to have all elements directly linked to foundations on a LOD 400 (checked and ready for production). Furthermore, other elements needs to be developed simultaneously, because the different elements in the design process are related. For instance, the structure needs to be finished at a certain level so they know the placement and size of the columns. Similarly, the structure is dependent on the façade and inner work (e.g. the placement of the columns are dependent on the floorplan and the use of the building).

The model is a conceptual model and it is just meant as an illustration on how LOD could be used to show the design workflow and important decision on a project. Each project has to define its own LOD-values and BIM-workflow. Furthermore, using BIM as a planning tool opens for new ways of illustrating the schedule and dependencies amongst disciplines. In the focused group interview with ten design managers we showed how the LOD-values with color-codes could illustrate the workflow by using 4D. Figure 4, shows a picture from the 4D representation of a small building on a fast-track project. The Blue colour represent where the construction work should be and the orange colour represent the LOD-values that the model has. All participants of the focused group interview saw a great potential in this way of representing the schedule. This could potentially rectify the difficulties some designers have with communicating their needs between each other.

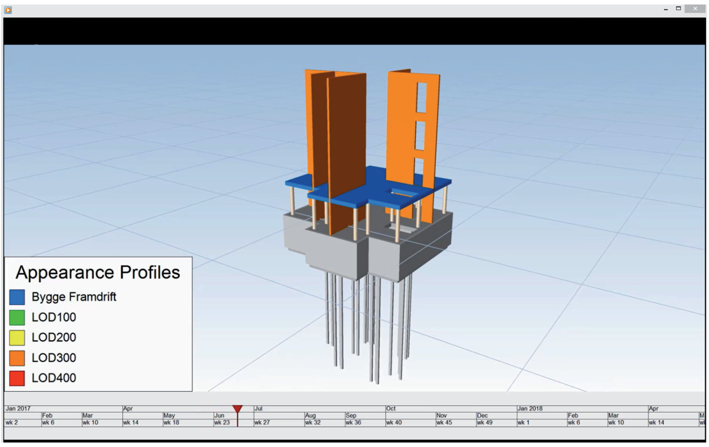

Figure 4: a movie capture of a 4D presentation of LOD and BIM workflow on a project.

Conclusions

This article set out to learn more about how building design management can learn from other comparable industries. Based on previous literature and cases studies the article compares the management of the design process in three different industries and investigates specific challenges regarding planning of the building design process. The article set out to answer three research questions based on case studies of the AEC, OC and SB industry.

The first research question was to describe what characterizes the planning process in the different industries today. Our research shows that there are some differences in the planning processes. However, all industries need to face the same challenges with interdependencies in the design process, as illustrated in figure 1. As depicted in figure 2 the industries handles these challenges differently. The OC chose a strategy of much more parallel design development. The process was structured and had a strong focus on the plan and to re-plan. Each area of design was color-coded according to their maturity level to better communicate what maturity the area has in the BIM-model.

The second research question is to answer how the challenges in the building design process stand out from the other industries. The AEC industry, compared to the OC and SB industry have more fragmented teams. Both the OC and SB have in-house design capabilities with good working experience, contributing to a more autonomous work progress. Further, the OC have much more focus on planning and re-planning throughout the whole design process.

The third research question was how to improve planning in the building design process. Based on the research this article proposes a conceptual model of workflow in a LOD-decision plan. LOD is not a new concept in the AEC industry, but implementation on construction projects have not been as straight forward as wished for. OC have had a greater success with implementation of a similar concept with maturity levels. So, a comparison with what they had done benefit the building design management. Furthermore, based on the principles of Lean, this conceptual model proposes to define the LOD not only based on pre set definitions e.g. AIA, but through a collaborative agreement in the project, through CPD. This is believed to increase the design teams' understanding and commitment both to the use of BIM in the project and to planning of the design process.

Altogether, this article addresses a problem of planning in building design: to make comprehensive design information handoffs. Visualizing and communicating this, to better align the plan with the design team is important. A natural next step is try this conceptual model and use CPD with LOD in a project.

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