



Sigrun Lurås

SYSTEMIC DESIGN IN COMPLEX CONTEXTS

An enquiry through designing a ship's bridge

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ISSN 1502-217x

ISBN 978-82-547-0283-3

CON-TEXT

PhD thesis 77

A doctoral thesis submitted to
The Oslo School of Architecture and Design, Norway

PUBLISHER:

Arkitektur- og designhøgskolen i Oslo

COVER ILLUSTRATION:

Jesper Egemar

PRINTED BY:

Akademika forlag

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ABSTRACT

In recent years designers seem to increasingly be engaged in projects for complex, high-risk domains. Yet, little research has been conducted that addresses how designers experience such projects, what kinds of challenges they face, and how they may manage these challenges. This thesis addresses the design in one such domain: the offshore ship industry. The presumptions for the thesis are that designing for such contexts is complex and that systemic design approaches may prove valuable. *Systemic design* is a recent initiative in design that integrates systems thinking and human-centred design, with the intention of helping designers cope with complex design projects.

The aim of the thesis is to understand designing for complex, high-risk control environments, and how systemic design may be of help when designing for such contexts. This has been investigated through ‘research by design’ that addresses the design of a ship’s bridge, and by an interview study with industrial and interaction designers with experience in the maritime and offshore industries. *Research by design* is a research approach where design practise is at the core of research. The design practise of this thesis was carried out within the Ulstein Bridge Concept (UBC) design research project.

The thesis confirms that designing for the offshore ship industry is complex and challenging on many fronts. First, the domain is unfamiliar to most designers, and acquiring the insights needed for designing requires substantial effort. Second, the products to be designed constitute highly advanced technology that is used in complex, uncertain, and high-risk situations. Third, the industry is global; it has many stakeholders and is highly regulated, both of which make the framework conditions for offshore-specific design projects difficult to grasp.

In the thesis, systemic design is conceptualised by a *systemic model of the design situation* that makes explicit what designers need to make sense of in such projects. The operationalisation of systemic design was conducted within the UBC project and includes the development of two systemic design methods: *design-driven field research at sea* and *layered scenario mapping*. Further, the designs developed by UBC, the Ulstein Bridge Vision™, can serve as design exemplars resulting from systemic approaches.

This is a thesis by publication, which consists of an exegesis (included as Part 1) and six publications (included as Part 2). The exegesis presents the research design and theoretical perspectives that are used, and includes an overarching reflection on the results of the thesis that binds the publications together.

ACKNOWLEDGEMENTS

First and foremost I would like to express my gratitude to my supervisors Birger Sevaldson, Margareta Lützhöft, and Kjetil Nordby. I appreciate your support and positive attitude towards my Ph.D. research, and also your critical remarks, which increased my insights and improved the quality of this thesis.

I would like to thank the Oslo School of Architecture and Design and the Institute of Design for accepting me as a Ph.D. fellow, and the Research Council of Norway, Ulstein, and Kwant Controls for funding this Ph.D. I would like to give special thanks to Arne Ove Rødstøl at Ulstein for his support, especially in helping to organise the field studies, which played an important role in this thesis.

My fellow team members at the Ulstein Bridge Concept project deserve a mention: Sigbjørn Windingstad, Jesper Egemar, Natasha Barrett, Morten Knutsen, Svein Inge Bjørkhaug, Stian Børresen, Christian Steinskog Sørnes, and Helge Tor Kristiansen. Thank you to all: I really enjoyed our collaboration! Special thanks to Jesper Egemar for also designing the cover illustration of this thesis. Furthermore, thanks to Sashi Komandur at Aalesund University College who was associated with UBC. Special thanks are further due to Marianne Støren Berg at AHO's Ocean Industries Concept Lab for your support and encouragements, and for your critical reading of my research writings.

I am grateful to the Leader of the Institute of Design, Rachel Troye, and the Director at the Centre for Design Research, Andrew Morrison, for your support and care. My colleagues at the Institute of Design also deserve thanks. Our daily encounters at lunch or by the coffee machine, often leading to insightful discussions, have been both enjoyable and helpful to my research. Special thanks to Henry Mainsah for always taking the time to discuss research issues and for posing questions that made me think, and to Linda Blaasvær for your positive remarks and encouragement.

I owe special thanks to the other Ph.D. fellows at AHO. Special thanks to Nina Lysbakken; I have really enjoyed our fruitful conversations on design research and other aspects of life. Thanks also for all the advice you gave me on the illustrations and layout of the thesis. Special thanks also to Julia Schlegel for your insightful feedback on my research and for your friendly support and encouragement, and to Snorre Hjelseth for your optimistic attitude and positive words.

I would also like to mention the librarians at the AHO library, who have given me priceless help, and the administration and other support

functions at AHO for helping me with practical issues and for providing me with good working conditions.

I am grateful to DNV GL for giving me leave to pursue my Ph.D. degree. Thanks to my colleagues at DNV GL for making sure that I've always felt included throughout these years, even though I was mostly away. Special thanks to my former leader, Christoffer Serck-Hanssen, for supporting me when I wanted to pursue a Ph.D. degree, and to Anne Wahlstrøm, for supporting me in the finishing stages.

I am indebted to all of the users, designers, researchers, and subject matter experts I have met during this research project, all of whom have openly shared their knowledge and thoughts with me. This input has been vital for my understanding of the complex landscape of design in the offshore ship industry. My gratitude also goes to members of the Systemic Design Research Network and the Overlap community, who have helped me to gain a deeper understanding of the challenging topics of systems thinking, complexity, and risk in relation to design. Special thanks to Peter Jones, who was a critical reader of the first draft of Part 1 of the thesis, and Harold Nelson and Alex Ryan, for giving me useful advice and something to think about every time we met.

Thanks to Marit Brentebraaten for making sure that I have been fit for the task of pursuing a Ph.D. degree.

Finally, I would like to thank my family and friends for your support, and also for helping me focus on other things than the Ph.D. during this time. Special thanks to my friend Ida Nilstad Pettersen, who as a design researcher helped and encouraged me from start to finish and also gave me useful feedback on my various writings, and to my mother Grace Romsland for inspiring me to pursue research and for her invaluable help, advice, and support along the way. Last but not least, I would like to thank my husband Guttorm and my son Teodor; I couldn't have done this Ph.D. without you!

This thesis is dedicated to my late father Torbjørn Lurås, who inspired me to be a curious and reflective person in all areas of life.

PREFACE

I grew up in the 1980s in Grenland, one of Norway's largest industrial areas. The industry influenced the community to a great degree during my childhood. I remember the bad smell from the factories, and warnings on the radio telling people to stay indoors when there had been excessive air pollution emissions. My father worked at the magnesium plant at Hydro Herøya, and many of the fathers of my classmates had similar jobs. In my early twenties I myself worked as a shift worker at the Norske Skog Union paper mill for two summers. These personal experiences influenced my initial interest in industrialised domains. My interest in designing for high-risk settings—in particular control environments—was further sparked by two summers of internships at Statoil, Norway's leading oil and gas company, during my university studies in Industrial Design Engineering in 2003 and 2004. The topic interests me both on a societal level—ensuring safety and protecting the environment—and on an individual level, ensuring a satisfying working environment for those working in such settings.

In my work as an interaction designer at the design consultancy Halogen from 2005 to 2008, I worked on the design of different kinds of systems, ranging from commercial websites, to the intranet for a Fortune 500 company, to graphical user interface (GUI) design for control systems used in the industry. The scope of the design work was usually quite narrow, however, and I rarely got the chance to address issues beyond the computer screen. In my work at DNV (now DNV GL) from 2008 to 2011, I had the chance to view issues related to the operator environments of high-risk contexts at a more systemic level. In this job, however, I mostly worked with risk analyses and human factor assessments of current systems, and only rarely got the chance to pursue design work myself. When I became a Ph.D. research fellow with the Ulstein Bridge Concept design research project at the Oslo School of Architecture and Design, I suddenly had a unique chance to combine my interest in design with my interest in systems thinking and high-risk industrial environments, as well as an opportunity to contribute to the development of the design profession.

This thesis describes the insights I have gained through three years of Ph.D. research related to designing in the complex domain of the offshore ship industry and for the complex, high-risk control environment of a ship's bridge. By *design*, I refer to industrial and interaction design, although it is my belief that this thesis will also be of interest to related professions, such as human factors and ergonomics (HFE) and engineering.

PART 1

1 INTRODUCTION

Designers¹ are occasionally engaged in professional settings where they must design for expert users conducting complex, high-stakes tasks (Roesler and Woods 2008). One such domain is the offshore ship industry, addressed in this thesis. Designers face challenges on many fronts when they take on design projects for this industry. First, the domain is unfamiliar, and gaining the insight needed for designing requires substantial effort. Second, the products to be designed constitute highly advanced technology, and are used in complex and high-risk situations. Third, the industry is global, with many stakeholders throughout the world, and it is highly regulated, both of which make the framework conditions of offshore-specific design projects difficult to grasp.

The maritime and offshore ship industries need designers who are trained in developing functional and attractive designs that support users while taking advantage of the possibilities found in new technologies. Several observations support this claim. The current working environments and equipment aboard ships often do not support the users in a satisfactory manner (e.g. King 2000; Lützhöft 2004; Grech et al. 2008; Lützhöft et al. 2011), and the large number of technologies that have been introduced on ships in the last few decades has resulted in mariners feeling alienated (Størkersen et al. 2011). Despite an extensive focus on safety, the number of marine casualties attributed to ‘human error’ remains high (Rothblum 2000; Hetherington et al. 2006; Chauvin et al. 2013). One example of marine casualties that there have been several examples of in recent years is ‘ECDIS-assisted accidents’ (e.g. MAIB 2009; MAIB 2014)—that is, accidents caused by erroneous use of electronic charts during navigation. Many causes contribute to such accidents, and the design of the equipment is not without fault; studies suggest that bad design of equipment contributes to one-third of all marine accidents (Rothblum 2000; Rowley et al. 2006). One reason for the issues with the design of marine equipment may be that the designing of such equipment has largely been carried out with a focus on technology rather than on the human user (Petersen 2012).

Still, the maritime industry has ambitions for taking advantage of new technologies in ways that support the mariners and enhance safety.

¹ By *designers* in this thesis I refer to people trained in industrial or interaction design.

Examples include the concepts of *integrated bridge systems*, which implies interconnecting systems on a ship's bridge² in a way that allows for centralised information and control from workstations (IMO [International Maritime Organization] 1996); and *e-navigation*, which is 'the harmonised collection, integration, exchange, presentation and analysis of marine information' (IMO 2014). Since the IMO's strategy for focussing on such concepts was introduced twenty years ago, few concrete examples have been presented. In recent years, however, a few examples of integrated bridge solutions have been introduced, and designers have played a role in the development of some of these.³

Given the complex nature of offshore-specific design projects and the needs of the industry to be more human-centred, *systemic design* seems appropriate when designing for the offshore ship industry. Systemic design is a recent initiative whose purpose is to integrate systems thinking and human-centred design to support designers with complex design projects (Systemic Design Research Network 2015). Aspects of systemic design relevant to offshore-specific design projects include:

- Considerations of the greater context of that which is being designed;
- The use of visual mapping and modelling techniques, which may help designers cope with substantial amounts of fragmented data;
- The emphasis on connections and relations, which can help designers understand causes and effects;
- A focus on system boundaries and leverage points, which can help designers see opportunities beyond the original task and identify which kinds of designs may have a significant impact; and
- An emphasis on multiple perspectives.

The systemic design community has so far mostly paid attention to service design, organisational design, social design, architecture, and theory development. In the literature review conducted as part of writing

² The ship's bridge is the place from whence the captain and the deck officers control the ship. For more information, see Section 2.2.

³ In addition to the integrated ship's bridge presented in this thesis, examples from Norway include Kongsberg Maritime's K-master operator chair, Rolls Royce Marine's Unified Bridge, and Vard's bridge concept SeaQ.



Figure 1: The Ulstein Bridge Vision™ (2012 iteration), designed by the Ulstein Bridge Concept design research project. (Illustration: UBC)

this thesis, I have not been able to identify examples of systemic design for industrial or interaction design for expert users and complex, high-risk environments.

In this thesis I report on a study that addresses design in the offshore ship industry and the appropriateness of systemic design in offshore-specific design projects. Through engaging in designing for the offshore ship industry myself, and by conducting an interview study, I have investigated how designers find designing for this industry, and what challenges they face. Given the lack of attention to systemic design for designing for such domains, to be able to investigate the usefulness of systemic design I also had to conceptualise and operationalise it for this context. Coming from practise as I do, my ambition has been to develop knowledge that would be of relevance to practitioners. Therefore the thesis proposes theories and methods that can effortlessly be put into use in design practise.

This thesis is part of the Ulstein Bridge Concept (UBC) design research project carried out at the Oslo School of Architecture and Design (AHO). The aim of the UBC project was to develop new design-centred knowledge by designing a future ship's bridge, taking into consideration human needs and the complex operations that ships take part in while also utilising new technology. The ship's bridge developed by UBC is shown in Figure 1.

1.1 EVOLUTION OF THE RESEARCH

I started the Ph.D. research with the idea that I would investigate interface designs that could support the deck officers' sensemaking and situational awareness while on the ship's bridge. Similar topics have been addressed by the human factors research community; for example, Endsley and Jones (2012) and Burns and Hajdukiewicz (2004). I wanted to take on the topic from a design point of view, however, and to focus on the generative and explorative aspects of designing for sensemaking, with a particular focus on information design. My aim was to come up with completely new ways of presenting the information on the bridge that could be considered to be new research in itself and would function as exemplars (Schön, 1983) for designers.

Yet, the insight necessary to design the information required on the bridge is substantial, and a year after starting the Ph.D. I realised that what interested me most from a researcher's perspective was not the users' sensemaking and the information designs, but the designers' sensemaking when designing for such contexts. I still aimed to address

design for users' sensemaking in my practical design work through the UBC project, and knowledge *for* design would be developed on the users' sensemaking. However, I aimed to develop knowledge that would qualify as research into the designers' sensemaking and how systemic design could help in this. This change of direction led to the aim and research questions presented in the next section.

1.2 AIM AND RESEARCH QUESTIONS

The overall aim of this Ph.D. research is:

to understand designing for complex, high-risk control environments, such as a ship's bridge, and how systemic design may be helpful when designing for these contexts.

By *designing* I refer to the act of creating something. This is not restricted to a specific profession. However, in this thesis, I refer to the designing that is carried out by the design profession with people trained in industrial or interaction design. For more on the understanding of design used in this thesis, see Section 3.1.

Systemic design is a collective term for recent developments in the merging of systems thinking and design. While no agreed-upon definition of systemic design yet exists, one suggested purpose of systemic design is to integrate systems thinking and human-centred design to support designers working on complex design projects (Systemic Design Research Network 2015). Systems thinking and systemic design are discussed further in Section 3.4, while my conceptualisation and operationalisation of systemic design are introduced and discussed in the publications and Chapter 5.

Complexity commonly refers to something we find difficult to understand. Simon (1996, 183–184) states that a system is complex if it consists of a large number of mutually interacting parts, while Gell-Mann (1994, 30–33) argues that the complexity of a system instead depends on how complicated it is to describe the system—‘the length of the description’—and that this depends on who is doing the describing. Warfield (1995) argues that complexity is ‘a state of mind, triggered into emergence by unsuccessful efforts to comprehend a system immersed in a problematic situation’. Building on these discussions, complexity in this thesis is understood to be ‘systems that contain a large number of parts interacting with each other and their environments on multiple levels, making it difficult to understand cause-and-effect relationships’ (Publication 1). Complexity is further seen as being subjective, context-

dependent, and relative. This means that to what degree something is complex depends on who is describing it, in what situation, and compared to what.

Risk comes from the Italian word *risicare*, which means ‘to dare’ (Bernstein 1998, 8). Risk is often defined as the consequence of an event, multiplied by the probability of the event occurring (Aven 2007, 41). *High-risk* therefore refers to something that has high levels of both consequence and probability. Risk may be positive, yet it is commonly used to refer to the probability and consequences of an undesired and negative event, such as an accident. The probability of major accidents with high consequences is difficult to assess because they are very rare (Reason 1997, 1). Hence, *high-risk* as used in this thesis in practise refers to something that may have a high degree of undesired consequences, without regard to its probability. The notion is further related to *safety*, and the functions that are performed by the operators in high-risk environments are often *safety-critical*—that is, they can contribute to a system hazard (Leveson 1995, 156).

A *control environment* is a working environment in which selected personnel (often referred to as *operators*) carry out some type of monitoring, assessment, and planning of measures (i.e. control) using technical aids (Aune 2002, 12). Such environments are characterised by their dynamic nature (Olsson 2004, 12). Thus, a high-risk control environment is a dynamic environment in which operators carry out monitoring, assessment, and control, and where undesired events with high levels of consequences may occur. In this thesis I use the design of a ship’s bridge in an offshore service vessel (OSV) as an application case of such an environment. The aim of the thesis is addressed by the following research questions:

1. How do designers find designing for the offshore ship industry, and what challenges do they face?
2. How may systemic design be conceptualised and operationalised in offshore-specific design projects?
3. How can systemic design help a design team make sense of the design situation when designing a ship’s bridge, and thus support making design judgements?

1.3 THESIS OUTLINE

This is a *thesis by publication* that consists of two parts:

Part I is an exegesis (Norwegian: *kappe*) that expands and situates the publications of Part II. It consists of an introduction to the topics covered by the thesis, a review of related research, an overview of the theories and concepts drawn upon, a description of the research methods used, and an overarching reflection on the results of the thesis that binds the publications together and advances the arguments put forward in them.

Part II consists of the six publications included in the thesis.

Chapter 2 of Part I provides an introduction to the offshore ship industry and presents a review of research that has been conducted on design for the maritime domain. In Chapter 3, I introduce the theories and concepts I draw on in the thesis. I present my understanding of design and the design situation, and introduce the theories about sensemaking and judgement-making that are used. The chapter also provides a brief overview of the use of systems thinking in design, and presents the most important systems concepts applied in this thesis. In Chapter 4, I provide a thorough description of the research approach and the methods used. I reflect on knowledge development in the research and the quality of the research, given the chosen approach. I also make a few ethical considerations about the research. In Chapter 5, I tie the results of the research together. I provide a ‘thick’ description of challenges that come with designing for the offshore ship industry, establish what I mean by *systemic design* in offshore-specific design projects, and argue why it is of value through three design exemplars from the UBC project. I also discuss the transferability of the research. In Chapter 6, I summarise the main conclusions of the thesis, highlight its contributions, reflect upon the strengths and limitations of the research, and suggest paths for further research.

1.4 SUMMARY OF THE PUBLICATIONS

This thesis contains six publications, which are presented in an order that is logical to the argumentation of the thesis rather than in chronological order of publication.

1.4.1 Publication 1

Citation: Lurås, Sigrun, Margareta Lützhöft, and Birger Sevaldson. 2015. "Meeting the Complex and Unfamiliar: Lessons from Design in the Offshore Industry." *International Journal of Design* 9 (2): 141–154.

Type of publication: Journal article

Summary

This article presents a study in which we interviewed a total of eight industrial designers and interaction designers with experience in designing for the Norwegian offshore industry (both the offshore ship and oil and gas industry). The objectives of the study were 1) to investigate how industrial and interaction designers find designing for the offshore industry, 2) to identify the challenges designers face, and 3) to examine the strategies used to meet these challenges.

The study showed that offshore-specific design projects are complex on many levels. The designers interviewed described a number of challenges that made gaining the insights needed to develop adequate designs difficult. One major challenge they faced was gaining access to users and field sites. The designers had different coping strategies for these challenges. Systemic approaches, however, were used to differing degrees by the designers interviewed. We conclude the article by proposing that systemic approaches could help designers in this field acquire a better understanding of both the system they design *for* and the system they design *within*.

Relation to the thesis's research questions

The article mostly addresses research question 1 and provides new knowledge about what challenges designers experience when designing for the offshore industry. The article also touches upon research question 2 by initiating a discussion about how systemic design approaches can prove valuable, given the identified challenges of offshore-specific design projects.

1.4.2 Publication 2

Citation: Lurås, Sigrun, and Henry Mainsah. 2013. "Reaching Hard-to-Reach Users. Using Online Media to Get a Glimpse of Work in Marine Contexts." *Interactions*, 20 (6): 32–35. doi:10.1145/2530539.

Type of publication: Journal article

Interactions is a journal directed towards both researchers and practitioners, with the aim of having ‘a special voice that lies between practice and research with an emphasis on making engaging human-computer interaction research accessible to practitioners and on making practitioners’ voices heard by researchers’ (ACM Interactions 2015). This article thus is less academic in its tone and includes fewer references than what is normally found in academic journals.

Summary

As described in Publication 1, because gaining access to field sites offshore is challenging, designers often have to learn about the users and context of use through alternative sources. In this article we discuss how online media can be used as a secondary source of information to gain an understanding of the users and context of use. We conclude that following ‘hard-to-reach’ users (like mariners) through online media can help designers develop domain knowledge, familiarise themselves with the working environment and the tools used, and become acquainted with users’ personal aspects. We stress that online media is ideally only used as a supplementary source of information (for example to prepare for field studies on site), and not as a substitute for real field studies.

Relation to the thesis’s research questions

This article takes as its starting point that gaining insight is difficult when designing for the offshore industry and suggests an alternative and complementary approach to gaining insight by observing how the users themselves communicate about their lives. Viewing a system from multiple perspectives is important in systemic approaches (Checkland 1999; Linstone 1989; Nelson and Stolterman 2012). The publication can thus be seen as an example of a systemic design approach that informs how systemic design can be operationalised. Hence, it is related to research question 2 of the thesis.

1.4.3 Publication 3

Citation: Lurås, Sigrun, and Kjetil Nordby. 2014. “Field Studies Informing Ship’s Bridge Design at the Ocean Industries Concept Lab”. In *Human Factors in Ship Design and Operation*, 26–27 February 2014, London, UK, 27–35. London: The Royal Institution of Naval Architects.

Type of publication: Conference paper

Summary

In this paper we describe how field research has been used in the UBC project and, drawing on our experiences, discuss the role that field research may play in design projects for the offshore ship industry in general. The paper introduces the *model for design-driven field research*, which emphasises three focus areas: 1) data mapping, 2) experiencing life at sea, and 3) onsite design reflection. The offshore domain is normally unfamiliar to designers, and is environmentally and culturally very different from the contexts that most designers work with ashore. We found that the field studies helped us gain a holistic understanding of the situation we designed for, and specific insight into the operations, users, and tasks. Going to sea further provided us with a spatial understanding of the bridge environment, and an ‘embodied’ understanding of what being onboard a vessel is like. Finally, the field studies helped us assess the appropriateness of emerging designs in the context of current use. For these reasons we conclude in the paper that field research is vital when designing for the offshore ship industry.

Relation to the thesis’s research questions

Understanding the users’ situation is essential in applying a systemic design approach. Furthermore, the model for design-driven field research emphasises the importance of employing several perspectives in field research to gain the insight needed for designing. The research presented informs how systemic design can be operationalised, and therefore addresses research question 2.

1.4.4 Publication 4

Citation: Lurås, Sigrun, and Kjetil Nordby. 2015. “Shaping Designers’ Sea Sense: A Guide for Design-Driven Field Research at Sea”. In *Marine Design 2015, 2–3 September 2015, London, UK*, 53–63. London: The Royal Institution of Naval Architects.

Type of publication: Conference paper

Summary

In this paper we introduce the notion of *designers’ sea sense*: the part of designers’ maritime domain knowledge that involves ‘tacit’ and ‘explicit’ knowledge about work and life at sea. Designers’ sea sense is connected to the model for design-driven field research introduced in Publication 3, and includes having: 1) insights into the generic and specific data that affect the design process, 2) a tacit understanding of physical and mental

aspects of being in a ship environment, and 3) the ability to connect domain knowledge with design practise through design reflections. We claim that designers must go to sea to be able to develop ‘sea sense’. The main part of the paper is devoted to describing a guide for design-driven field research at sea, building on the experiences of the field studies conducted in UBC.

Relation to the thesis’s research questions

This paper builds on Publication 3 and similarly addresses research question 2.

1.4.5 Publication 5

Citation: Lurås, Sigrun. 2015. “Layered Scenario Mapping: A Multidimensional Mapping Technique for Collaborative Design”. *CoDesign*. doi:10.1080/15710882.2015.1072221.

Type of publication: Journal article

Summary

In this article I describe a technique derived from the UBC project called *layered scenario mapping*. The technique was developed to support the design team in making sense of fragmented data collected from field studies and other sources, sharing insights among the design team, and presenting the data in ways that supported our situated design work. The article describes the technique, compares it with related techniques, and discusses the usefulness of it. We found that layered scenario mapping helped us to make sense of data, and that the resulting map helped us to share insights among the team and supported our collaborative work. A practical guide describing the technique is part of the article, making it easy for others to put the technique to use.

Relation to the thesis’s research questions

The article presents a concrete example of a systemic design technique that was developed and used to address a few of the significant challenges with sensemaking and judgement-making we experienced during the UBC project. It is an example of operationalisation of systemic design and is therefore related to research question 2. The article also discusses how the technique supported our design work, and thus addresses research question 3.

1.4.6 Publication 6

Citation: Lurås, Sigrun. Forthcoming. "Systems Intertwined: A Systemic View on the Design Situation". *Design Issues*.

Accepted: 20 August 2015

Type of publication: Journal article

Summary

In this article I introduce a *systemic model of the design situation*, developed based on experiences from the UBC project as well as insight gained through the interview study and the literature review. The model presents the design situation as a 'system of systems',⁴ consisting of the *systems we design*, the *systems we design for*, and the *systems we design within*. These systems are intertwined and influence each other. I place specific emphasis on the necessity of understanding the *systems we design within*, because this system both introduces limiting factors and provides possibilities for the *system we design*, and thus influences our ability to change the *system we design for*. The model can be of assistance in framing a design project and in judging how we as designers can influence and change both the *systems we design for* and the *systems we design within* through the *system we design*.

Relation to the thesis's research questions

The systemic model of the design situation introduced is a conceptualisation of systemic design, and is thus related to research question 2. With this article I specifically aim to show how a systems perspective on all aspects of the design situation can help designers gain a better understanding of the system they design and the system they design for, as well as the systemic framework conditions of the system they design within, which limit and enable designers. Thus this article also addresses research question 3.

⁴ The term *system of systems* comes from systems engineering, and refers to a complex system that constitutes several independently operating systems with a common mission (Held 2008). In this thesis it merely refers to a system that consists of several systems.

2 BACKGROUND AND CONTEXT

To establish the context of this thesis, I start this chapter by briefly introducing the offshore ship industry and the ship's bridge. I then present a review of research relevant to designing for this domain. Finally, I introduce the Ulstein Bridge Concept (UBC) design research project, in which the research presented in this thesis was developed.

2.1 THE OFFSHORE SHIP INDUSTRY

Shipping is a unique mode of transportation and the sea remains the most important connecting link between nations (Grech et al. 2008). More than 90 percent of global trade is conducted by sea (IMO 2012). The maritime industry can be defined as all enterprises that own, operate, design, build, or supply equipment or specialist services to all types of vessels and other floating installations (Jakobsen 2011, 12). The offshore ship industry addressed in this thesis is the branch of the maritime industry that serves the offshore oil and gas industry specifically (Norwegian Shipowners' Association [Norges Rederiforbund] 2014a). The Norwegian offshore ship industry is at the forefront of technology development, and is described as having the world's most advanced offshore fleet (ibid.). There are eight 'maritime clusters' in Norway, which has contributed to the high competency and innovative culture that led to this position (Jakobsen 2011). These clusters constitute shipyards, maritime equipment suppliers, shipping companies, and educational institutions. One of the clusters is on the northwest coast of Norway, where Ulstein, the project owner of the UBC project, is located. Ulstein is a provider of ship design, shipbuilding, and system solutions for ships, and specialises in offshore service vessels (OSVs).

OSVs are ships that support the offshore oil and gas industry. Examples include platform supply vessels (PSVs) that bring cargo to and from the offshore rigs, anchor handling tug supply vessels (AHTSs) used to handle anchors for the rigs, and subsea vessels designed for underwater operations. Figure 2 shows a PSV by a rig in the North Sea, while Figure 3 shows one of Ulstein's most recent PSVs. Seventy-eight fields are in operation on the Norwegian continental shelf (Norwegian Ministry of Petroleum and Energy [Olje- og energidepartementet] 2014) and the Norwegian offshore fleet consists of five hundred OSVs (Norwegian Shipowners' Association 2014a). All types of OSVs are involved in challenging operations in tough environments, and there are high demands on the technical outfitting of the ships and the performance of the crews. The offshore ship industry is an example of a high-risk industry, where the consequences of an accident may be disastrous (Perrow 1999).



Figure 2: Platform supply vessel next to a rig in the North Sea. (Photo: Ulstein Group)



Figure 3: *The Blue Queen*, platform supply vessel of Ulstein's PX121 ship design. (Photo: Ulstein Group)

2.2 THE SHIP'S BRIDGE

The design case used throughout this thesis is the design of a ship's bridge. The bridge (or wheelhouse) is 'the centre where control is exercised over the behaviour of a vessel as a mobile entity' (Wilkinson 1971, 237)—that is, the place from whence the captain and the deck officers monitor the ship's status and control the ship. The first wheelhouse had already been built by the end of the sixteenth century, to give the helmsman shelter from the elements (*ibid.*, 237). From the first wheelhouse (consisting of one operator, one instrument, and one controller) the wheelhouse has evolved into modern ships' bridges, which consist of a large amount of equipment and technology used for a range of functions.

The placement of the wheelhouse/bridge on a typical OSV is at the top deck at the front of the vessel, as shown in Figure 4. An example of a modern ship's bridge on an OSV is shown in Figure 5. Unique to the bridges of OSVs is that they consist of two main work stations: the 'front bridge' (also referred to as the 'navigational bridge') and the 'aft bridge' (the 'operational bridge'). The front bridge points towards the forward part of the ship and is where the officers navigate and manoeuvre the ship during transit. The aft bridge (pointing towards the cargo deck) is where the deck officers monitor and control the ship during offshore operations.



Figure 4: The bridge of an OSV is typically positioned at the top deck at the front of the vessel. (Author's illustration, based on Ulstein's PX105 ship design)



Figure 5: The ship's bridge of a modern OSV. (Photo: Ulstein Group)

2.3 RELEVANT RESEARCH

In the following I present a review of design research in the maritime and offshore ship industry. Relevant research can also be found within research on maritime human factors and ergonomics (HFE), as well as research on designing for other high-risk settings. For these areas, however, I present only selected work from the literature. A review of systemic design is included in Section 3.4.2.

2.3.1 Design research in the maritime and offshore ship industry

Already in 1967, Walraven had established that there was a need for improved design of the navigational bridge with human users in mind. He suggested what may today be seen as a 'designerly approach', emphasising that 'the building of a full-scale mock-up of the centres, the apparatus, the bridge *etc.* is a very useful tool' (1967, 607). Over the years, however, researchers have paid little attention to design in the maritime industries. In his Ph.D. thesis, Porathe (2006) evaluates the appropriateness of 3D charts for navigational purposes. Røed (2007) and Bjelland (2008) both investigate design for high-speed crafts in their Ph.D. research. Røed considers the navigation aboard fast patrol boats used by the Royal Norwegian Navy. He concludes that the development

of navigation equipment would benefit from being multidisciplinary and iterative, and should employ a user-centred approach. Bjelland addresses the use of ‘haptic interfaces’ (i.e. interfaces that enables tactile or force-feedback output from the technical systems to the users) in high-speed crafts. He concludes that there is unused potential in haptic interaction and physical interfaces on such ships, and identifies a lack of theory and recommendations related to such interaction in the HFE literature.

Through conducting several design cases, he found that prototyping is vital, both for coming up with ideas and for engaging users.

Bjelland’s research is positioned within design research, whereas Porathe and Røed would seem to be positioned between HFE and design, with an emphasis on understanding the current situation and evaluation more than on the generation of new designs. Bjørneseth and colleagues, also at the intersection of HFE and design, have evaluated new interaction styles for dynamic positioning (DP) systems (Bjørneseth et al. 2008; Bjørneseth and Hornecker 2010). Their studies particularly look at the use of multi-touch and hand gestures. They conclude that direct gesture manipulation allows for more efficient task performance compared to using traditional button/menu interaction.

Linder (2008), from a design management perspective, has studied industrial designers’ contributions to innovation in the offshore ship industry on the west coast of Norway. She highlights how innovation in this industry has been technology-focussed, and suggests that industrial designers can contribute with more human-oriented innovations of the ships, and thus humanise the technology. Hjelseth and Kristiansen also consider the role of design for innovation in the Norwegian maritime industry. Hjelseth (2011; 2013) is currently investigating how 3D visualisations made by ‘game engines’ (i.e. the software suites used to create games and simulators) can be used to simulate scenarios to support collaborative design processes at the ‘fuzzy front end’ (Koen et al. 2001) of maritime innovation. Kristiansen (2014) has been using the UBC project (which this thesis also originates from) as a case in his research on design-driven innovation within the maritime industries. He identifies that the future design visions developed by UBC have led to discussions among the various disciplines of designers, engineers, management, and users, and concludes that conceptual designs are valuable means of increased innovation in the maritime industry.

Sevaldson et al. (2012) report on experiences from design students’ use of systems oriented design (SOD; see Section 3.4.2) when designing for the maritime and offshore industries. They conclude that SOD and visualisation techniques such as GIGA-mapping (see Section 3.4.2) is a promising approach for ‘generating the whole “landscape” where the

project takes place' (Sevaldson et al. 2012, 25). This leads to a holistic understanding that can help designers cope with complexity and find 'grounded innovations' (ibid., 25). (The 'GIGA' in GIGA-mapping refers to the large size of the maps made using this technique.)

The increased focus on design for the maritime domain in recent years has resulted in a newly created branch of design referred to as *marine design*. McCartan et al. (2014, 2) introduce marine design as a multidisciplinary approach to design for the maritime domain, based on the principles of industrial design and 'a holistic design process with a strong focus on the end users as well as stakeholders in the design process'. In 2011, the first international conference on marine design was organised by the Royal Institution of Naval Architects (RINA), and the same year the *International Journal of Marine Design* (IJMD) was published as Part C of the *Transactions of the Royal Institution of Naval Architects*. This journal encompasses the 'full spectrum of marine design, from small craft to superyachts, including commercial and specialist vessels' (RINA 2015).

The variety of research on marine design becomes apparent when reviewing the IJMD and the proceedings of the conferences on marine design. The following selection of papers illustrates the range of topics covered: McCartan and McDonagh (2011) address the design of luxury yachts, and Nelson (2014) compares superyachts to architecture found on shore. Both Sheridan et al. (2012) and Nazarov (2012) discuss the balancing of functionality and aesthetics in boat design, while several researchers compare marine design to design in the automotive industry, such as Tabor et al. (2011), who discuss the application of visualisation technologies used in car design when designing ships. Maritime design-driven innovation is considered by McCartan et al. (2014), among others. Several authors present design cases. Smit and Monchy (2014) discuss an industrial design approach to the design of the console for a harbour tug, while McCartan et al. (2015) have investigated the next generation 'mother ships' for wind farm support vessels. A few authors address neighbouring disciplines, such as Abeysiriwardhane et al. (2014), who discuss the introduction of human-centred design to naval architects, and Gernez et al. (2014), who propose incorporating service design thinking into the ship design process.

Marine design aims to 'improve the aesthetics, human factors and functionality of a vessel or system, and its marketability' (McCartan et al. 2014, 2); it is clear that marine design relies heavily on other fields, in particular HFE. For this reason I present a brief review of maritime HFE in the following section.

2.3.2 Maritime human factors and ergonomics

Within maritime HFE there is a larger body of research that designers may draw on. Maritime HFE was already considered in trade magazines in the 1930s and 1940s, and in the 1950s researchers began to focus on maritime HFE (Sherwood Jones 2005). Much of the maritime HFE research since then has addressed the impact of new technology on ships, and the maritime HFE community has long argued that what needs improvement on ships is not the technology, but the human-machine interfaces (e.g. Wilkinson 1974; Ivergård 1976). Yet there is still a range of human factors issues aboard ships.

Looking at the ship's bridge specifically, automation and integrated bridge systems introduce several challenges. Through several field studies on Swedish ships, Lützhöft and her colleagues found that increasingly automated and integrated systems on the bridge required the mariners to do less manual work, but more cognitively demanding integration work (Lützhöft and Dekker 2002; Lützhöft 2004; Lützhöft and Nyce 2008). Olsson and Jansson (2006) reached a similar conclusion in their observational study of work on the bridges of high-speed ferries. They found that the way in which information is integrated and presented to the officers is inappropriate and influences officers' ability to operate safely.

Mills (2006; 2008) identified several issues related to integrated systems on fishing vessels, including screen design issues and providing the user with the proper amount of user control without compromising safety. She further found that a main prerequisite for successful design of marine equipment is domain knowledge. Chauvin et al. (2009) also studied fishing vessels; addressing the use of communication technology onboard these vessels, they found that despite the range of communication means available, the fishermen's communication needs were not fully supported.

Grabowski and Sanborn (2003) studied the role of embedded intelligent technology on human performance in safety-critical systems, and found that the technology did not enhance the operators' performance, while Hanumantharao and Grabowski (2006), who investigated the introduction of new technology to enhance users' communication and performance in marine contexts, concluded that managers must acknowledge organisational factors to attain the intended benefits of new technology.

Grech et al. (2008), building on several maritime human factors studies, summarised that problems related to the design of the technology on ships include:

- lack of standardisation;
- bad usability;
- information overload issues;
- poor ergonomic design;
- technology that relies on the *absence* of human error, rather than being error-tolerant;
- automation issues, where the automation overloads, confuses, or distracts operators, rather than assisting them.

A few attempts at improving this situation can be found in the maritime HFE research. Petersen (2012), for example, conducted an extensive study within his own company, addressing the introduction of human-centred design (HCD) and usability standards in developing marine equipment. He found that a lack of tradition for involving users in the development process made the change of mindset towards HCD difficult. As a consequence, he introduced a pragmatic approach to HCD that emphasises user involvement in testing, evaluation, and assessment only. This approach proved to be valuable because it yielded observable results. He does, however, emphasise that this is just an initial step of operationalising HCD in the maritime domain.

The IMO has also paid considerable attention to the ‘human element’ in recent years. Most of the IMO’s emphasis has been on organisational issues, such as training, management systems, and safety culture (IMO 2015) and so far it has paid less attention to the ‘human element’ in the design of equipment.

A review of maritime HFE must include a mention of Edwin Hutchins and his seminal book *Cognition in the Wild* (1995), in which he reports on a substantial field study carried out on the bridge of a US Navy vessel where he investigated the cognitive aspects of ship navigation. Through this research Hutchins establishes that human cognition takes place both inside and outside of the minds of people, and emphasises the role of tools and other people in cognitive processes such as navigation. Hutchins’s work has been influential beyond the maritime field, because it bridges psychology and anthropology in a unique way and describes how cognition is always contextual and situated in a cultural setting.

2.3.3 Research on design in other high-risk domains

Looking to research on design in other high-risk domains is relevant when designing for the maritime and offshore ship industry. Examples of relevant domains include aviation, healthcare, and the process industries. Little research has addressed industrial and interaction design in these industries, however. As with the maritime industry, most of the relevant research is within HFE. The lack of research on design for such domains may be due to the limited use of design in these settings. As an example, Gannon (2010, 16–2) discusses the role of design and HFE in aviation, and describes how ‘historically, with few exceptions, these two disciplines were segregated at the cabin door: in general, human factors engineers turned to the left to design the cockpit, and industrial designers turned to the right to design the cabin’.

Examples do exist, however, of research that addresses design for high-risk environments. Roesler and Woods (2008), for instance, discuss designing for expertise in general, acknowledging that expertise is found in many serious domains where experts ‘act in high-stakes functions as surgeons, pilots, judges, commanders, and high-level decision makers’ (ibid., 216). They propose ‘practitioner-centred design’, which involves recognising the expertise of the people one designs for and acknowledging that substantial effort is required to gain the level of expertise needed to be able to design for practitioners, while at the same time acknowledging that one cannot hope to acquire the practitioners’ level of expertise. Thus, they emphasise that extensive user involvement is necessary.

A few examples may also be found within healthcare. Blomkvist et al. (2010), for instance, looked at how ‘barrier analysis’ (which is aimed at identifying that which may prevent unwanted events from taking place, or that lessen the impact of their consequences) can be used as a design tool when designing a home healthcare system. They found that actively adopting a safety perspective is important for the design of such systems, and that barrier analysis, used in conjunction with a more traditional design method, provided a richer picture that pointed out various safety issues. They state, however, that in order for barrier analysis to be an effective design tool it needs to be better described and fitted to the needs of the designer. Other examples from healthcare include Lehoux et al. (2011), who examined how professionals from different fields collaborate in the development of medical innovations, and Bredies (2009), who explored the use of systems analysis to support the design process when designing an electronic patient record.

A substantial body of HFE research from other domains may also be relevant to designers in the offshore ship industry. Examples include research on situation awareness (e.g. Endsley 1995; Endsley and Jones 2012), mostly derived from aviation, and research on ‘ecological interface design’ (e.g. Burns and Hajdukiewicz 2004), which is mostly applied in the nuclear industry. A complete review of this research literature is beyond the scope of this thesis.

2.3.4 Concluding remarks on relevant research

The existent research on design for high-risk settings in general and the maritime and offshore ship industry in particular is limited. Marine design, however, is an emerging and growing field of research and a promising development. The research literature I have identified on design in the maritime domain mainly addresses the design process or the design outcome. None of the reviewed publications address how designers cope with the complex design situation they face in this industry (one of the main topics of this thesis), except for a paper on SOD in the maritime domain by the main supervisor of this thesis (Sevaldson et al. 2012). With the increased inclusion of designers in these domains, however, there is a need for more research to learn how designers may contribute to and be better prepared for designing in such domains.

2.4 THE ULSTEIN BRIDGE CONCEPT DESIGN RESEARCH PROJECT

The Ph.D. research reported in this thesis was part of the Ulstein Bridge Concept (UBC) design research project. The aim of the UBC project was to design a *concept bridge* making visible what a near-future ship’s bridge of an OSV may look like. The concept bridge draws on the notion of the ‘concept car’ used in the automotive industry, which is ‘designed to project a vision of the future’ (Bell 2003, 9) and is ‘a calculated exercise in making the unknown visible, extrapolated from available knowledge, a sneak preview of next season’ (ibid., 9). Publically, the concept bridge developed by the UBC project is referred to as Ulstein Bridge Vision™ (see Figure 1 from Chapter 1).

The initial research objectives of the UBC were to develop a new ship’s bridge concept that would encompass the complexity of marine operations (and related safety issues) and to develop design-centred knowledge that would support the design of future ships’ bridges. Given that UBC was an innovation project aimed at ‘stimulating R&D activity in

business and industry’ (Research Council of Norway 2015) with Ulstein as a project owner, one objective of the project was also to put Ulstein in a front position in radical ship design. (Note that these are different from the research aim and questions of this thesis, presented in Section 1.2.)

The UBC project was a continuation of a pilot study called Ulstein Bridge Visions (UBV), which was carried out from March to December 2010. The UBV project was funded by the Norwegian Design Council’s Design-driven Innovation Programme (DIP) and Ulstein, whereas the UBC project was funded by the Research Council of Norway’s MAROFF programme, Ulstein, and Kwant Controls. The participants of UBC included the Oslo School of Architecture and Design (AHO), Ulstein Power & Control (a subsidiary of Ulstein Group), Kwant Controls, and Aalesund University College (Høgskolen i Ålesund). The project manager was associate professor Kjetil Nordby from AHO. The UBC project was conducted from April 2011 to May 2014; I joined the UBC project in September 2011.

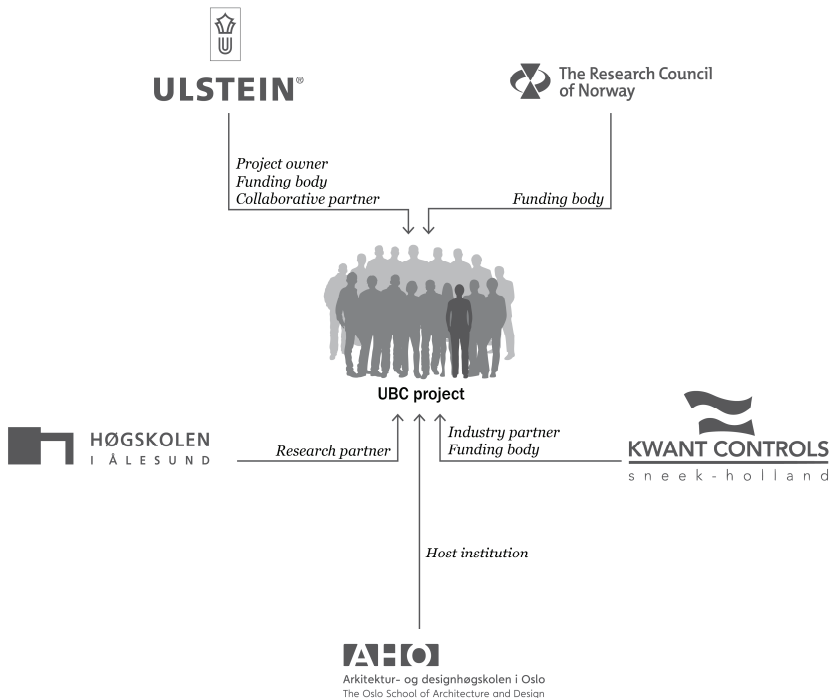


Figure 6: The UBC project and its connections with its partners.

Eighteen people were involved in UBV and UBC in total: some throughout the whole duration, and others for shorter periods of time. The team included researchers and designers from the fields of interaction, industrial, sound, and graphic design, as well as experts in human factors and engineering. The core team of the UBC project consisted of nine people, and was located at the project's lab at AHO. Of these nine people, six were engaged as designers, one as a software engineer, and two (of whom I was one) had the role of designer-researchers. Figure 6 shows the UBC project and its connections with its partners. I am represented by the person in dark grey, the rest of the core team is represented by the people in the middle tone of grey, and those who were associated with the project are shown in light grey.

The research method of UBC was 'research by design' where design is at the core of research (see Section 4.1). The design approach was design-driven, human-centred, holistic, and systemic. In addition to having a strong focus on the users' needs, much of the design work focussed on the potential of emerging new technologies, and in considering how these could be used to create better working environments on the ship's bridge. Four main design iterations of the Ulstein Bridge Vision™ were conducted:

- 2010: The design developed by the UBV pilot study (not presented publically);
- 2012: The design presented publically through a professionally produced film at the ONS trade fair in Stavanger, Norway, 29 August 2012 and online;
- 2013: The design presented publically through an interactive installation at the Nor-Shipping fair in Lillestrøm, Norway 4–7 June 2013;
- 2013/2014: Further development and detailing of the design (not presented publically).

I will in this thesis refer to the two iterations shown publically when I discuss the design. These will be referred to as the *2012 iteration* and the *2013 iteration*, respectively.

3 THEORETICAL PERSPECTIVES

The core of the research presented in this thesis has been design practise, and thus the choice of theory has been guided by the practise. This implies that an eclectic and pragmatic approach has been used in choosing concepts and theories that would inform the practise that is carried out, and that also could be used to understand it.

A common denominator across the theories used is that they are holistic and situated. They acknowledge the broader whole and context of the phenomenon addressed.

Holistic thinking is not new. Aristotle formulated his famous idea that ‘the whole is greater than the sum of its parts’ in 350 BCE. Holistic thinking further evolved through Hegel during the Enlightenment and the evolutionary biologists and gestalt psychologists in the early 1900s, and ended up as the diverse and multifaceted modern systems thinking we have today (Skyttner 2005; Capra and Luisi 2014).

Situatedness is often linked to Suchman’s (2007) notion of *situated action* and Hutchin’s (1995) work on *distributed cognition*, both of which critique the traditional view of cognition as something that merely takes place within a person’s head; they highlight that cognition is situated in (and affected by) the sociocultural setting in which it occurs.

I start the chapter by clarifying what I mean by the terms *design* and *design situation* in Section 2.1. The results of the research presented in this thesis show that the design situation of offshore-specific design projects is demanding of designers’ sensemaking abilities. Section 2.2 summarises the theoretical perspectives on sensemaking and judgement-making used in the thesis. One presumption for the UBC project was that designing a ship’s bridge is a complex task, and that systemic approaches would prove to be valuable. For this reason the use of systems thinking was pre-determined in this research; it was even stated in the advertisement for the Ph.D. position. The choice of which systemic approaches to use, however, was left to me. In Section 2.3, I provide a brief overview of systems thinking in design and present the systems theories and concepts applied in this thesis.

3.1 DESIGN AS A BALANCING ACT

I am trained in industrial design engineering, and my practical experience stems from interaction design and HFE. The view of design used in this thesis, however, builds on industrial design and interaction design.

Industrial design can be defined as:

... the professional service of creating products and systems that optimize function, value and appearance for the mutual benefit of both user and manufacturer. (IDSA 2015)

whereas the notion of interaction design when first introduced was suggested to be considered a distinct design discipline

... dedicated to creating imaginative and attractive solutions in a virtual world, where one could design behaviors, animations, and sounds as well as shapes. This would be the equivalent of industrial design but in software rather than three-dimensional objects. Like industrial design, the discipline would be concerned with subjective and qualitative values, would start from the needs and desires of the people who use a product or service, and strive to create designs that would give aesthetic pleasure as well as lasting satisfaction and enjoyment. (Moggridge 2007, 14)

Looking to other design-related professions and disciplines has been important in the research reported in this thesis for identifying knowledge and methods relevant to designing the ship's bridge. HFE, human-computer interaction (HCI), and computer-supported cooperative work (CSCW) are particularly relevant. HFE provides knowledge on humans' cognitive and physical capabilities, as well as methods for identifying human needs and evaluating work environments (e.g. Wickens et al. 2004; Stanton et al. 2005). In the UBC project, we found that several HFE methods proved useful in analysing the current situation on the ship's bridge. Further, the industrial designers of the team used anthropometry developed by HFE to detail the work-station design, and the interaction designers considered HFE guidelines on humans' information processing capabilities in their work.

HCI provides knowledge on a good 'cognitive coupling' between humans and computers (Bannon 1992). Knowledge of the characteristics of good usability developed in HCI—such as Nielsen's (1995) 'usability heuristics' and Shneiderman's (2005) 'golden rules of interface design'—proved useful in designing the user interfaces on the ship's bridge. HCI has been critiqued, however, for a narrow view of individuals' cognitive abilities and for focussing on experiments in lab settings. Hence, CSCW evolved as a reaction to these problems (Wasson 2000). In CSCW, the importance of the social context of a use situation is highlighted, and as a consequence ethnographic approaches are emphasised. Publications 3, 4, and 5 show that field research has also played a predominant role in the

UBC project and that CSCW and ethnographic approaches have influenced our fieldwork practise.

HFE, HCI, CSCW, and design are all highly human-centred fields that aim to create better situations for human users. Design, however, has a strong tradition of emphasising other aspects in addition to human needs (Figure 7): the client's *commercial objectives* must be met; the *technological factors* influencing a design must be understood⁵; *domain-specific requirements* might apply, such as rules and regulations that apply to a product within a specific context; and designers emphasise *design craft*, which is part of a designer's craftsmanship and considerations of quality, and also includes aspects such as aesthetics and 'formgiving'. Studies have shown that designers tend to frame design problems in a personal way (Schön 1983; Cross 2003; Suri 2011), and thus the *designer's intention* also influences designing. Last but not least, designers are concerned with *innovation* and making something new. In Nelson and Stolterman's (2012, 12) words, they seek to develop 'that-which-does-not-yet-exist'.

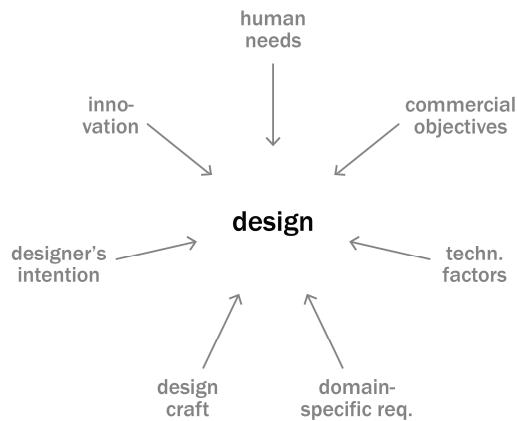


Figure 7: Design as a balancing act between different aspects of the design situation.

⁵ In interaction design, technological factors refer to the technology the user interface should make the user understand and use. It is also the material shaped by the designers (Nordby 2010). In industrial design, technological factors refer to material qualities and production technology.

When considering these aspects of design, one will always experience conflicting goals and competing design issues (Lloyd 2009). This is the paradoxical situation in which designers find themselves (Dorst 2006), and for which designers must find the solution that ‘best fits the pattern of conflicting requirements’ (Rittel 2010a, 97). One example of such a paradoxical situation can be found in interaction design. For the purpose of usability, there may be a need to standardise and be consistent with conventions. The need to standardise, however, may conflict with the need to improve the design, the client’s need to stand out in the market, and the desire to make an aesthetically pleasing product. Other such dilemmas that designers face are those between innovation, commercial objectives, and the brand. As discussed by Hestad (2013), building a brand implies coherent communication across all ‘touch-points’ with the consumer. Although innovation is needed for commercial success, innovations that are too radical may bring a product too far away from the brand, where it will no longer be recognisable and acceptable to the consumer. To design is to find a balance among these goals.

Seeing design as a balancing act implies that design is concerned with ‘satisficing’, rather than with optimising (Simon 1975). In design, there is never one best solution but rather many possible satisfactory solutions. What is considered a good design solution depends on who is judging. Designers will always have limited freedom, resources, information, or time, and must embrace ‘the adequate’ and do the best that is possible within the limits of the current project (Nelson and Stolterman 2012, 99). This view of design implies that design is a situated activity. The aforementioned Hutchins (1995) is famous for his study of distributed cognitive processes on the bridge of a navy ship. When designing a ship’s bridge, we can use his work to learn about the situatedness of navigation. We can also use his insights, however, to consider the situatedness of *designing for navigation*. Regardless of whether the cognitive work in question is planning a ship’s route or designing the electronic charts used in such planning, we must acknowledge that ‘human cognition is always situated in a complex sociocultural world and cannot be unaffected by it’ (Hutchins 1995, xiii).

The view of design presented here differs from the more positivistic views of design sometimes found within the HFE and HCI communities. In these branches of HFE and HCI, adherence to the ‘correct’ design process, the ‘proper’ choice of methods, and application of ‘best practice’ solutions are claimed to ensure a good result.

Considering design as a balancing act is similar to Dorst’s (2006, 17) proposed description of design as ‘the resolution of paradoxes between discourses in a design situation’. Because my understanding of the term

design situation may differ slightly from that held by Dorst and others, in the next section I will clarify what I mean by this term.

3.2 THE CONCEPT OF THE SITUATION IN DESIGN

Despite the frequent use of the term ‘design situation’, its meaning is often unclear. Inspired by Flach et al. (2004) and their text ‘The Concept of the Situation in Psychology’, in the following section I will attempt to unpack the concept of the situation in design, ultimately concluding with a description of what is meant by the ‘design situation’ in this thesis.

3.2.1 The users’ situation

The concept of the situation in design is highly related to the users’ situation, also referred to as the ‘use situation’, the ‘usage situation’, or the ‘context of use’. Context of use is defined in ISO 9241-11 as ‘users, tasks, equipment (hardware, software and materials), and the physical and social environments in which a product is used’ (ISO 1998, 2).

Understanding this situation is critical in all human-centred design approaches. Several methods and techniques for learning about this situation can be found in the literature.

The term ‘design situation’ is occasionally used to refer specifically to the users’ situation. Carroll (2000), for example, states:

The designers can become ‘unsituated’ with respect to the real design situation, which is not the marketing manager’s projection, or the instructional designer’s list of steps, or the software engineer’s system decomposition. The real design situation is the situation that will be experienced by the user, and designers need to stay focused on that. (Carroll 2000, 57)

John Chris Jones also seems to refer to the users’ situation when using the term ‘design situation’ in his seminal book, *Design Methods* (J. C. Jones 1992). Although he does not provide a definition or clear description of what he means by the term, a review of the methods he presents for exploring design situations (Section 3 of his book) shows that he emphasises methods for gaining insights into users’ situations by, for example, interviewing users and investigating their behaviour.

3.2.2 The design problem

In design practise, the term ‘design situation’ is sometimes used to refer to the ‘design brief’: a client’s written description of a design problem they want help with, which is used when hiring designers. In design research, the term can also be used to refer to the ‘design problem’. Dorst (2006, 11) uses *design situation* in reference to ‘the design problem as seen through the eyes of the designer’. He suggests that it is a term used to avoid the challenge that comes with the term ‘design problem’: that design is not a linear process that starts with a problem and ends with a solution. Rather, the design process should, according to Dorst, be seen as ‘the resolution of paradoxes between discourses of the design situation’ (ibid., 17), in which ‘discourses’ refer to the different ‘aspects’ a designer must take into consideration, such as technology, aesthetics, and ergonomics (ibid., 15). This fits well with the understanding of design used in this thesis (see Section 3.1).

3.2.3 The act of designing

Schön (1983; 1992a) describes designing as ‘a reflective conversation with the design situation’ through the process of ‘seeing-moving-seeing’. The designer 1) *sees* (considers) the design situation, 2) makes a *move* (draws out an idea in relation to the design situation), and 3) *sees* the design situation again and judges what he/she has drawn. These judgements are then used to inform future designing. In Schön’s application, the term ‘design situation’ refers specifically to a material situation understood through active sensory appreciation (Schön 1992a, 4). This situation is part of the designer’s ‘virtual world’ (Schön 1987, 75).

The design situation Schön discusses is restricted, consisting of the designer and the thing that he or she designs while at the drawing table. When using the term ‘design situation’, Schön thus addresses the individual designer’s judgements of the proposed solution, and not the broader aspects of the designer’s situation or how these influence the designing.⁶

⁶ It should be noted that Schön emphasises the situatedness of practitioners in other parts of his writings (e.g. Schön 1983; Schön and Rein 1994). I refer here only to his use of the term ‘design situation’.

3.2.4 The situation in which designers find themselves

Weick (2004) discusses how designers face situations of uncertainty. He uses Heidegger's concept of 'thrownness' (German: *Geworfenheit*) to describe how designers are 'thrown' into unexpected and dynamic situations 'where people are already acting, where options are constrained, where control is minimal, and where things and options already matter for reasons that are taken-for-granted' (Weick 2004, 76). Weick suggests that 'what separates good design from bad design may be determined more by how people deal with the experience of thrownness and interruption than by the substance of the design itself' (ibid., 74).

Whereas Weick does not use a specific term to describe the situation in which designers find themselves, Nelson and Stolterman (2012, 77), also using the notion of thrownness, describe that 'designers are thrown into a complex milieu when invited into a design situation'. Although they do not define 'design situation', they do devote considerable attention to the characteristics of the situation and the ways in which good designers deal with it. Most importantly, 'each design situation is an ultimate particular and requires its own unique understanding' (ibid., 221). In Publication 1 of this thesis, we describe how eight interviewed designers experienced being 'thrown' into the offshore ship industry, while the rest of the publications address how to gain insights into this situation in different ways.

3.2.5 A broader view of the design situation

A *situation* is a part of reality (Checkland and Poulter 2006) seen as a contextual whole (Dewey 1938, 66). This contextual whole consists of 'a nested set of constraints that have the potential to shape performance' (Flach et al. 2004, 44). Building on these descriptions, I use the term *design situation* to refer to the full, ill-defined, dynamic situation designers face in their situated design work, and all issues related to the 'design problems' they face. Whereas Carroll (2000, 57) clearly states that external factors that constrain design are not part of the design situation, in this thesis such external factors are explicitly included because they shape our performance and, as such, influence our possibility of ultimately addressing the users' situation. This view of the design situation incorporates all of the aspects referred to above. In Publication 6, I argue that the design situation can be seen as consisting of three overlapping systems that designers need to make sense of: the *system we design*, the *system we design for*, and the *system we design within*. This

view of the design situation and its implications are discussed further in Chapter 5.

3.3 DESIGNERS' SENSEMAKING AND JUDGEMENT-MAKING

Many design scholars and practitioners speak of sensemaking and meaning-making in design; some even define design as making sense of things (Krippendorff 1989). In this thesis, I see sensemaking as an inherent part of design and something the generative part of designing is completely dependent on.

3.3.1 A situated view of sensemaking

In Publication 6, I describe the theoretical view of sensemaking and judgement-making used in this thesis. The understanding of sensemaking that is used builds on systems thinking (in particular soft systems methodology [Checkland 1999; Checkland and Poulter 2006]) and Dewey's (1925; 1938) and Schön's (1983; 1987; 1992b) theories on experience and inquiry. I am also influenced by sensemaking as used in organisational psychology (Weick 1995; Weick et al. 2005; Klein et al. 2007) and library and information sciences (Dervin 1999). Building on these theories, I describe sensemaking in Publication 6 as 'the continuous process of attempting to gain insight into situations', where a situation is understood to be 'a part of reality seen as a contextual whole'. Sensemaking is hermeneutical (Bontekoe 2000) and always relies on pre-existing understandings, including explanatory descriptions (mental models) that are used to make sense of that which is experienced and are updated based on that which is experienced.

In Publication 6, I define the purpose of sensemaking for design to be to acquire knowledge that enables designers to develop 'adequate designs' (Nelson and Stolterman 2012, 99), and I highlight that 'there is no "correct" sensemaking and we cannot be certain that insight gained at one stage of the process will still hold at a later stage'. Thus, the knowledge we aim for is one that gives us 'an ability to answer' to the challenges of the situation we face (Lindseth 2015). It is similar to what Schön referred to as *knowing-in-action*, 'the sorts of know-how we reveal in our intelligent action' (Schön 1987, 25) 'described in terms of strategies, understandings of phenomena, and ways of framing a task or problem appropriate to the situation' (ibid., 28). *Knowing-in-action* when expressed is converted into *knowledge-in-action*, and when referring to past events, it becomes *knowledge-on-action*. Designers need such knowledge to answer to a

design situation and make design judgements that will lead to satisfactory designs given this situation.

Developing this kind of knowledge (which designers depend on in their work) relies, as described by Schön, on reflections both in and on action. Designers develop such knowledge through a continuous sensemaking-process that Schön describes as *seeing-moving-seeing* (Schön 1983). Visual sensemaking thus plays an important role in sensemaking in design (VanPatter and Jones 2009), and designers use techniques such as GIGA-mapping (Sevaldson 2011) and modelling (Dubberly 2009), both of which take advantage of visual thinking, to increase their understanding of the situations they face.

3.3.2 Judgements in designing

Sensemaking is closely linked to judgement-making and decision-making. I use Vickers's (1965) theory on *appreciative systems* to discuss the judgement-making that takes place in design. Vickers's theory is useful because it provides a vocabulary for discussing judgements, both at the individual level and at the group level, and because it makes visible the broader system in which judgement-making takes place.

The appreciative system involves making *appreciative judgements* and *action judgements* in relation to the continuous flux of events and ideas in the world. Vickers further divides *appreciative judgements* into two interconnected types of judgements: *reality judgements* and *value judgements*. Reality judgements are judgements about which facts are relevant to a current situation and help a person identify 'what is the case', whereas value judgements involves considering 'what ought to be the case'. As pointed out by Vickers, reality judgments and value judgments are inseparable. These judgements depend on our *appreciative settings*, which build on our experiences and include our standards of value and what we consider an 'ideal norm'. The notion of appreciative setting is very useful for designers, because it makes the basis that we make our judgements on explicit, and also invites designers to consider the appreciative setting others use in judging our designs.

The notions of mental models and the appreciative setting may at first seem to overlap, and one might question the need for both. The two concepts do, however, cover different aspects of what our sensemaking and judgement-making rely on and, as shown in the systemic model of the design situation introduced in Publication 6, prove valuable to use in combination. Whereas mental models are explanatory structures, our appreciative setting is not an explanation but rather represent our

standards of value and what we deem to be good or bad. Which mental model we use depends on our appreciative setting, because identifying and developing mental models involves making appreciative judgements.

Action judgements (which Vickers [1965] originally referred to as ‘instrumental judgements’) depend on the appreciative judgements. They involve judging what is possible and not possible given the situation at hand, and answering the question ‘What are we going to do?’ Vickers connects these judgements to innovation, and stresses that they require imagination. In Publication 6, I tie these judgements to Schön’s (1983) concept of a *repertoire of exemplars*. The repertoire is a practitioner’s collection of images, ideas, examples, and actions they can draw upon in their work and thus use to find answers to the question of what to do (ibid., 138). Although not discussed in depth in Publication 6, action judgements can also be tied to Nelson and Stolterman’s (2012) notion of *design judgements*. These are judgements that designers make to identify what to do. They also address ‘how to do what to do’ and include design-specific judgements such as *appearance judgements*, which involve ‘determinations of style, nature, character, and experience’ (ibid., 151); *quality judgements*, associated with craftsmanship and connoisseurship; *instrumental judgements*, (not the same as Vickers’ use of the term) ‘which [deal] with choice and mediation of means within the context of prescribed ends’ (ibid., 152); *compositional judgements*, which involve ‘bringing things together in a relational whole’ (ibid., 153); and finally *connective judgements*, which ‘make binding connections and interconnections between and among things’ (ibid., 153).

Design judgements rely to a large degree on making judgements on design proposals against a set of tacit criteria, rather than relying on a set of predefined requirements. These types of judgements play an important role in Schön’s notion of *seeing-moving-seeing* (1983). Similarly, Alexander (1964) describes how a designer judges a design through evaluating whether the fit between a form and its context is in fact a misfit. Obviously, such judgements are dependent on the designer’s appreciative setting. As Schön (1983) has described, designers also make sense of things through their generative acts in a ‘conversation with the materials of the design situation’. Thus, as made visible in Publication 6’s model, sensemaking, judgement-making, and decision-making in design cannot be separated, but must be seen as one ongoing process.

3.4 SYSTEMS THINKING

Nelson and Stolterman (2012), among others, stress that systems thinking may help designers make sense of the messy and complex design situations they face. Their rationale for this is that '[e]very design is either an element of a system or a system itself and is part of ensuing causal entanglements' (ibid., 47). Systems thinking, however, is not a single theory or approach. Rather, it is a conglomerate of theories and approaches. For this reason, it is not a straightforward task to apply systems thinking in design.

In this thesis, an eclectic approach to systems thinking is used in which concepts and theories from different systems approaches are combined. Because it is beyond the scope of this thesis to explore systemics in depth, this section is limited to a brief description of systems thinking and its role in design; it then presents a selection of the systems concepts used in this thesis. Excellent accounts of systems thinking, and how it has evolved, can be found elsewhere (e.g. Midgley 2000; Skyttner 2005; Capra and Luisi 2014).

3.4.1 The evolution of systems thinking

The modern 'systems movement' evolved throughout the twentieth century in response to the dominating mechanistic view of the world. The two main branches of systems thinking (which was conceived of in the 1940s) are *general systems theory*, proposed by the biologist Ludwig von Bertalanffy (1968), and *cybernetics*, initiated by the philosopher and mathematician Norbert Wiener (1967). A range of other approaches evolved in the years following World War II, including *systems analysis*, *systems engineering*, *operations research*, and *system dynamics*. From the late 1960s onwards, motivated by the unsuccessful attempt to apply systems engineering approaches to human systems, *soft systems methodology* (SSM) was developed (Checkland and Poulter 2006), which deals with understanding complex situations with the intent to impose change. *Critical systems thinking* (CST) is a more recent systems approach that was developed in the 1990s. It was influenced by SSM, as well as by Churchman's and Ackoff's versions of operations research (Ulrich 2012). One aim of CST is to bring different systems approaches together to support the systems practitioner in the selection of an adequate method for the problem at hand (Jackson 2003).

The different systems approaches today exist side by side. Although diverse, they all share the idea that systems are organised wholes and an

emphasis on relationships as the main building blocks of a system (Schwaninger 2006, 586).

3.4.2 Systems thinking and design: The design methods movement

In the 1960s, with the increasing need for new developments in Europe and the United States, it became apparent that traditional design approaches that viewed the product as the centre of the design task were insufficient (Bayazit 2004, 19). Hence, the design profession began to seek a more systemic and systematic approach to design, referred to as the *design methods movement*. Due to the successes of operations research and systems engineering in such areas as the military and in the space programmes, these systems approaches began to influence design (ibid., 17-18). Churchman, however, warned that this would lead to illegitimate simplifications (ibid., 21). In the 1970s two of the most important figures in the 'design method movement' of the 1960s, Christopher Alexander and J. C. Jones, refuted the first-generation design methodology they had taken part in developing (Cross 2001, 50). A new direction in the use of systems thinking in design was needed, one that would build on the 'systems approach of the second generation' (Rittel 1972). This approach acknowledged that the problems designers face are different in nature from those that can be solved by rationalist approaches such as systems engineering. Rittel proposed that these problems are 'wicked problems'—which, in comparison to 'tame problems', are 'fuzzy' and never quite solved. In-depth descriptions of the distinguishing properties of wicked problems can be found in the articles 'On the Planning Crisis' (Rittel 1972) and 'Dilemmas in a General Theory of Planning' (Rittel and Webber 1973). I shall only touch on the main points here, as described by Rittel and Webber (1973, 161–167).

A 'wicked' problem is one that is characterised by not having a definitive formulation, thus implying that formulating the problem and conceiving of the solution are the same process. The choice of explanation determines the nature of the problem's resolution; how a wicked problem is defined is a judgement task, since '[t]he analyst's "world view" is the strongest determining factor in explaining a discrepancy and, therefore, in resolving a wicked problem' (ibid., 166). Finding a solution to a wicked problem is potentially daunting because there is no 'enumerable (or an exhaustively describable) set of potential solutions' (ibid., 164) to use as a starting point. Every wicked problem is essentially unique, and the direct transfer of the solution of one wicked problem to another wicked

problem can, according to Rittel and Webber, be positively harmful. When engaging in wicked problems, the problem-solver has no criteria that can be used to tell when the problem has been solved, or for deciding whether a true or correct solution has been found. Assessing a solution of a wicked problem is dependent on judgement-making, and who is making these judgements matters. Because every implemented solution of a wicked problem is consequential and leaves traces that cannot be undone, ‘every trial counts’ and any solution is a ‘one-shot operation’ (ibid., 163). This means that designers are liable for the consequences of a proposed solution to a wicked problem.

Since its introduction, designers have embraced the concept of wicked problems to describe the nature of design problems (e.g. Buchanan 1992; Coyne 2005; P. Jones 2013). In Section 5.1.6, I discuss how the designing of a ship’s bridge can be seen as a wicked problem.

3.4.3 Recent evolvments: Systemic design

In 2001, Findeli called for the integration of systems theory in design education for the twenty-first century (Findeli 2001). Two years later, Broadbent predicted that the next-generation design methodology would take on an evolutionary systemic thinking-approach, where science and design, as well as reductionist and holistic approaches, would merge (Broadbent 2003). In 2010, Valtonen posed the question ‘Is systemic design the next big thing for the design profession?’ (Valtonen 2010). And design education institutions, design researchers, and practicing designers have indeed paid increasing attention to systems thinking in recent years.

Krippendorff has, for the last three decades, encouraged a systemic view of design through his writings on product semantics (e.g. 1989; 1997; 2007), while Jonas has considered the use of systems thinking in design research since the mid-1990s. He uses cybernetics to consider the nature of design research, and suggests that design and design research (in the form of *research through design*) can be seen as cybernetics processes (Jonas 1996; 2007a; 2012; 2015). He also argues for the use of CST to meet the challenges of practise-based design research (Jonas 2014).

The research on product service-systems (PSSs), which originated in the 1990s, is also an example of the application of systems thinking in design. PSSs are an integrated combination of products and services that are often motivated by environmental sustainability, while at the same time fulfilling customer and business needs (Manzini et al. 2001).

Harold Nelson has worked with the integration of systems thinking in design for a number of years. In 2003, the first edition of the seminal

book *The Design Way* by Nelson and Stolterman was published; a second edition was published in 2012. In this book, the authors consider design theory and practise from an inherently systemic perspective, and present a systemic vocabulary and schemas to help designers cope with the complexity of the design situations they face.

In the last few years, an increased consideration of systems thinking in design has been visible from the great interest shown in the ‘Relating Systems Thinking and Design’ (RSD) symposia. These events have taken place annually since 2012, with the intention to ‘promote and foster the emerging dialogue of rethinking systems approaches in design’ (Systemic Design Research Network 2015). *Systemic design* has been used within the community that has taken part in these symposia as an umbrella term for attempts to merge systems thinking and design. This term invites a diverse range of perspectives and approaches (Sevaldson and Ryan 2014). At the second RSD symposium, Nelson (2012 referred to in Ryan, 2014) defined systemic design broadly as ‘inquiry for action’. Further definitions have been developed by Ryan (2014) and Peter Jones (2014a). Jones suggests the following definition:

Systemic design is concerned with higher order systems that encompass multiple subsystems. By integrating systems thinking and its methods, systemic design brings human-centered design to complex, multi-stakeholder service systems as those found in industrial networks, transportation, medicine and healthcare. It adapts from known design competencies—form and process reasoning, social and generative research methods, and sketching and visualization practices—to describe, map, propose and reconfigure complex services and systems. (P. Jones 2014a, 93)

Jones emphasises that systemic design is not a design discipline, but rather an orientation. With the intent of answering the question ‘[w]hat relationship between systems thinking and design thinking will improve design practice?’ (ibid., 104), he proposes ten systemic design principles for social system design, building on concepts found in systems sciences and design theory.

Ryan (2014, 12) describes systemic design as being ‘intended for challenges characterised by complexity, uniqueness, value conflict, and ambiguity over objectives’. Building on this definition, he introduces a framework for systemic design that consists of the three levels *mindset*, *methodology*, and *method*. Ryan characterises a systemic design mindset as one that is inquiring, open, integrative, collaborative, centred, and having a tendency to employ multiple perspectives. The methodology in

this framework guides the application of methods, while the method level involves the selection of design methods, systemic methods, systemic design methods, and even methods that are neither systemic nor ‘designerly’. The latter methods are included because what matters is that the project as a whole is systemic and designerly, and not the individual methods. The framework is originally intended for organisational design and for the initial stages of a design process, however, may also be used at the later stages of the design process (Alex Ryan, e-mail correspondence 18 August 2015).

An example of a systemic design approach that takes design practise as its starting point is SOD, which is a design approach developed at AHO since 2006 that aims to develop ‘designers’ own interpretation and implementation of systems thinking’ (SOD website 2015). It is ‘based on designerly skills’ (Sevaldson 2013, 2) and does not entail following one specific systems approach, but rather (inspired by CST) encourages designers to use approaches from different systems theories as they are deemed useful (ibid.). Despite this vague and open description, a few common denominators of the SOD approach can be identified. The most important aspect is visual sensemaking and mapping techniques, particularly GIGA-mapping, which involves ‘creating an “information cloud” from which the designer can derive innovative solutions’ with the purpose of trying to ‘grasp, embrace and mirror the complexity and wickedness of real-life problems’ (Sevaldson 2011). SOD has influenced the view of systemic design put forward in this thesis, with its eclectic approach to systems thinking and its emphasis on systems mapping.

The second RSD symposium in 2013 resulted in two special issues of the design research journal *FORMakademisk* (vol. 7, nos. 3 and 4 [2014]). A review of the presentations given at the first three symposia, as well as the articles published in *FORMakademisk*, suggests that the main emphasis on systemic design in recent years has been within the practises of service design, organisational design, social design, and architecture, as well as in theory development. Little attention has been paid to systemic design for industrial or interaction design. One exception is Sheiner (2014), who, in his presentation at RSD3, proposed the use of systems models at different abstraction levels to bridge the gap between interaction designers and software developers. Despite this tendency, systemic design is—according to Birger Sevaldson, one of its initiators—also intended to include the traditional design disciplines, such as industrial and interaction design (personal communication 25 August 2015).

Although not framed as systemic design, marine design (McCartan et al. 2014) incorporates systems thinking through ‘human systems integration (HSI)’ developed within the military and ‘the Five M

framework', which is a sociotechnical system approach to ergonomics that emphasises the integration of user (human), machine, task (mission), medium (social context), and management (Harris and Harris 2004, 554). While these approaches are valuable in understanding the users' situation (referred to in this thesis as the *system we design for*), marine design has so far not used systems thinking to consider the situation within which the design team finds themselves (the *system we design within*).

In the next section I will present the systems concepts that have proved important in informing the practise conducted as part of this Ph.D. research, and that have informed the conceptualisation and operationalisation of systemic design proposed in this thesis.

3.4.4 Systems thinking in this thesis

Traditional systems approaches, such as systems engineering and operations research, build on an assumption that the world consists of interacting, observable systems. Checkland (1999) referred to this idea as a 'hard systems stance', and proposed SSM as an alternative, where the world is seen not as consisting of systems, but rather 'the (social) world is taken to be very complex, problematical, mysterious, characterized by clashes of worldview' (Checkland and Poulter 2006, 21–22). Checkland (1999) critiqued hard systems approaches for taking on the mindset that the world can be controlled and engineered. The notion of worldviews is fundamental to SSM, which claims that there is no such thing as systems, but rather different views of a situation.

Jackson (2003), using the concepts of hard and soft systems theories, proposed the concept of 'creative holism', where one may draw on both stances, and the choice of a hard or soft systems method depends on the needs at hand. Such an approach is in line with the one applied in this thesis, where systems concepts and approaches are used as they are deemed useful in the design situation at hand, without worrying about adhering to one systems theory. In an unpublished paper, the late communications theorist W. Barnett Pearce (1998) referred to a distinction similar to that of hard and soft systems stances as 'thinking about systems' and 'thinking systemically':

The distinction between thinking about systems and thinking systemically hinges on the perspective of the person doing the thinking. One can and usually does think 'about' systems from outside the system. That is, whether we might describe the thinking as ontologically a part of the system or separate from it, in this instance the thinker takes the observer-perspective. When thinking

systemically, on the other hand, the thinker is self-reflexively a part of the system and takes the perspective of a participant or component of the system. (Pearce 1998, 2)

Although not commonly referred to in the systems literature, I find Pearce's terms more descriptive than those of Checkland, and will in the following refer to 'thinking about systems' rather than 'hard systems thinking', and 'thinking systemically' rather than 'soft systems thinking'. Both, however, rely on a comprehensive understanding of systemics.

At the third RSD symposium, on 17 October 2014, Hugh Dubberly urged designers to develop systems literacy, and presented a list of more than a hundred systems concepts that, in his opinion, designers should be familiar with. Discussing in detail all the systemic concepts that are potentially relevant to design would be beyond the scope of this thesis. Instead, I will present a selection of systemic concepts that have played a role in the research presented in this thesis. These concepts are sorted under thematic headings and are accentuated with *italics*.

The system

Many definitions of the term *system* have been proposed, and how a system is understood is an ontological question—that is, a question of how we understand the reality. A system can be broadly defined as a whole that consists of interacting parts (Laszlo 1996). Often, a system is defined as also having an emergent property or a common function/purpose. The *function* (for non-human systems) or *purpose* (for human systems) is that which the system tries to achieve (Meadows 2009, 14). *Emergence* is a property that is not present in the parts but arises from the whole.

I find it useful in design to have a flexible understanding of systems, and to build on the view that 'a system is not something given in nature, but something defined by intelligence' (Beer 1994/1966, 242). This implies that anything can be called a 'system' that can be 'perceived/conceived as consisting of a set of elements, of parts, that are connected to each other by at least one discriminable, distinguishing principle' (Jordan 1981, 24). What this 'discriminable, distinguishing principle' is depends on what is deemed useful by the designers in their situated work.

A *subsystem* is 'equivalent to *system*, but contained within a larger system' (Checkland 1999, 317; emphasis in original). In Publication 6, I propose seeing the design situation as a system that consists of three overlapping and intertwined subsystems: the *system we design*, the *system we design for*, and the *system we design within*.

A system's *environment* is a set of elements that are not part of the system, but that, if changed, can produce a change in the state of the system (Ackoff 1971, 662–663). Given the belief that anything that is deemed useful to consider a system *is* a system, the drawing of the boundary between a system and its environment is up to the system observer. Thus, *system boundaries* are invented (Meadows 2009, 97). Setting system boundaries in design is related to *framing* (Schön 1988). CST emphasises *boundary critique*, in which what should be included in a system is critically considered. Engaging in such a critique implies judging 'what "facts" (observations) and "norms" (valuation standards) are to be considered relevant and what others are to be left out or considered less important' (Ulrich 2002), and thus involves making appreciative judgements (Vickers 1965).

Parts and the whole

The concept of the *whole* is important in systems thinking and the term 'holism' is sometimes used interchangeably with 'systems thinking'. Nelson and Stolterman (2012, 97) describe the whole as a 'functional composition' that can be either natural or designed. The whole is related to emergence, which is caused by a system's *structure* and is 'the result of the relations and connections binding the elements together in unity' (ibid., 96). The authors (2012, 70) make the following distinction between *relationships* and *connections*: 'Relationships define how things contrast and compare with one another while connections determine how causal power or influence is transferred between things'. It is useful for designers to acknowledge that the parts of a system can be linked and can influence each other in different ways, and that all links are not causal. Sevaldson highlights this, and has developed an overview of the variety of systemic relations that can be used in GIGA-mapping (Sevaldson 2015).

System changes and circularity

The *state* of a system is 'a set of relevant properties which a system has at a moment of time' (Ackoff 1971, 662) and a 'well defined condition or property that can be recognised if it occurs again' (Ashby 1956, 25). States are related to *change*, which can be described as the *transition* from one state to another (ibid., 10). A *dynamic system* is one 'to which events occur, whose state changes over time', whereas a *static system* is a one-state system 'to which no events occur' (Ackoff 1971, 663). Most (if not all) systems that designers engage in are dynamic.

Cybernetics emphasises the notion of *goals*, which can be described as desired states. Ackoff and Gharajedaghi (1996) emphasise that a goal is not the same as a purpose. While *purpose* implies will (and is normally

used for human systems), a technical system can be goal-seeking, but does not have its own will.

Closely associated with dynamic systems and goals is the concept of *feedback*. Loosely defined, feedback is an effect on the input by the output. Wiener (1967) illustrates the concept with the example of a steersman of a boat: when the boat deviates from its course (i.e. its goal), the steersman assesses the deviation and uses the rudder to counter-steer. Thus, the steersman controls the ship. On a ship's bridge, many of the technical systems are automatically and continuously controlled towards a goal (the system's *set point*) through feedback control. Understanding the concept of feedback is absolutely necessary for designers to be able to design the user interfaces of such systems. Feedback is also related to *self-regulation*, which is self-correction through feedback (Capra and Luisi 2014, 67). Wiener's example of the steersman is one of self-regulation. Glanville (2007) has suggested that designing can also be described as a feedback loop, and a continuous process of self-regulation.

Constraints and variety

Variety is formally defined by Ashby (1956, 126) as the number of distinct elements in a *set*, whereas he defines *constraint* as 'a relation between two sets, [which] occurs when the variety that exists under one condition is less than the variety that exists under another' (ibid., 127). Requisite variety means that the variety of a control system must be equal to or greater than the variety of the system controlled (ibid., 207). Ashby used the concept to describe how organisms are able to adapt to their environment.

Rittel (2010b, 107), influenced by Ashby, used the concepts of variety and constraints to describe the design process as a twofold process involving: 1) the generation of variety and 2) the reduction of variety. In the solution space for a design problem, there are potentially billions of alternatives. Constraints reduce variety and make the search for a solution more manageable. A design process can be constrained either from the outside or from within (Fischer and Richards 2014). In this thesis, I mainly refer to the external constraints of the design situation that shape designers' performance (and thus influence the designs), and only briefly touch upon internal constraints, which designers themselves impose. The external constraints that designers experience are discussed primarily in publications 1 and 6.

Systemic intervention

Midgley (2000) defines *intervention* as 'purposeful action by a human agent to create change' (ibid., 113), and *systemic intervention* as

‘purposeful action by a human agent to create change in relation to reflection on boundaries’ (ibid., 129). Meadows (1999) uses the concept of *leverage points* to identify the most effective and powerful interventions in a system ‘where a small shift in one thing may produce big changes in everything’ (ibid., 1).

The notion of interventions is useful in design; designing can itself be seen as an intervention. In Publication 6, designs are seen as ‘events and ideas’ that contribute to the world’s flux, and thus influence people’s appreciative setting (Vickers 1965). These events and ideas thus function as interventions. In a paper that is not included in this thesis we initiated a discussion on how the designs of the UBC project serve as systemic interventions (Lurås and Nordby 2013). In this paper, we suggest that Meadow’s (1999) ‘places to intervene in a system’ can be used to judge the systemic impact of a design outcome. The topic of the systemic effects of the UBC project is also touched upon in Section 4.7.3, in the discussion on the relevance of the research.

In SOD, ‘ZIP-analysis’ (short for ‘Zoom, Innovation, Potential’) is used to identify potential areas for interventions and innovations in a system (Sevaldson 2013, 17). ‘Z-points’ are areas in a system that require more research; ‘P-points’ are areas with potential for improvement; and ‘I-points’ are ideas or solutions to a problem in the system. In SOD, ZIP-analysis is used to identify such areas in a GIGA-map. In UBC, we also used ZIP-analysis to interpret observations in field research, and in Publication 4 we encourage using ZIP for such a purpose in our guide for design-driven field research.

Mapping and modelling

A *model* is a representation of a system and an intellectual construct (Checkland 1999, 315). The purpose of a model is to organise, clarify, and unify knowledge in order to give people a better understanding of a system (Forrester 1991, 15). System dynamics and cybernetics both stress the development of formal models that can be used for simulation. In design, models can help us make sense of things and serve as hypotheses of how the world works (Dubberly 2009, 54). Modelling is related to *mapping*, used to organise and represent knowledge (Novak and Cañas 2008, 1), and can help us to identify patterns (Capra and Luisi 2014, 83). The mentioned technique of GIGA-mapping is a design-oriented mapping technique that is used for system mappings that aid designers’ sensemaking (Sevaldson 2011).

Mapping and modelling have played important roles in this thesis. They were used in the analysis of the interview study presented in Publication 1, and were also used extensively in the practical design work

of the UBC project. Section 4.3.4 touches on the role of mapping and modelling in UBC. In addition, Publication 5 is devoted to describing and discussing a mapping technique developed in UBC.

Perspectives

A systems approach ‘begins when first you see the world through the eyes of another’ (Churchman 1968, 231 cited in Ulrich and Reynolds 2010, 243). Complex systems cannot be considered from one point of view only: applying different perspectives is important in systems thinking (Nelson and Stolterman 2012) and paramount in ‘thinking about systems’ (Pearce 1998).

The *multiple perspective approach* is a systemic approach that emphasises that any system should be considered using three types of perspectives, and the interactions between them (Linstone 1989, 312):

- T:** The technical perspective;
- O:** The organisational or societal perspective; and
- P:** The personal or individual perspective.

Design for the maritime domain traditionally has been carried out by engineers (Lützhöft 2004), and has tended to employ the T-perspective only. Emphasising all three perspectives is important to designers in the offshore ship industry. The T-perspective is important because these industries rely heavily on highly advanced technology, and (as described in Publication 1), most design projects for the maritime and offshore industries involve technology. In many cases, technology is the design material that we need to understand before we can shape it (Nordby 2010), or it is what we should help the user to understand and control. Either way, it must be understood in depth. The P-perspective represents the human users and other actors, and already holds a strong position in design. The O-perspective is present all the way throughout the design process, from setting the initial framework conditions of the designing to implementation.

The multiple perspective approach forces us to distinguish between **how** we are looking at something and **what** we are looking at (Linstone 1989, 312). Another important consideration emphasised in systems thinking is **who** is doing the looking. The Chilean biologist and systems thinker Humberto Maturana (cited in von Foerster [1979, 1]) proposed that: ‘Anything said is said by an observer’. This acknowledgement of the *observer*, inherent in second-order cybernetics, implies (as argued by von Foerster) that objectivity is impossible. In addition, the acknowledgement of the presence of the observer implies acknowledging that the observer

has a purpose for entering the system, and thus can be held accountable for his/her actions. Glanville's (1997) concept of observer positions in first- and second-order cybernetics makes the distinction visible between thinking about systems and thinking systemically. With a first-order cybernetics view, the observer is outside looking inwards, and thus thinking about systems. Taking a second-order cybernetics view, the observer is within the system, and thus thinking systemically.

SSM also emphasises **who** is making an observation, and underlines the importance of their *worldviews* (Checkland and Poulter 2006). Worldviews are tied to Vickers's (1965) notion of the appreciative setting introduced in Section 3.3.1. Engaging a broad set of stakeholders is important for ensuring that several worldviews are catered to. CST uses the method 'critical systems heuristics' (Ulrich and Reynolds 2010) to make the values of different stakeholders explicit. Involving stakeholders is also stressed by champions of transdisciplinarity, who claim that traditional disciplinary investigations limit our understanding (e.g. Gibbons et al. 1994). As Gharajedaghi (2011, 89) points out, however, 'the notion of a multidisciplinary approach is not a systems approach'. It is rather the ability to synthesise the different perspectives into a coherent whole that is systemic.

3.4.5 Reflections on the use of systems thinking

As I have described, systems thinking is not one topic but a diverse field, and a conglomeration of theories and approaches that can be difficult to grasp in full. Gaining an overview and understanding of the field of systems thinking has been the most challenging part of my research, and it took me a long time to figure out what systems thinking means in my practise and in my research, and to identify the systemic theories and concepts that fit my view. I reviewed a substantial amount of literature on different systems theories and approaches, which made it no easier to decide on one theory to use. I felt what Collopy (2009) states: systems thinking in itself is a complex system that is challenging to understand. The amount of foundational knowledge required to employ systems thinking has become so vast that it is a substantial barrier to using it.

In his keynote at the second RSD symposium on 11 October 2013, Harold Nelson encouraged the audience to consider 'systems thinking *and* design' rather than systems thinking '*either/or*' design. My struggle was exactly how to consider this *and*. I felt as if the theory I reviewed would be 'added on' to my practise, rather than being integral to it. And, since most systems theories were developed within other areas (such as

biology, control theory, and management studies), the systems concepts often had to be used as metaphors—making the concepts at times more likely to confuse than illuminate. In response to these struggles, I found that I had to use my practise, rather than the literature, as a starting point. I knew that I was systemic in my practise. Yet as a practitioner, I did not have a clear view of which traditions of systems thinking my systemic practise utilised. In my research, I had to identify the systemic concepts that were of importance in my practise, which I used consciously or unconsciously. In Section 4.5, I describe this process of identification, which resulted in the concepts presented in Section 3.4.4. These concepts are derived from different systems approaches. Such an eclectic and pragmatic approach to the use of systems thinking is a prominent feature of the emerging field of systemic design. Sevaldson describes that SOD builds on CST in its selective and critical use of systems frameworks in relation to what purpose they serve. Peter Jones (2014a) draws on different systems theories in his proposed systemic design principles for complex social systems.

There are certain limitations to the selected systems concepts that are worth addressing. Although considering both the whole and the parts is emphasised in systemic design—for example in SOD, through the ‘multi scalar approach’ in GIGA-mapping (Sevaldson 2011)—there is the risk of forgetting the importance of the parts at the expense of the whole. To be able to go beyond design at a conceptual level and to reach designs that are possible to implement in offshore-specific design projects, a designer must pay substantial attention to the details. Otherwise, designers may (as one of the designers referred to in Publication 1 stressed) end up only developing the superficial aspects of a design, thus leaving a substantial part of the design decisions to the engineers who are implementing the design. As Charles Eames said, ‘The details are not the details; they make the product’ (2015). Consequently, the focus on the whole and the parts must be consciously balanced in systemic design.

A further challenge with systemic design is that the focus on systems concepts, such as relationships and connections, mapping and modelling, and constraints and variety, may make it difficult to maintain focus on the human user. This is ironic, given that the use of systems thinking in design is partly motivated by the limitations of human-centred design. Sanders and Stappers (2008, 10) state that ‘it is now becoming apparent that the user-centred design approach cannot address the scale or the complexity of the challenges we face today’, while Norman and Verganti (2013) claim that radical innovation is unlikely with traditional human-centred design involving user studies and usability testing. Hence, systemic design needs to balance the system focus and the human focus.

Another tension between systems thinking and human-centred design may be that the ‘system goal’ and ‘the users’ goal’ may not be the same. At times, they may even be contradictory. This dilemma brings us to the notion of goals in general, which can be problematic. Goals, as used in cybernetics, are obviously useful to designers in understanding technical systems. When addressing the human part of the system, however, goals are not useful in the same way. A human will always have many—sometimes conflicting—goals. In Wiener’s example of steering a boat (1967), only the steersman’s goal of keeping a ship’s heading on course is acknowledged, and not all of the other more or less rational goals the steersman will have. Vickers (1965, 31–33) also criticised the use of goals when discussing human systems; he stressed that humans are not goal-seekers, but rather strive to maintain relationships. This view of humans is also relevant when considering the human-activity system of designing. Implicit in the view of design as a balancing act is that designers do not strive to fulfil one specific goal but rather strive for a satisfactory relationship between the different aspects they need to balance in their designs. Glanville’s proposal (2007) that design is cybernetics in practise can thus hold true only if one considers a designer’s goal to be to balance different goals, and not to achieve one specific goal.

4 RESEARCH APPROACH AND METHODS

In this chapter, I describe and discuss the research approach I have applied. I start by giving a short introduction to research about, for, and by design in order to position my research and to be able to discuss what kind of knowledge has been produced through this thesis. Following this, I present my research strategy and describe the research methods applied and the design activities carried out. Finally, I reflect upon the research approach, knowledge development, quality of the research, and ethical issues faced.

4.1 RESEARCH ABOUT, FOR, AND BY DESIGN

Research in design is often described as being of three types: research *into/about* design, research *for* design, and research *through/by* design. The distinction was introduced by Archer already in the 1960s (Pedgley and Wormald 2007), although it was later popularised by Frayling (1993), who is most often referred to as the originator of the framework.

The design research community seems to agree that research *into/about* design refers to research about design's objects and processes, or the meaning of design (for instance to society). Examples of this type of research include research about design practise, such as Schön's (1983) investigations into designers' 'reflective practice' and Cross's substantial research on design activity and expertise (e.g. Cross 2001; 2004; 2011), and research on design history, such as that of Heskett (1980) and Margolin (1995; 2010).

Research *for* design has different uses in the literature. Frayling (1993) originally described it as the gathering of reference material and a research activity 'where the goal is not primarily communicable knowledge' (ibid., 5). Findeli et al. (2008) similarly describe research for design as activities that ensure that a design project is properly informed. Archer uses the notion of 'option research' in his article on the nature of research (Archer 1995). Option research is research that is 'valid only in the circumstances of the situation enquired into' (ibid., 7). Both Archer and Findeli et al. state that such research usually does not conform to the standards of academic research, and rarely produces new knowledge.

Zimmerman and Forlizzi (2014), who use Frayling's framework in the context of HCI, have a different understanding and describe research for design as 'research intended to advance the practice of design' (ibid., 169). This includes any research that 'proposes new methods, tools, or approaches; or any work that uses exemplars, design implications, or problem framings to discuss improving the practice of design' (ibid., 169).

The definition of research *through/by* design may also be ambiguous. Whereas research *about* design and research *for* design refer to the object of research and the potential outcome, research *through/by* design suggests an approach or method where design is at the core. While this may imply the use of design to develop new knowledge about or for design, from the term it may also suggest the use of ‘designerly approaches’ to develop new knowledge on phenomena other than design. Frayling (1993) has been criticised for not defining research through design properly (e.g. Jonas 2007b; Friedman 2008; Sevaldson 2010), and several attempts have been made to concretise the concept.

In his approach to research through design, Jonas (2007b) proposes a generic design research model that is guided by the design process rather than the scientific process. This implies an understanding of design as a cyclical learning process, with a focus on knowledge about creating objects rather than knowledge about objects *per se*. He further observes that research through design in cybernetic terms ‘means a shift from 1st to 2nd order observation’ because ‘[w]e include our own observing and acting, not as deplorable limitation but as a constitutive and essential part of the inquiry’ (Jonas 2015, 30). Building on Glanville’s (1997) notion of observer positions, Jonas (2012, 34) suggests that research through design implies that the observer is inside the design system, looking outwards.

Findeli and his co-authors (2008) suggest a research through design-method named ‘project-grounded research’ (French: *recherche-projet*), in which a design project is core and where the aim is to develop a theory of design based on the design work within the project. They stress that such research must be both rigorous (as research about design) and relevant (as research for design).

Within the HCI community, research through design has gained considerable attention since the beginning of this century (Fallman 2003; Zimmerman et al. 2007). Zimmerman and Forlizzi (2014, 167) describe research through design as ‘an approach to conducting scholarly research that employs the methods, practices, and processes of design practice with the intention of generating new knowledge’, while Gaver (2012, 937) stresses that in research through design, ‘the resulting designs are seen as embodying designers’ judgments about valid ways to address the possibilities and problems ... [of] situations chosen for their topical and theoretical potential’. Koskinen et al. (2011) suggest the wider concept of *constructive design research*, encompassing all types of design and HCI research within which something is designed (constructed).

At AHO, there has been a tendency in recent years to use the term ‘research *by* design’ to describe research that encompasses design practise. Sevaldson (2010) describes research by design as an particular research

mode where ‘the explorative, generative and innovative aspects of design are engaged and aligned in a systematic research inquiry’ (ibid., 11). In research by design, according to Sevaldson, the researcher is also a practitioner and the research is conducted from a ‘first-person perspective’, where new knowledge is developed through self-reflection.

I build on Sevaldson’s definition and use the term ‘research by design’ to describe research carried out *by* designing to develop knowledge *for* and *about* design. Designing here is not restricted to the act of designing, but refers to all activities necessary in order to create designs. As pointed out by Findeli et al. (2008), such research is naturally conducted within the context of a design project. The aim of such a project is to develop new generic knowledge relevant to the design profession by engaging in a design project chosen for its suitability for addressing a given research aim. In order for the knowledge that is developed to qualify as academic research, it must be carried out as a systematic research inquiry and should be complemented by a reflective text (Archer 1995; Findeli et al. 2008; Sevaldson 2010; Gaver 2012). Table 1 summarises how research about, for, and by design is understood in this thesis.

Research about design	Research with the purpose of gaining new knowledge about design activities
Research for design	Research conducted as part of a design project, with the purpose of informing designing
Research by design	A research approach in which design practise is at the centre of research, and where designing is conducted with the purpose of developing knowledge <i>about</i> and/or <i>for</i> design

Table 1: The terms research about, for, and by design as used in this thesis.

Research by design is still in its infancy and no agreed-upon approach for how to carry it out can be found in the design research literature. Some consider such research in art and design to be a specific research paradigm in line with quantitative and qualitative research (e.g. Haseman 2006). I, however, find it more useful to see research by design as an offspring of qualitative research, where the designer-researcher is responsible for the full process of generating, capturing, and interpreting/analysing the research data. Similarities can be found with social sciences that use fieldwork, where the researcher also generates what is interpreted through the creation of field data (Banks 2007, 59). A

major difference, however, is that the purpose of research by design is not only to understand what *is*, but also what *could be*.

4.2 RESEARCH STRATEGY

The research presented in this thesis is research *about* design, and the main research approach applied has been research *by* design (involving research *for* design). The research by design-approach has been complemented by an interview study with designers who have experience in the maritime and offshore industries. A literature review was also conducted. This is a ‘flexible research design’ (Robson 2011) inspired by the concept of triangulation, which means to use ‘two or more aspects of research to strengthen the design to increase the ability to interpret the findings’ (Thurmond 2001, 253). Publication 1 of this thesis relies solely on the interview study, publications 2, 3, 4, and 5 rely on the research by design-approach, and the results of the triangulation are presented in Publication 6 and Chapter 5 of this thesis. In Publication 6, the interview study and experiences of the UBC project informed the model that is presented, which was developed further by considering it in relation to the systemic concepts and theories about sensemaking and judgment-making derived from the literature. Chapter 5 builds on a triangulation of the findings from all three research approaches. It expands the insights found on challenges in designing for the offshore industry, and advances my view of systemic design in the context of offshore-specific design projects.

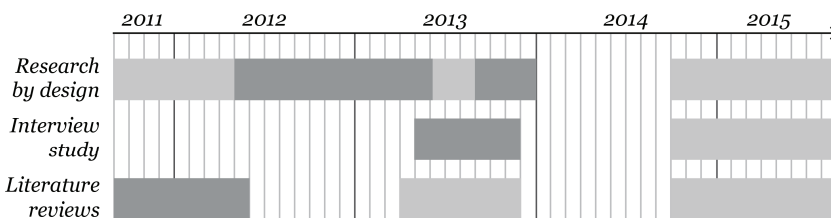


Figure 8: Emphasis on the different research methods used throughout the Ph.D. project. The tone of grey indicates how much emphasis I placed on the activity at the time (dark = more emphasis).

Figure 8 indicates when in time the different research methods have been emphasised in my Ph.D. project. The tone of grey indicates how much emphasis was placed on the activity. As the figure shows, most effort was

put on research by design. I placed little emphasis on research by design, however, during the first eight months due to obligatory research training as part of the Ph.D. programme at AHO ('Research School'). In the summer of 2013, I again placed less emphasis on research by design-activities, as I was conducting the interviews for the interview study. Most of my efforts were on literature reviews at the beginning and end of the Ph.D. work, although I also conducted literature reviews as part of writing articles and papers throughout the project. From January 2014 to October 2014, my engagement in research activities was limited due to maternity leave. The UBC project ended May 2014, and as a consequence it was not possible to engage in more design work once I returned from maternity leave. Interpretation of the data collected from the UBC project, however, continued until the thesis was submitted in September 2015. Interpretation of the data from the interview study also continued with the triangulation.

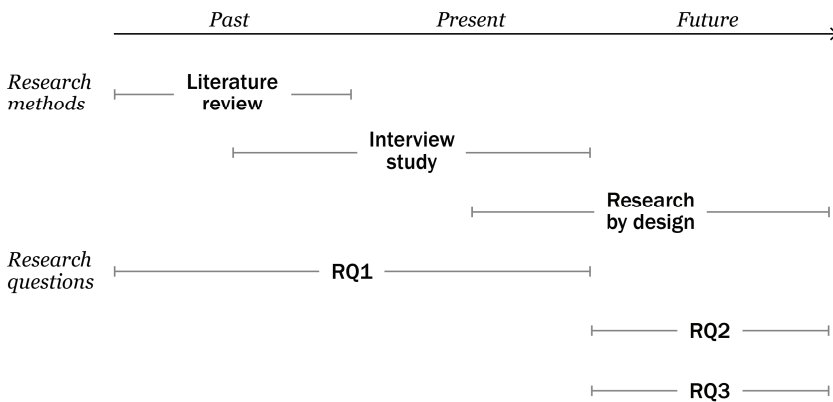


Figure 9: Situating the chosen research methods and the defined research questions with their focus: the past, present, or future.

The nature of the different research methods means that they are suited for addressing different aspects of the research questions. As indicated in Figure 9, literature review is more appropriate for investigating the past, and the interview study more appropriate for investigating the past and present, whereas research by design is more appropriate for investigating the present and future. The figure also shows that RQ1 is concerned with the past and present, whereas RQ2 and RQ3 are concerned with the future. Thus, the literature review and the interview study mostly relate to RQ1, whereas research by design mostly relates to RQ2 and RQ3.

In the following section I will describe and discuss how each research method was carried out.

4.3 RESEARCH BY DESIGN

In order to describe how the research by design was carried out, I will first describe my role in the UBC project. I will then discuss how I have applied research by design and the methods I have used to ensure that knowledge that qualifies as academic research has been developed through the work. Finally, I provide an overview of the design activities of the UBC project, emphasising those I took part in.

4.3.1 My role in the UBC project

As indicated in Figure 6 of Section 2.4, my Ph.D. research was situated within the broader context of the UBC project and its partners. The research aim of UBC was different—although not contradictory—to the aim of my Ph.D. research, and conducting my own research and finding my place within the UBC project was challenging at first. When my role was established, however, a fruitful relationship between my research and the UBC project emerged. My fellow team members on the UBC project provided valuable input on my research, and my research also informed the UBC project.

I participated in the UBC project as a senior interaction designer. I contributed to the project with systemic design approaches, screen-based interaction design skills, knowledge of design and human factors methods and techniques, experience with designing for high-risk control environments in general, and insight into the domain of the offshore ship industry in particular, the latter of which I acquired throughout the project work. I did substantial work on gaining insight into the context at sea, in particular through doing field research.

In the spring and summer of 2012, I worked on the initial interaction design of the ‘common bridge alarm system’. This work was further developed and expanded by others in the project. In the spring of 2013, I played a key role in the development of the ‘conning displays’ that were included in the Nor-Shipping demonstrator (see Section 5.3.2). In the autumn of 2013, I led the interaction design work of a new iteration of the design of the aft bridge, which was not presented publically. This work, however, included developing the layered scenario mapping technique presented in Publication 5. I also contributed to the design developed within the UBC project by taking part in workshops and discussions

initiated by other team members, and by mentoring the less experienced designers of the team.

4.3.2 Relationship between the design project and the research

Practitioner-researchers are frequently uncertain about the role of practise in their research (Niedderer 2007). I made the diagram presented in Figure 9 early in the research process to clarify what the object of my research would be and to illustrate the relationship between the design project and the research process. The diagram shows that the focus of the research was the design context, the design team's sensemaking of the 'requirement factors' (e.g. human needs, operative requirements, and regulations), and the design team's sensemaking of the design solutions they were developing.

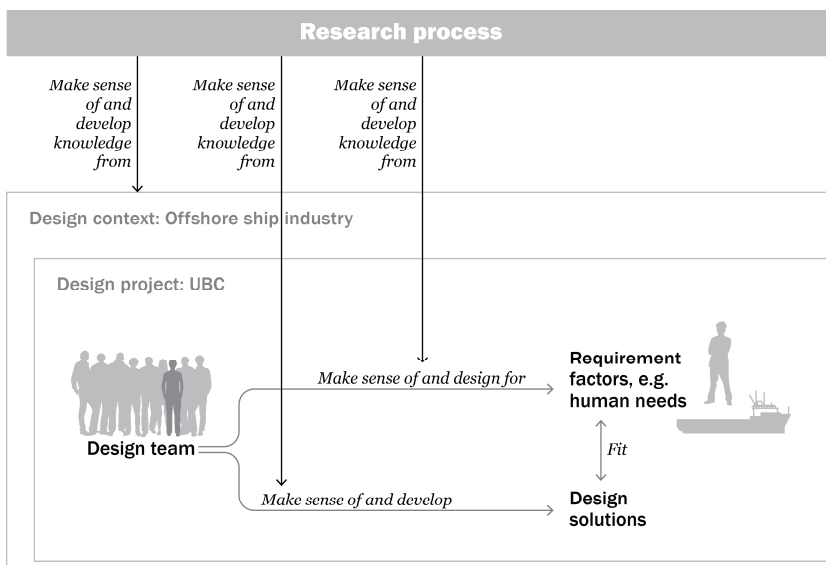


Figure 10: The relationship between the research process and the design project.

Figure 10 makes the fact that other aspects of the design project could have been part of the research visible. As an example, the users' situation⁷, which serves as the object of research in many HFE studies, was not

⁷ In the diagram, this is included in the 'requirements factors'.

explicitly the object of my academic research, although it was an object of the research *for* design that was conducted as part of the design work. Neither was the evaluation of solutions a focus of the research, even though the fit between the design solutions and the requirement factors was continuously assessed (as discussed related to synthesis in Section 4.3.4).

4.3.3 Research methods in research by design

In the following section, I will describe my approach to *generating*, *capturing*, and *interpreting/analysing* the research data.

Generating the data

The potential research data generated by the design work carried out constituted all material made in the process of developing the design outcomes, the design outcomes themselves, and the reflections on the process of developing the design. These reflections took place while engaged in the design work through ‘reflection-in-action’, and after designing through ‘reflection-on-action’ (Schön 1983).

On two occasions I conducted short, semi-structured interviews with the other members of the UBC project to elicit their reflections on selected topics. In December 2013, I conducted four interviews addressing experiences with field studies, which directly informed Publication 3. In April 2014, the topic of five of these interviews was the *layered scenario mapping* technique addressed in Publication 5.

These interviews were conducted as qualitative research interviews built around an interview guide with predefined topics. This method facilitated mutual knowledge construction (Kvale 2007) between me as the interviewer and the other team members as interviewees, and thus served the purpose of generating data through shared reflections. The interviews lasted from ten to twenty minutes and were audio-recorded and transcribed. These short interviews were part of the research by design-approach, and should not be confused with the interview study with designers with experience in the maritime and offshore industries (see Section 4.4).

Capturing the data

As noted by Pedgley (2007), capturing one’s own design activity is challenging. Even with the activities that are possible to capture, documenting everything will result in an overwhelming amount of data.

For these reasons, I decided to focus on only capturing data from selected activities of the project, including:

- Field research for design, in particular the four field studies I took part in (September 2011, July 2012, September 2012, and December 2012);
- Initial GIGA-mapping workshops (May and September 2012);
- Mapping workshop with the purpose of sharing insights gained during field studies (April 2013);
- My own work with the initial design of the common bridge alarm system (spring and summer 2012);
- My own work with the design of conning displays (spring 2013);
- The team's work with developing interaction design for the aft bridge, in particular the development of the layered scenario mapping (autumn 2013);
- Workshop with users (November 2013).

These activities were chosen because I actively took part in them. Activities that were not explicitly considered were those carried out before I became part of the project (e.g. carried out in the pilot study UBV), as well as the detailed design activities of the other team members. Capturing data from these activities was difficult for practical reasons, and also would have added to the already considerable amount of data.

I also chose to limit the amount of data selected. The data captured consisted of:

- My own sketches and notes;
- My own and others' reports from field studies and workshops;
- My own research diary, which included reflections on field studies, design work in the lab, and workshops; the diary also covered some of the substantial amount of sketches, models, and mappings that were developed by the UBC project as a whole;
- Audio recordings and transcriptions of the interviews with other team members;
- Video-recording of one workshop (only carried out for the layered scenario mapping, see Publication 5).

The research diary proved to be the most valuable of these data sources, as it both documented the work and invited reflection-on-action and an initial interpretation of the data. I kept the research diary in Evernote, a cloud-based service that lets the user take notes, images, sound files, etc.

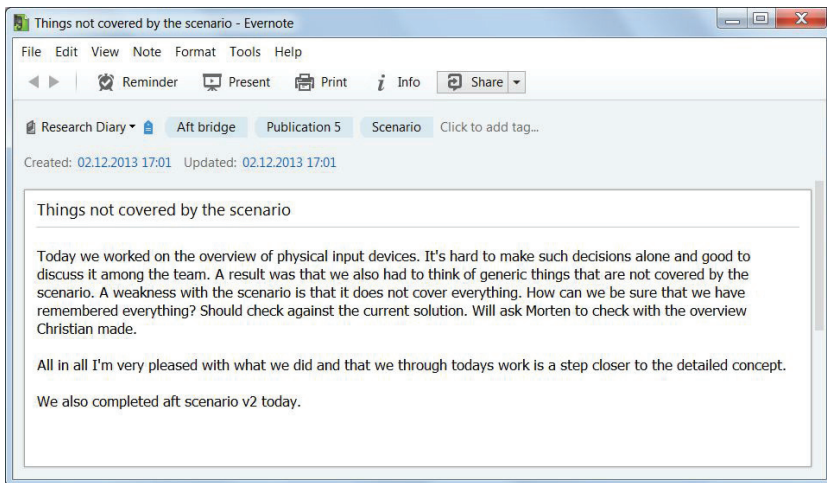
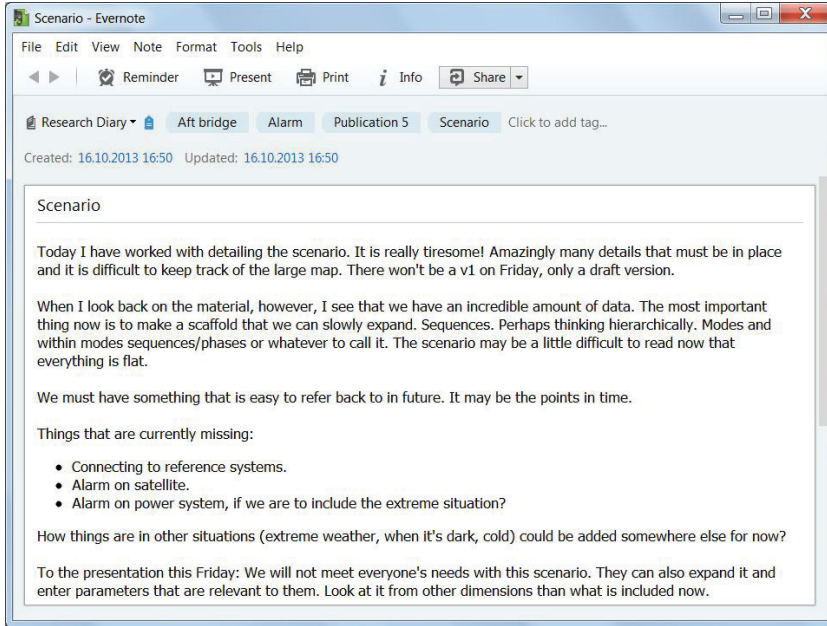


Figure 11: Extracts from the research diary in Evernote (translated from Norwegian).

levels. The immediate reflection-in-action and reflection-on-action represented an initial level of interpretation. As notes were written in the research diary, I carried out a second level of interpretation in which I started to get ideas of what was more or less important for my research. The third level of interpretation was more structured. The approach was motivated by the need to examine a specific topic that I found interesting for research, for example our experiences with field research. The analysis was carried out as follows:

1. I gathered relevant textual material for analysis. This included relevant notes from Evernote (identified using the tags and by going through the notes manually); the transcriptions from the short semi-structured interviews with fellow team members; and data and reports from field studies and workshops.
2. I printed the textual material and reviewed it manually. In the review, I highlighted interesting sections and noted any notable findings and remarks.
3. If there were many findings to make sense of, I wrote down the findings on Post-it notes and sorted and categorised them so that I could identify relationships and see patterns. This stage was inspired by thematic coding, which is a way of defining what the data is about by identifying reoccurring themes (Gibbs 2007).
4. I made a list of findings and/or aggregated written reflections on the topic of interest.
5. I conducted further analysis and interpretations through the writing of articles/reports or the making of presentations, e.g. through the application of theory to the findings or by contrasting it with related research.

As the data of the research by design stems from the design work I took part in, in the next section I will briefly discuss the design activities of the UBC project.

4.3.4 UBC design activities

Describing the design work that took place within UBC is not an easy task. There is no nice and neat story to tell, and no one person knows all parts of the story. Still, I will strive to describe the UBC work in a way that will, I hope, make sense to the reader.

A number of design activities and methods were applied in order to design our ship's bridge. The project was not carried out along a pre-defined design process. The focus of the design work at any given time relied on: 1) the focus and milestones defined throughout, in collaboration with Ulstein; 2) opportunities that came from outside of the project, for example new technology relevant to our work that we wanted to investigate, or the possibility of conducting field research; or 3) the personal interests and focus areas of the individual team members.

A lot of the work was carried out in parallel by individual team members or mini-teams within the project. As an example, in the autumn of 2012, while the industrial designers worked on designing the operator chair, the sound designer worked on alarm sounds, the interaction designers focussed on the overall interaction design framework and design patterns, and the graphic designer was concerned with the aesthetics of the visual displays. Our work became aligned when the object of the different design professions met, such as with the industrial designers and interaction designers, when designing the physical input devices, and the interaction designers, sound designer, and graphic designer when designing the visual and auditory information environment that portrayed the ship's status information.

Even though a structured design process with distinct phases was not followed in the UBC project, it is helpful to use phases as a framework for sorting and describing the design activities that took place in the project. The generic model of the design process proposed by Jonas (1996), which uses the phases *analysis*, *projection*, and *synthesis*, provides such a framework. Jonas (2007b) ties these phases to Nelson and Stolterman's (2003) notion of the *true*, the *ideal*, and the *real*. Analysis is concerned with identifying that which is true (Jonas 2007b, 200). The purpose of inquiry into the true, according to Nelson and Stolterman (2003, 39) is understanding that will lead to 'facts' about the world. In this thesis, 'gaining insight' and 'sensemaking' is sometimes used with the same meaning. Projection is tied to the ideal (Jonas 2007b, 200). Inquiry into the ideal has the purpose of progress, and is a conceptual inquiry that results in that which is desired (Nelson and Stolterman 2003, 44). Synthesis is tied to the real, and what is possible (Jonas 2007b, 200). An inquiry into the real aims to 'serve and fulfil' and leads to 'an ultimate particular' (Nelson and Stolterman 2003, 40)—that is, an adequate solution to a particular problematic design situation.

In the following sub-sections, I will use Jonas's model as an organising principle to describe the activities conducted during the UBC project, with an emphasis on those activities I took part in myself.

Analysis in the design project

Knowing the domain and understanding the context of use are particularly important when designing for the maritime or offshore industries (Husøy et al. 2010; Koester 2001; Mills 2006; Petersen et al. 2011). Gaining such insight involves research *for* design activities, and was done both individually and collaboratively during the UBC project.

I did a number of things to get to know the domain at the individual level. I subscribed to newsletters and other information sources from the maritime and offshore domain, I followed workblogs and online forums, and I attended a summer course in maritime human factors in 2012 at Chalmers Technical University in Gothenburg, Sweden. In addition, my understanding of the domain was expanded by attending industry-specific events such as the RINA's Systems Engineering Conference in March 2012, the ONS fair in August 2012, the Nor-Shipping fair in June 2013, and a meeting with the Nautical Institute in Gothenburg in November 2013.

Document reviews were conducted throughout the whole project. I and others from the design team reviewed user manuals to understand the technical systems on the bridge, and from that to gain an indirect understanding of the users' tasks. We reviewed documents from the IMO, such as guidelines and resolutions. We looked at class notations, such as DNV's 'Nautical Safety—Offshore Service Vessels' (DNV 2012). We also read training material, such as *DP Operator's Handbook* (Bray 2011), *Integrated Bridge Systems, Vol. 1: RADAR and AIS* (Norris 2008), and *Integrated Bridge Systems, Vol. 2: ECDIS and Positioning* (Norris 2010).

Different members of the team obtained insight of different parts of the design situation, and several workshops were carried out to share and align the insight gained among the team. Two GIGA-mapping (Sevaldson 2011) workshops were conducted. In May 2012, we held an initial GIGA-mapping workshop with the aim of making explicit what we really knew about the situation (system) we designed for, what we believed was true, and things we wondered about and wanted to get answers to (figures 13 and 14). This session proved to be important, because it made assumptions explicit and helped us to identify what we needed to gain further insight into. Another GIGA-mapping workshop, building on the first, was held in September 2012 (Figure 15). In this workshop, we mapped out what influences the situation we design for, and what consequences the situation we design for may lead to. In addition, we held a mapping workshop in April 2013 with the purpose of sharing insight gained during field studies (Figure 16). These workshops proved to be valuable for sharing knowledge and eliciting who knew what on the project team. They also helped us to generate ideas and identify areas for improvement.



Figure 13: GIGA-mapping workshop, May 2012. (Photo: UBC)

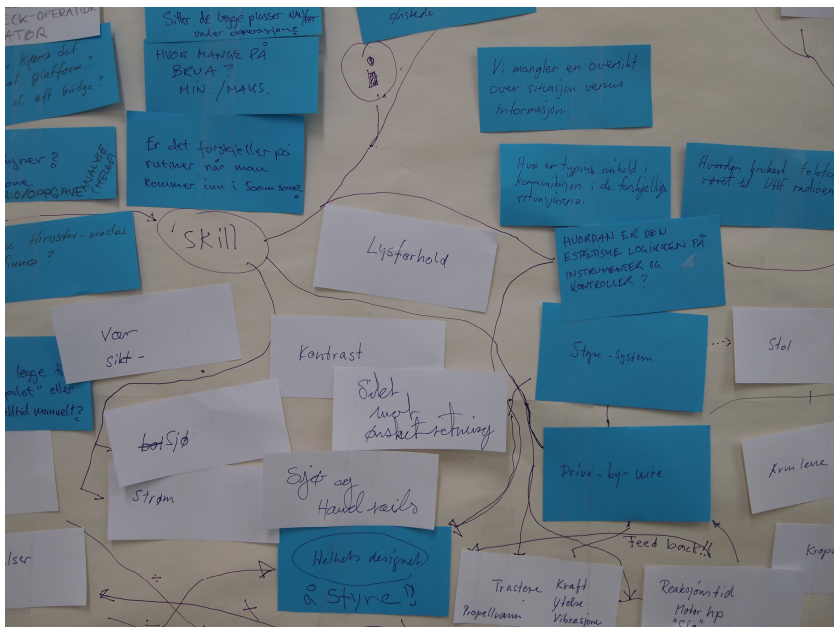


Figure 14: Close-up GIGA-map created in May 2012. The white notes included things we knew, while the blue included things we were uncertain of. (Photo: UBC)



Figure 15: GIGA-mapping workshop, September 2012. (Photo: UBC)



Figure 16: Workshop for sharing insights from field studies, April 2013. (Photo: UBC)



Figure 17: The distribution of the field studies conducted within UBV and UBC. I took part in the ones carried out in September 2011, July 2012, September 2012, and December 2012 (indicated by a darker tone of grey).

Field research was the most important method we used to gain insight on what we were to design, and the context of use (what I later refer to as ‘the system we design’ and ‘the system we design for’). The importance of conducting field research is touched upon in Publication 1, and our experiences with conducting field research are discussed in publications 3, 4, and 5. We conducted seven field studies within the UBC project in total (Figure 17). In addition, we were informed by three other field studies carried out at the Ocean Industries Concept Lab, as well as field studies carried out by students. As described in Publication 3, these field studies were carried out aboard different vessels owned by different shipping companies and chartered by different oil companies. The time of year (and, as a consequence, weather factors) differed in the field studies. I took part in four of the field studies, and spent a total of nineteen days at sea.

The first field study I took part in (September 2011) was conducted with the purpose of getting acquainted with the bridge environment of an OSV. The field study was carried out onboard a well intervention vessel, which was staying in port to mobilise for offshore operations. The field trip lasted for two days. The methods used included unstructured interviews in context, mapping out of the bridge environment using sketches and photos, and reviewing the documentation on the equipment, which was available on the bridge.

My second field study was carried out onboard a PSV in the Norwegian sector of the North Sea for three days in July 2012. The purpose of this study was to get more familiar with the PSV operations, and also to gain ideas for future field studies and to test out methods I wanted to use. During this study, I paid particular attention to the working environment as a whole, workarounds and retrofitting, and communication. I conducted structured and unstructured observational studies and unstructured interviews in context. The interviews centred around the users’ tasks, roles, responsibilities, and challenges, and the adequacy of

their equipment. For structured observation of the communication that took place on the bridge, I tested out the HFE method ‘Comms Usage Diagram’ (Stanton et al. 2005, 87–93).

The third field study was carried out onboard a PSV in the British sector of the North Sea for eight days in September 2012 (Figure 18). In this field study, I particularly aimed to analyse in depth a common PSV scenario. In addition to the techniques used in the second field study, I used ‘applied cognitive task analysis’ (ACTA) interviews (Stanton et al. 2005, 374–379; Militello and Hutton 1998) to analyse cognitive demands and expertise used to carry out particular tasks. This method requires an incident as a case. The case used was a collision between the vessel *REM Fortune* and the rig *EKOFISK 2/4 J* (ConocoPhillips 2011). The incident was identified through online news articles, and the incident report was obtained from the Petroleum Safety Authority Norway.

The final field study I took part in was carried out onboard a PSV in the Norwegian sector of the North Sea for six days in December 2012. The aim of this field study was to complement the previous field study and to gain a better understanding of how we can design the information environment on the bridge in ways that will make the users' sensemaking easier. I built on the plan from the third field study, and conducted one more ACTA interview.

During all of the field studies, a substantial number of photos were taken and many sketches and field notes were made, both in a notebook used during observation (Figure 19) and in the research diary after each observation session. Throughout the project, my teammates and I saw a need to develop our own approach to field studies in design, referred to as ‘design-driven field research’ (Publication 3). I developed two guidelines describing our approach (one project-specific and one generic) to conducting design-driven field research at sea. The generic guideline is presented in Publication 4.

As discussed in Publication 3, we used a range of techniques for reporting findings from the field research, including written reports, spoken reports, images, video recordings, audio recordings, and personas (Cooper et al. 2007). The *layered scenario mapping* was a mapping technique I developed with help from other team members as part of our work with the design of the aft bridge during the autumn of 2013. We used this technique to combine and analyse data from different sources on ‘the system we designed for’ to aid sharing of insight and to help with the transition from insight to design, or analysis to projection in Jonas’s (2007b) words. The technique is described in detail and evaluated in Publication 5 of this thesis, and is also briefly discussed in Section 5.3.



Figure 18: The author doing fieldwork onboard a PSV, September 2012. (Photo: UBC)



Figure 19: Field notes from field study, July 2012. (Photo: Author)

We spent considerable time gaining insight into the technical systems onboard the ship, in particular the DP system, which plays an important role in offshore operations and is connected to most of the ship's other technical systems (see Section 5.3.2). Analysing and understanding the new technology that constituted our design material was also an important aspect of the UBC project (Figure 20), although I was not heavily involved in that aspect of our work.



Figure 20: Understanding technology was part of the analysis carried out during the UBC project. April 2012. (Photo: UBC)

Projection

The scope of the UBC project was the design of the whole ship's bridge, including everything from overall room layout to developing multimodal interaction and graphic design to design of the furniture, workstations, levers and other input devices, physical interaction, digital interaction, and sound. (Multimodal interaction implies using different modes—e.g. touch, voice, gestures—of providing input to a computer system [Oviatt 1999].)

The design work was carried out in an exploratory manner in a maritime design lab at AHO (Figures 21 and 22). The lab was our 'virtual world' (Schön 1983, 157–162) and provided a space for our collaborative work (Nordby 2014). It enabled us to work together on emerging design ideas, and was a context for experiments where we could create and

manipulate our future ship's bridge. Sketching was important in developing conceptual ideas, and we made drawings, wireframes, 2D computer drawings, computer-aided design (CAD) models, and 3D renderings. We also built physical prototypes and full-scale mock-ups. In the lab we built one-quarter of a ship's bridge, which provided an environment for our prototypes and mock-ups. The lab also provided a ship simulator, which enabled us to use realistic data in our interface prototypes. The physical mock-ups enabled the industrial designers to do anthropometric assessments. The physical and digital prototypes together allowed us to experience how our design ideas could work and, as observed by Lim et al. (2008), stimulated our reflections and helped us see possibilities.

Synthesis in the design project

Our concept bridge was intended as a 'near-future' vision. Therefore it was important to us that the design would be both possible and believable. Being self-critical was absolutely necessary in achieving this. Throughout the process, ideas were continuously scrutinised by the design team. The mock-ups and prototypes were used in the day-to-day work in the lab to assess the workability of the ideas.

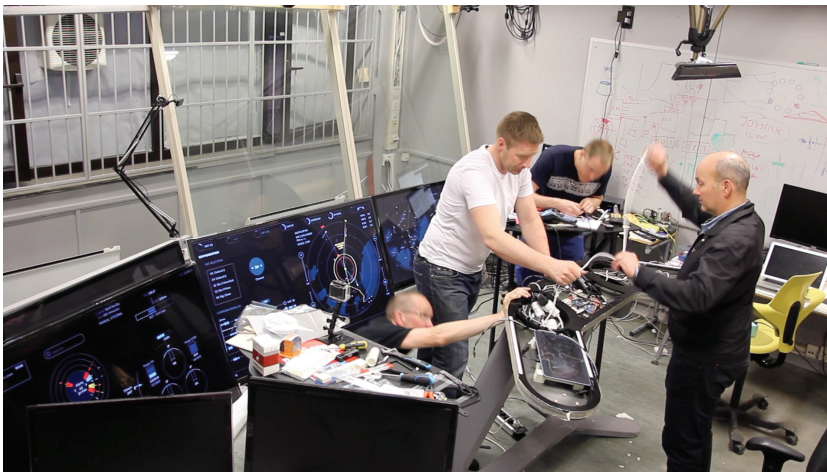


Figure 21: In the lab we built demos and prototypes. May 2013. (Photo: UBC)



Figure 22: The demos built in the lab enabled us to try out our designs. September 2012. (Photo: UBC)

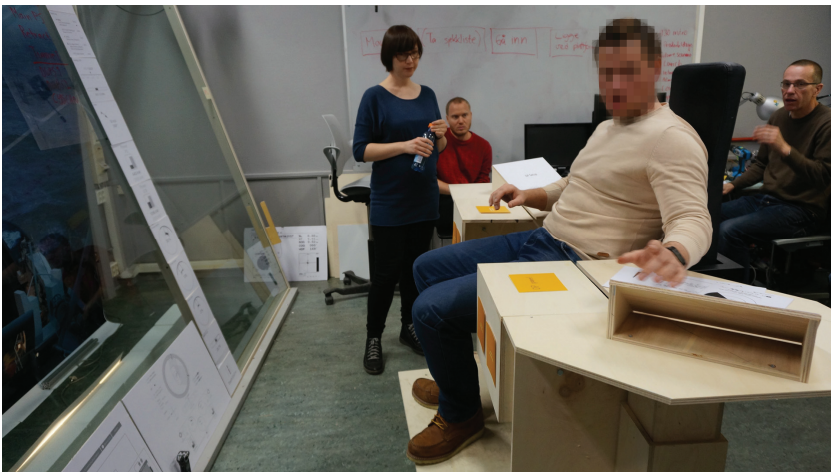


Figure 23: Workshop with user representatives in the lab gave us valuable feedback on our designs, November 2013. (Photo: UBC)

The lab also served as a ‘design collaboratorium’ (Bødker and Buur 2002) where the design team, industry partners, and users could together assess the appropriateness of design proposals through hands-on experience. Two workshops with users provided us with important feedback and directed our work. The first workshop was held within the UBV project, in which I did not participate. During the second workshop, held in November 2013, we had mock-ups and prototypes that the users could try out and criticise (Figure 23). This workshop gave us invaluable feedback on our design, and guided the last iteration of our concept bridge of 2013/2014.

We would have liked to have held more workshops with users in our lab, but as discussed in Section 5.1.2, gaining access to users while onshore is difficult. We thus tried to make the most of the field studies, and during some of the field studies we presented the users with ongoing design ideas and got useful input, as shown in Figure 24.



Figure 24: Presenting design ideas to a user at a field study, December 2012. (Photo: UBC)

4.4 INTERVIEW STUDY

In 2013, along with Margareta Lützhöft and Birger Sevaldson, I conducted an interview study with eight industrial and interaction designers with experience in the maritime and offshore industries. This study is reported in Publication 1, and it also informed the model presented in Publication 6.

4.4.1 Objectives of the interview study

The isolated objectives of the interview study were to investigate how industrial and interaction designers find designing for the offshore industry, to identify the challenges they face, and to examine the strategies they use to meet these challenges. Within the wider context of my Ph.D. project, the purpose of the interview study was to complement the insight gained through the UBC project, as described in the discussion of triangulation in Section 4.2. The perspectives and experiences of the practicing designers were somewhat different from the experience we gained in the UBC project. The interview study complemented the research by design-approach in two important ways:

1. The designers interviewed had experience with the full product development process, including the detailing of designs, whereas in the UBC project we developed a ‘concept bridge’ and did not work on realising the product and detailing it at the level necessary to put it into production;
2. The UBC project, being a research project, had different framework conditions than a strictly commercial project, which meant that we had somewhat less time pressure and possibly more resources (for example for conducting field research).

4.4.2 Research method of the interview study

The research method chosen was qualitative research interviews (Kvale 2007; Kvale and Brinkmann 2009). All designers interviewed held master’s degrees in industrial design or similar fields and worked as industrial or interaction designers. The designers had from two to ten years of experience in the offshore industry at the time of the interviews, and they worked at six different design offices / equipment suppliers.

The interviews lasted from sixty to ninety minutes, and were based on a semi-structured interview guide (Kvale and Brinkmann 2009), which is

included as an appendix. All interviews were conducted by me, and were audio-recorded and transcribed in Norwegian.

The interpretation and analysis of the interview data were conducted at several levels. An initial interpretation took place as part of the interview through shared reflections on the interviewee's experience. Immediately following the interview, I made a second interpretation by noting down my immediate thoughts. Data interpretation also took place during the transcription process. After all the interviews had been transcribed and anonymised, I shared the transcriptions with the other authors of the article, who individually interpreted the interviews. I also conducted an analysis of the data by coding the transcriptions (Gibbs 2007) using the QDA Miner Lite software. This aided the process of identifying patterns across the interviews. Visual mapping of the findings was used to make connections between findings visible. A final interpretation was carried out based on the analyses and interpretations of the individual authors. Further discussions of the research method and the validity of the interview study can be found in Publication 1.

Quotes from the interviews used in Publication 1 and in Chapter 4 of this thesis are made with reference to which designer made the statement (the first designer interviewed = D1, the last designer interviewed = D8) and the timestamp of the statement from the recording in the format provided by *f4*, the software used for the transcription. For example '(D3 #00:24:08-3#)' refers to something the third designer interviewed said 24 minutes and 8 seconds into the interview. All quotes were translated from Norwegian by the author, and the translations were approved by the designers who made the statements.

4.5 METHOD FOR THE LITERATURE REVIEW

Literature reviews were conducted on the following topics:

1. Design for complex, high-risk control environments in general, and designing for the maritime and offshore domain in particular;
2. Systems thinking in general, and systems thinking in design in particular;
3. Theories on sensemaking and judgement-making.

These reviews had different purposes: the review of literature on design for complex, high-risk control environments was done to position the research and to consider the originality and contribution of the research;

the review on systems thinking literature was conducted to position the research, and also to inform the practise carried out and the theoretical framework used to understand and analyse the practise; and the review of sensemaking and judgement-making theories also informed the practise that was carried out, and the theoretical framework.

For the review of design for complex, high-risk control environments, I conducted a number of searches in the most important research databases and design research journals. Examples of search queries used include *safety*, *safety critical*, *safety critical design*, *safety critical interaction design*, *safety critical HCI*, *risk*, *high-risk design*, *designing for safety*, *maritime*, *offshore*, and *mission-critical design*.

The literature on systems thinking is immense, as mentioned earlier, and reviewing all relevant references in depth has not been possible within the scope of this thesis. Thus, the review of the systems thinking literature was not done with the purpose of establishing the evolvement and current state of the topic, but rather to gain an understanding at a level applicable to my design practise and research. The reviewed literature consisted of selected classic writings on systems thinking supplemented with more recent writings, with the aim of grasping the most important aspects of contemporary systems thinking.

The starting point for the review of systems thinking in design literature was a reading list provided by my supervisor. This was supplemented by literature identified from a range of sources, including Internet forums and blogs, searches in journals and research databases, and suggestions from presenters at the RSD symposia. In addition, I reviewed the working papers from the 2013 and 2014 RSD symposia, as well as the two special issues of *FORMakademisk* devoted to systemic design (vol. 7, nos. 3 and 4 [2014]).

As described in Section 3.4.5, it was not easy to acquire an overview of the field of systems thinking. In order to tackle the challenge, I documented systemic concepts found in the literature on index cards, with a short explanation and references. This resulted in sixty-one index cards. I then used card sorting (Spencer 2011) to sort and make sense of the concepts. Although this did help me to gain an understanding of how the concepts were related, I still found the sheer number of concepts overwhelming. After struggling with this for some time, I decided to go through the index cards one by one, consider how they related to my research and design at the practical level, and select a limited number of concepts that I would use in the thesis. These systemic concepts are presented in Section 3.4.4.

An initial review of the literature on sensemaking and situation awareness was conducted as part of the Research School, part of the Ph.D.

programme at AHO. The purpose of this review was to identify theory that could prove valuable in designing for users' sensemaking. As the research evolved, however, my focus shifted from the users' sensemaking to the designers' sensemaking (see Section 1.1). Still, the initial review proved to be valuable, because the same theories could be used to discuss designers' sensemaking. Later in the research process, I also saw a need for addressing judgement-making, as designers' ultimate goal is not understanding, but making something based on their understanding. Nelson and Stolterman's (2012) discussions of design judgements were used as a starting point for this review, which led me to Vickers's (1965) theory of appreciative judgements.

4.6 KNOWLEDGE DEVELOPMENT IN THE RESEARCH

Research aims to develop new knowledge. Yet, what is meant by 'knowledge' in research is often not clearly stated (Niedderer 2007). Implicitly, in traditional research it refers to propositional knowledge describing the 'truth' (ibid.). As a reaction to such understandings of knowledge, the philosopher Anders Lindseth (2015) proposes that knowledge is defined as our 'ability to answer' (Norwegian: *svarevne*). This view implies accepting that knowledge is not true or false but good or bad, and that our purpose in investigating knowledge is to improve it. I find this view of knowledge useful in design research. In the following, I will use the understanding of knowledge as the ability to answer, and the framework of research *about* design, research *for* design, and research *by* design introduced in Section 4.1 to discuss the knowledge development in the research.

Research *about* design through the interview study elicited knowledge about other designers' experiences with working for the offshore industries. Qualitative research interviewing is not concerned with collecting knowledge that is already in the world, but rather about knowledge construction (Kvale and Brinkmann 2009, 48). This is an active process where the interviewer and the interviewee collectively produce knowledge (ibid., 17). The knowledge developed in the interview study gives an apt description of the typical design situations that designers face in the offshore industry. This is valuable knowledge in itself, since designers could use it to prepare for such projects and thus improve their ability to answer. In this thesis, it also provided a basis for discussing the appropriateness of systems thinking in such projects, and informed the development of the conceptualisation and operationalisation of systemic design that is developed in the thesis.

Research *by design* was conducted to develop knowledge both *for* and *about* design. Research *by design* relies on and develops both propositional and tacit knowledge (Polanyi 2009). While this is advantageous, because it enables tacit knowledge to inform research (Niedderer 2007; Sevaldson 2010), the tacit aspect of research *by design* is also a disadvantage. Knowledge in academic research implies something that is new for the research community, not just the individual researcher (Biggs and Büchler 2007). For the tacit knowledge to be considered by the research community, it must be communicated. This is challenging, because tacit knowledge is to a large degree embedded in practise (Polanyi 2009).

Substantial knowledge production in the UBC project was a result of research *for design*. We gained the insight needed to design the ship's bridge through a range of methods. The field research is one example of research *for design* from which we developed general and detailed knowledge related to life and work onboard an OSV. Research *for design* often does not meet the standards for academic research (Archer 1995; Findeli et al. 2008). It may not be conducted in a structured and transparent manner, which would make it difficult to evaluate by others in a peer-review process. I argue that designers are (or should be) concerned with the trustworthiness of the research they conduct *for design*. Unless we are designing custom-made solutions, I believe our final designs should be seen as a type of generalisation, because, based on the knowledge we build our design on, we come up with solutions that should hold for many different situations. Whereas qualitative researchers (such as ethnographers) often do not need to consider generalisation of their research, because their intention is to provide a detailed description of a unique case (Flick 2007, 92), I argue that designers must consider how the insight they have gained through research *for design* on particular situations could apply to the range of different (and often unpredictable) situations the final solution may be used in.

For this reason, I have strived to conduct the research *for design* I have done within UBC as rigorously as possible. As an example, I emphasised credibility in the development of the layered scenario mapping presented in Publication 5. The map was based on a range of data sources, the field studies being the most important. The methods used to gather data on the field studies were conducted in a structured manner, and the final map was formally validated by user representatives. Given that I cannot include the full map because it is business-critical to Ulstein (see Section 4.9), the map itself cannot be fully peer-reviewed by the research community. Still, Publication 5 includes an excerpt of the map that gives indications of its usefulness, and the technique itself is clearly

communicated in the article and made available online. As such, it can be reviewed, tested, and further developed, and thus counts as academic knowledge.

There are different views in the design research community about whether a designed artefact in itself can represent new academic knowledge. Most design scholars claim designed artefacts must be accompanied by a reflective text to qualify as academic research (e.g. Biggs and Büchler 2007; Findeli et al. 2008; Friedman 2003; Sevaldson 2010). As a consequence of viewing knowledge as our ability to answer, we must acknowledge that an artefact may represent new knowledge for practitioners, even if we do not consider it to be academic knowledge. By changing designers' appreciative settings (Vickers 1965) and becoming part of the designer's repertoire of exemplars (Schön 1983), the artefact gives designers more to draw on when faced with a new design situation, and thus enhances their ability to answer. For this reason, the Ulstein Bridge Vision™ concept bridge presented to the public can itself serve as new knowledge for practitioners. In order for the concept to be considered academic knowledge, however, it must be accompanied by a reflective text that would allow it to be reviewed and criticised by the research community. In Section 5.3, I provide a thick description (Geertz 1973) of the Ulstein Bridge Vision™ and discuss it with the aim of qualifying the designs as academic knowledge.

4.7 QUALITY OF THE RESEARCH

According to the Research Council of Norway (2000), quality in research is related to three aspects (translation from Norwegian to English by Utne [2007, 41]):

- *Originality*: to what extent the research is novel and has innovative use of theory and methods;
- *Solidity*: to what extent the statements and conclusions in the research are well supported;
- *Relevance*: to what extent the research is linked to professional development, or is practical and useful to society.

Given that this is a thesis by publications, the quality of the research has been assessed throughout through peer-reviews of the publications. The quality of the research in general is considered in the following subsections. Given the interconnections of this thesis and the UBC project, both will be discussed.

4.7.1 Originality

The originality of the UBC project can be assessed by considering the responses to the Ulstein Bridge Vision™, the attention it has gained, and the effects it has created in the industry. As reported by Lurås and Nordby (2013), our bridge design generated much interest when it was made public. It has been used as an example of innovation by industry actors beyond Ulstein; we have been informed that it has been used by engineers to discuss software safety in future systems; several politicians have used our project as an example of what Norwegian innovation is capable of (the former Minister of Trade and Industry, among others); the Norwegian Centre for Design and Architecture (DOGA, formerly the Norwegian Design Council) uses the UBC project to promote design-driven innovation (DOGA 2015); and the Royal Norwegian Embassy in China has used the Ulstein Bridge Vision™ to promote the Norwegian maritime industry (Royal Norwegian Embassy China 2013). Our concept bridge has also been repeatedly referred to as an example of ‘the future ship’s bridge’, ‘an integrated bridge solution’, and ‘e-navigation’, both in research settings (e.g. Gralak et al. 2013; Pan et al. 2014) and in industrial settings (e.g. Wingrove 2012; Norwegian Shipowners’ Association 2014b). No other ship’s bridge design is used to the same extent. These observations suggest that the design is novel.

This thesis concerns designing for complex, high-risk control environments and how systemic design may be helpful when designing for such contexts. As highlighted in Section 2.3, research on design for high-risk domains in general and the maritime industry in particular is limited. Further, research on systemic design within this context is even more limited. Although the field of marine design does emphasise the application of systems approaches, marine design is not specifically positioned as a designerly approach to systems thinking such as systemic design. Only two publications (other than my own) that address systemic design in this domain have been identified. One is a paper on the application of SOD in student projects in the maritime and offshore domain, written by the main supervisor of this thesis, Birger Sevaldson, and his co-authors (2012). The other paper, by Kowollik and Jonas (2014), addresses the social impacts of cruise tourism which, although it also falls within the maritime domain, has limited relevance to the topic addressed in this thesis. Based on these observations, I assert that the topic of the thesis is original.

4.7.2 Solidity

Solidity is related to rigour. According to Biggs and Büchler (2007, 69), ‘Rigor in research is the strength of the chain of reasoning’, and ‘[t]he central links of the chain comprise the method’. Findeli et al. (2008, 71) describe rigour as standing up to the usual scientific standards, and Archer (1995, 13) stresses that for any research to qualify as academic research, it ‘must be knowledge-directed, systematically conducted, unambiguously expressed. Its data and methods must be transparent and its knowledge outcome transmissible’.

As described earlier, the research presented in this thesis has been conducted in a *systematic manner*. The interview study was carried out in the form of semi-structured research interviews, following the recommendations of Kvale and Brinkmann (2009). Section 4.3.3 describes how the research by design was conducted as systematically as possible. I have aimed to make both the research methods and the design methods *transparent*. The *knowledge outcome* arising from the reflections on the design process have been *shared* through the publications (Part 2 of the thesis), and presentations of the research have been given publically. I have emphasised sharing our experience and the methods we have developed, such as the methods and guidelines presented in publications 3, 4, and 5. The guides have also been made available through AHO’s online digital archive.

Making the *data transparent* and the *design outcome transmissible* was not always possible (nor was it up to me, as discussed in Section 4.9). Still, given the considerable amount of work that was conducted within the project, the data and outcomes that I have been allowed to share is still significant. I have strived to make this data and outcomes as transparent and transmissible as possible to enable other designer-researchers and practitioners to make use of the knowledge developed through the research, and to increase their ‘ability to answer’ to the design situation when taking on similar design projects.

In order to enhance the trustworthiness of the results, I have sought feedback on my findings from the field (Flick 2007, 66). This applies both to the research *for* design and to the research *about* design. In the former case, the field constitutes the users and other stakeholders, while in the latter, the field constitutes designers working in the maritime and offshore ship industry.

Examples of feedback on the research *for* design include the validation of the layered scenario mapping by user representatives (presented in Publication 5) and the feedback on the design ideas during field studies and in the workshop with users in November 2013.

For the research *about* design, we invited the designers who participated in the interview study to correct our interpretations of their experiences during the interviews. A draft version of the article was also distributed to the interviewed designers, who were given the possibility of providing feedback. During the UBC project, I sought feedback on my findings and interpretations from my fellow team members by discussing my findings informally in daily work, formally in workshops, and by inviting comments from the UBC team on draft versions of the publications.

4.7.3 Relevance

As described in Section 2.3, a number of studies have shown that current ship's bridge designs do not support the deck officers in a satisfactory manner. Further, in recent years there have been tremendous developments in new technologies (e.g. touch, gestural interaction, speech interaction, improved speaker technologies, and 'head-up'⁸ technologies), which have not yet been fully utilised in ships' bridges. From this we can infer that designing a holistic ship's bridge that would better support users by taking advantage of the possibilities inherent in new technology was a relevant and timely framing of the UBC project.

Ulstein Bridge Vision™ won two innovation prizes in 2012: the DNB Regional Innovation Award for West Norway, and the DNB Innovation Award. The latter is a major Norwegian prize for the best innovation idea of the year, and goes to an idea that applies new knowledge or develops existing practise in an innovative manner. The bridge design has, as mentioned, been referred to in many contexts as an example of a ship's bridge of the future. Further, in 2013 the UBC project was asked by the Norwegian Maritime Authority to provide input for the development of future regulations for e-navigation based on the Ulstein Bridge Vision™. From all of these observations we can conclude that our resulting design is relevant.

The work of UBC has proved valuable to Ulstein both internally and externally (Arne Ove Rødstøl, market manager at Ulstein; personal communication 28 August 2015). In particular videos and photos derived from field studies that makes visible what things are like during offshore operations and how the current designs work. The use of field studies in

⁸ 'Head-up' technologies, discussed at more length in Section 5.3.1 and seen in Figure 33, refer to presentation of information without requiring users to look away from their viewpoints.

UBC has changed the practises of Ulstein Design, a subsidiary of the Ulstein Group that does ship design. According to Rødstøl, while previously they seldom went aboard ships during operations, now all the designers of Ulstein Design have taken part in field research at sea.

As mentioned the use of designers in the offshore and maritime industries seems to be increasing, however, little research addressing designing for these contexts exists. A further observation is that systemic design is by many designers considered relevant for design for other complex settings, however, not paid a lot of attention in this industry. For these reasons we can assert that the topic of this thesis is timely and relevant.

The substantial work on field research carried out in UBC has further led to a new three-year research project named 'ONSITE', funded by the Research Council of Norway under the Maroff programme. The aim of this project is to develop more knowledge about how to conduct field research in marine design projects, and how to collect, process, store, and share field data for design. This project is conducted at AHO with three industrial partners (Ulstein, DNV GL, and Pon Power Scandinavia) as well as several national and international academic partners (Aalesund University College, University of Tasmania, University of Aarhus, and University of Warwick). This continuation of the research presented in this thesis further supports the claim that the thesis is relevant.

4.8 REFLECTIONS ON THE RESEARCH APPROACH

I decided early in the research process that gaining a deep understanding of designing for the offshore ship industry would require engaging in designing for this industry myself. Thus, I chose research by design as the main research method.

As discussed in Section 4.3.3, a key issue with research by design is that it is dependent on capturing one's own design activities, and that you are the object of your own research. Similarly to participant observation, research by design involves obtaining data by inserting oneself into the situation that one is researching (Goffman 1989, 125). However, whereas one challenge with participant observation is getting close enough to the people one is investigating, the challenge when investigating one's own design practise is to maintain enough distance (Boess 2009). Furthermore, all observational studies imply issues with observational biases, including selective attention, selective encoding, selective memory, and interpersonal factors that affect how things are seen (Robson 2011, 328–329).

I employed two strategies to address these issues. First, I decided to trust that reflection-on-action would capture the most important aspects of the design activities I took part in. In the periods when I focussed on practical design work, I tried to write down reflections in the research diary daily or every other day. By writing on a regular basis, I aimed to overcome the bias of selective memory (Robson 2011, 328). Diaries may, however, also result in large amounts of data. Around 500 notes in my research diary addressed the design work of the UBC project, and an additional 1,100 notes were related to the research in general. Some notes were longer reflections, while others were short memos. The tagging in Evernote helped me handle these notes, and the number of notes did not feel overwhelming. I did find, however, that many of the notes were irrelevant to the analyses. It was difficult to foresee at the time what kinds of diary reflections I would need at a later stage in my research process. I tended to focus on what was on my mind, and did not always consciously consider how the reflections would be of use in the research process.

A second strategy for meeting the challenges of research by design was that I alternated between different perspectives. Sevaldson (2010) uses the notions of first-, second-, and third-person perspectives in action research to describe the different positions a designer-researcher might hold. He writes,

The first-person perspective corresponds with the practising individual designer, the insider perspective where the designer has access to tacit knowledge and deep process knowledge. The second-person perspective corresponds with group work, and the third-person perspective corresponds with the traditional observer position. (ibid., 21–22)

Alternating between the different perspectives was part of the flexible research design I employed. When taking active part in the design practise of UBC, I held a first-person perspective. I held a second-person perspective towards my fellow project members in UBC and the activities of the project that I did not directly participate in. I elicited their input through informal conversations and the short semi-structured interviews I conducted on a few occasions. When I interviewed other designers, I maintained a third-person perspective, which is more in line with a traditional observer position.

The research by design-approach implied using myself and my experiences both as an origin of data and a tool for data gathering. As a consequence of this approach, I write about my research mostly using a first-person narrative. Inspired by ethnographic writing, my aim is to

‘convey the feel and the facts of an observed event’ (Fetterman 1998, 123)—that is, designing for the offshore ship industry. While ethnographers share the experiences of the people they study through their writing, I shared my own experiences as well as those of the other designers I have observed or interviewed. To do this in a trustworthy way, I found that I had to acknowledge my presence, and hence to use a first-person point of view.

It would have been possible to consider my research aim through traditional research approaches, such as qualitative research from a third-person perspective only. Doing so, I could have avoided some of the distortions that may follow from monitoring one’s own process (Boess 2009). However, I could also risk developing knowledge that would not be of relevance to design (Findeli et al. 2008; Stolterman 2008).

Research by design was also the research approach applied in the UBC project as a whole. This approach allowed us to consider the future rather than only the past and the present, and it enabled us to communicate our understanding of the design situation and its inherent possibilities by creating and presenting the Ulstein Bridge Vision™.

4.9 ETHICAL CONSIDERATIONS

I have experienced several ethical issues conducting this Ph.D. research. First, pursuing a Ph.D. degree with an industrial partner introduces certain dilemmas. There is an inherent conflict of interest between an industrial actor’s commercial interests and its needs to protect what can be of competitive advantage to the company, and the goal of being open and transparent in research. On the one hand, having an industrial partner presented me with opportunities I normally would not have been given. In particular, Ulstein helped organise the field studies at sea, which provided me with invaluable insights. On the other hand, I could not necessarily share all the insights I gained. Both ethically and through a non-disclosure agreement, I was obliged to consider carefully whether what I wanted to publish from the project would be of commercial value to Ulstein (and thus would remain confidential), or if it was something that I was free to share openly. I should mention that Ulstein has been accommodating and has allowed me to share a substantial amount of information, but this issue has still been a dilemma in my research.

A second ethical issue I experienced was ensuring the privacy of those who informed my research. My research involved interaction with a number of people. The people I met during my field studies at sea were in a unique position, given that it was presumably difficult for them to

refuse to participate (even though they were told they could). I had to ensure their privacy, and to respect that I visited them not only at their workspace, but also in their home, because they spend half their lives aboard these vessels. Following each field study I took part in, I offered to report back to the shipping companies that had allowed me to do field research on their vessels. The purpose of these reports was to show how the data from the field studies were used, and to encourage ownership and a positive experience with having us aboard. One example of such a report is the article I wrote for a shipping company's affiliate newsletter following the second field study I took part in, as shown in Figure 25.

I also had to ensure the privacy of the designers who participated in the interview study, as well as my fellow project team members in the UBC project. The research had to be in accordance with the Norwegian Personal Data Act, and when necessary it had to be reported to the Data Protection Official of Norway, an office that verifies the processing of personal data in Norwegian research projects. This was done for the interview study as well as for the field studies at sea (by the project manager of the UBC project). Informed consents were obtained from the participants in these studies. The Data Protection Official of Norway informed the UBC project early on that informed consent was not required by the non-researchers of the project. Still, I strived to communicate clearly how I used the data I collected from their work and ensured their privacy, as I would have done if informed consent had been required.

Finally, in research by design-projects, the designer-researcher must, in addition to addressing ethical issues as a researcher, also face ethical dilemmas as a designer. Designing and ethical thinking are interlinked (Lloyd 2009). When designing for high-risk industries such as offshore, making conscious ethical considerations is particularly relevant. A bad design may contribute to disastrous events, while a good design may prevent undesired consequences. Yet, as discussed in sections 5.1.3 and 5.1.6, it is very difficult to predict the possible consequences of a new design in such domains.

A VISIT TO SEA WITH THE BOURBON TOPAZ: INFORMING THE FUTURE SHIP'S BRIDGE

By Sigrun Lurås, PhD-Fellow, The Oslo School of Architecture and Design

The gates at quay 23 in Tananger opened slowly and I walked in to the restricted area at the port with butterflies in my stomach. I was going out with a supply vessel to the North sea for the first time. The reason why I was going out with Bourbon Topaz this morning in July was to learn about the bridge environment and its users. I work as a designer and researcher at the Oslo School of Architecture and Design in a project called the Ulstein Bridge Concept project. In this project, carried out in collaboration with Ulstein, Kwant Controls and Aalesund University College, we look at what the future bridge may look like. To be able to say anything about that, we need to talk to the users and learn about what they do on the bridge.

I climbed up the ladder to the bridge where I was met by the captain and some of the officers. The crew were busy with loading and unloading, but the captain still took the time to give me an overview of the ship and the bridge, its functions and how it worked for them. I felt welcomed by the crew and thought that this would be some nice days at sea. A few hours later we were on our way out, heading for the oil rigs. There was a lot to grasp and following what happened required a lot of attention. When I went to bed after 12 hours on the bridge I was exhausted, but I slept really well rocked to sleep by the waves of the sea.

The next few days I spent all my waking time on the bridge, only leaving it at meal times. I didn't follow any specific watch, but spent time with both watch teams. I wanted to talk to all the officers and observe different kind of operations. When there was little to observe, I systematically went through all the equipment on the bridge. I specifically looked at adaptations the users had done to the equipment after it was installed. Such adaptations is like a gold mine for designers. Not only do they show what designs haven't worked, they also often suggest clever solutions to how the designs ought to have been in the first place. The ship I visited had a number of adaptations like that.

Looking at the equipment and room layout is a good start when you want to get acquainted with a new working environment, but the real insight you get from talking to the users. I was quite surprised by how busy it was while we were by the platforms. It was not easy finding time to talk to the crew in-depth, rarely they had more than a few minutes between their tasks. If they got a longer period where nothing happened at the platform, they used the opportunity to do tasks that were awaiting, like paper work or cleaning.

When I did get the chance to ask the crew about their wishes for the future bridge, I found that the captain and some of the officers had a lot of ideas about what makes a good working environment, while others hadn't thought about how things could be differently. I was surprised by their humble approach and how little they demanded of the design of equipment that, if used in the wrong manner, could mean life or death to them. It seemed like they had made some strategies to ensure that they were in control of the situation, and didn't consider how a different design could make it easier for them to get this control.

After three days we were back in Tananger and it was time for me to depart the ship. Back at the office I shared my new insight with my colleagues as best as I could. We are 14 researchers and developers working at the Ulstein Bridge Concept project. These days we have just launched the first version of our bridge design together with Ulstein Group. This bridge called the Ulstein Bridge Vision™ is based on user's needs and delivers a completely new bridge environment. The design will be developed further and the new insight we gained from my trip this summer, as well as from previous and future field studies, will be used to inform and inspire the design. I learned a lot from these days at sea, but the most important learning experience was maybe how much more there is to know. Therefore I want to go out to sea again soon.

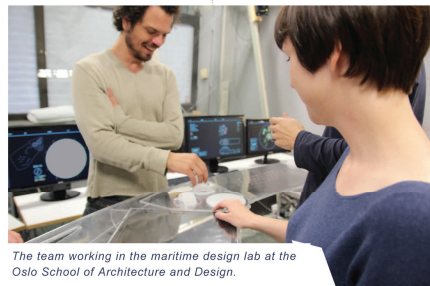
I would like to thank the captain and the crew at Bourbon Topaz for their kind hospitality and for sharing their thoughts and ideas with me. This input is invaluable to the further development of the Ulstein Bridge Concept.

Read more about the Ulstein Bridge Concept:
<http://www.designresearch.no/projects/ulstein-bridge-concept>

See a presentation of the Ulstein Bridge Vision™ at
<http://ulsteinlab.com/>



The project team looking at photos from the field study.



The team working in the maritime design lab at the Oslo School of Architecture and Design.

Professional Enthusiastic United Responsible

Figure 25: Account from a field study published in *BON News* #6, September 2012. Reproduced with permission from Bourbon Offshore Norway.

5 RESULTS AND DISCUSSION

The research presented in the publications of this thesis establishes that the design situation when designing for the offshore ship industry is complex on many levels. In Publication 1, we suggest that systemic design can help design teams cope with the complexity of offshore-specific design projects, while in Publication 6 I propose a systemic model of the design situation that should help designers make sense of this complexity. Publications 2, 3, 4, and 5 present practical design work carried out within UBC that serve as examples of systemic approaches, which helped us cope with the complexity of designing a ship's bridge.

In this chapter, I will bind the results from the publications together and advance my view of systemic design in the context of offshore-specific design projects. I start by expanding the discussion on the challenges of designing for the offshore ship industry in Section 5.1. In Section 5.2, I discuss the conceptualisation and operationalisation of systemic design for offshore-specific design projects proposed in this thesis. None of the publications describe the design developed by the UBC project in depth. For this reason, a thick description (Geertz 1973) of the Ulstein Bridge Vision™ is provided in Section 5.3, while the designing and resulting outcome is discussed with regards to the proposed conceptualisation and operationalisation of Section 5.2. Finally, Section 5.4 discusses the transferability of the research to design projects in other complex domains.

5.1 DESIGNING FOR THE OFFSHORE SHIP INDUSTRY

The interview study presented in Publication 1 elicited a number of characteristics of offshore-specific design projects. In the following, I will focus on the characteristics and challenges of designing for the offshore ship industry that contribute to the complexity of offshore-specific design projects. I will expand the insights gained through the interview study with experiences from the UBC project and findings from the literature. I highlight these challenges because having a good understanding of the challenges that designers face is necessary for discussing how they can be better prepared for taking on such projects, and also for discussing the appropriateness of systemic design.

In conducting the analysis across the different data sources, I refined the challenge categories developed in the interview study and ended up

with the following factors that contribute to the complexity of offshore-specific design projects:

1. Designing for an unfamiliar field;
2. Experiencing barriers to gaining insight;
3. Designing for uncertain and high-risk situations;
4. Facing difficulties in understanding advanced technology;
5. Organisational factors adding to the complexity

These will be discussed in depth in sections 5.1.1 to 5.1.5. In Section 5.1.6, I summarise how designing a ship's bridge can be viewed as a 'wicked' problem, and discuss how systemic design may help.

5.1.1 Designing for an unfamiliar field

Designers often refer to their own experiences when designing (Cross 2011). When designing for the offshore ship industry, however, designers rarely have personal experience to draw upon. Because few designers have a background as mariners and the situation at sea is very different from that on shore, it is difficult to envision the users' situation (figures 26 and 27). Based on insights gained through the interview study and the field studies conducted in the UBC project, I have divided the factor of unfamiliarity into: 1) environmental factors, 2) job- and task-related factors, and 3) social factors, all described below.

Environmental factors: Working in a moving environment

The most notable difference between working at sea and working from a land-based location is that working at sea involves working in a moving environment. Ship motions are defined by the 'six degrees of freedom', including (Fossen 2002, 19):

- Surge: motions in the x-direction (alongship: front/back)
- Sway: motions in the y-direction (across: side-to-side)
- Heave: motions in the z-direction (up/down)
- Roll/heel: the rotation of the vessel about the x-axis
- Pitch/trim: the rotation of a vessel about the y-axis
- Yaw: the rotation of a vessel about the z-axis (heading)

Motions influence people at sea in many ways. The UBC field studies made it clear that heavy motions can make it difficult to carry out tasks, because, for example, one must hold on to something to avoid falling over. The moving environment also means that every loose item must be



Figure 26: The situation one designs for; Steaming during the field study in January 2010 (Photo: UBC).



Figure 27: The situation one designs for; Loading operations at night during the field study in July 2012. (Photo: UBC).



Figure 28: The PSV *Bourbon Topaz* on the Skarv Field in the North Sea in 25–30-metre-high waves during the cyclone Berit in 2011. The photo is taken from the rig Polar Pioneer. (Photo: Jøran A. Mannes. VG’s readers’ photos, available at: <http://www.vg.no/protokoll/send-oss-dine-uvarsbilder/1016/>)

secured so that they do not break or cause injuries. Further, the vessel’s motions result in physical fatigue (Wertheim 1998) and the mariners’ performance may decrease because cognitive abilities can be negatively affected by the motion (Dahlman 2009). Some of the mariners interviewed during the field studies described how longer periods of rough weather make the crew irritable because of motion sickness and lack of sleep, and as a result the atmosphere onboard becomes unpleasant. Others described how the motion at times frightens them. On one of the field studies, I was shown pictures from when the crew was out during the cyclone Berit in 2011 (Figure 28). The waves reached 30 meters in height, and even the most experienced deck officers admitted to being terrified. Because ‘landlubbers’ rarely experience such circumstances, it is very difficult for most designers to envision.

The characteristics of the moving environment influence design in many ways. When designing the operator chair of our ship’s bridge, for example, the industrial designers on our team devoted a lot of effort in ensuring that the deck officers would sit securely and comfortably during rough weather. When designing the controllers and input devices, we also

had to consider a ship's movements; we avoided designs that require fine motor skills for functions that could well be used during rough seas.

Prison and his colleagues investigated mariners' 'feeling' for a ship's behaviour when manoeuvring in this moving environment. They identified that many mariners have something that can be referred to as *ship sense*, which is based on bodily input and used to strive for harmony between the ship and its surrounding environment (Prison et al. 2013). In the UBC project we found that designers with experience of boat life (such as sailing) had an advantage because they more or less had such 'ship sense'. However, most designers will not have such a background. In Publication 4, we use the notion of *sea sense*, which is broader than Prison's 'ship sense'. Designers' sea sense refers to designers' insights into life and work at sea, and includes all tacit and explicit knowledge that designers need to make good design judgements in marine design projects.

As described in publication 3 and 4, one must experience the environmental, temporal, and bodily aspects of being at sea to understand them and to develop sea sense. For this reason, field research is particularly valuable when designing for a maritime environment. When conducting field research at sea, however, designers must be aware that they are not only observing work in a moving environment: they themselves are working in a moving environment. In the field studies conducted in the UBC project, we experienced tiredness and lack of concentration, presumably because of the ship's movements. Several were also forced to stay in their cabin for a day or two due to motion sickness.

Job and task factors: Requiring high expertise

The officers' responsibilities during transit are to ensure that the ship arrives safely at the destination at the right time while no harm is caused to crew, cargo, or ship, such as groundings or collisions with obstacles (e.g. other ships, shipwrecks, debris, or other objects). In coastal waters where there may be many ships and leisure boats and shallow water and reefs, the officers must actively control the ship, and fine manoeuvring is needed. In offshore waters, autopilot is normally used and the officers' interaction with the ship is mainly to change course or to accept changes of course at waypoints. Both in coastal and offshore waters, the officers must monitor what happens outside the ship by looking out of the windows and monitoring the RADAR and ECDIS (Electronic Chart Display and Information System). The officers must also follow what happens on the VHF radio and monitor the condition of the ship (although this is mainly the responsibility of the engineers).



Figure 29: Loading operations on a pleasant summer day during the field study in July 2012. (Photo: UBC)

We found many examples in our field studies of how the ship's current bridge design did not support the officers' tasks in a satisfactory manner, such as the work station layout not allowing the officers to keep their eyes on what was going on outside the window; design not fitted to people of different sizes; difficult working postures due to lack of ergonomic considerations; light issues; and little standardisation across equipment.

Many of these observations corresponded with those that were reported in the maritime human factors literature presented in Section 2.3.

Tasks carried out at sea require highly trained and experienced users. The Standards of Training, Certification & Watchkeeping (STCW) Convention, an international convention provided by the IMO, defines the requirements for obtaining deck officers' certificates. This includes a diploma or bachelor's degree in nautical studies, as well as practical experience. Most OSVs in the North Sea further use DP, which requires that the deck officers also serve as DP operators. This implies additional training and a specific certificate. DP is discussed further in sections 5.1.4 and 5.3.2. When designing for such expert users, designers will naturally have limited personal experience to draw upon. As such, a high degree of user involvement is necessary to succeed in such projects (Roesler and Woods 2008). This is also stressed by the results of the interview study.

One important difference between working on a ship and having a job ashore is the fact that such workers live at their workplaces. On Norwegian OSVs, the crew usually work for four weeks, then have four weeks off. While some land-based jobs do have similar regimes, most land-based workers are able to go home after a day's work. The shift work on ships also tends to be different from what is found ashore, even on work sites with 24-hour operations. Most OSVs in the Norwegian sector have a watch plan with six hours watch time and six hours rest time for the full four-week period onboard. Research shows that this type of shift plan results in accumulated fatigue; while other watch plans that allow mariners more rest have been developed, they are rarely used (Størkersen et al. 2011).

Social factors: Lack of privacy in an isolated workplace

As described by Ellis (2009), living inside the structure of a ship for long periods of time affects well-being in many ways, such as noise issues and issues with lack of daylight and aesthetically pleasing surroundings, as well as social factors. Living at one's workplace for weeks on end means being isolated from family and friends, while at the same time 'living on top of' one's colleagues. The mariners we met during field studies described the emotional strain of this life. Such issues are also brought up in the mariner workblogs, discussed in Publication 2. Another social factor unique to shipping is 'the hierarchical nature of shipboard teams blending civil-type structures with quasi-military norms' (Lützhöft et al. 2011, 283). The captain is responsible for the safety of the crew, ship, and cargo, and is in ultimate command of the vessel.

When designing a ship's bridge, as in UBC, or marine equipment, as the interviewed designers had done, it is not obvious how to address such

social factors. Both the interviewed designers and the UBC team were only designing for work. As we discuss in publications 2, 3, and 4, however, getting to know the people and the circumstances onboard enhances the designer's ability to empathise with the mariners. Empathy inspires designing (Leonard and Rayport 1997; Koskinen et al. 2003) and is thus important also in marine design projects.

The need for gaining insight into the unfamiliar context of offshore-specific design projects was stressed by all the designers interviewed. As one said, 'You can watch videos on YouTube and you can hear them say that "there are plenty of alarms, it is noisy, and the waves are high" but as long as you haven't experienced it for yourself, it is very difficult to understand exactly what it is like' (D8 #00:10:38-6#). In the next section I will discuss how gaining access to the users and field sites is a major challenge in offshore-specific design projects.

5.1.2 Experiencing barriers to gaining insight

Both the interview study and experience from the UBC project show that gaining insight into the users and their situation is a key challenge of designing for the maritime and offshore industries. Referring to this challenge, one of the interviewed designers said, 'It is incredible how difficult it has proved to do what you thought, while being a student and a fresh designer, was the most important part of a project, and the most natural thing to do as a designer' (D8 #00:46:41-8#). In Publication 1, we introduce a model that illustrates the different situations designers may find themselves in terms of access to users and context of use (Figure 30). In (a) the designers have direct access to users and the context, which is the most desirable situation. The diagram does not distinguish between gaining access to users and contexts at different times or at the same time. In the UBC project, we found that observing and conducting informal interviews in context is the best approach to gaining an understanding of what goes on at sea. In (b) the designers have direct access to users, but must learn about the context indirectly through the users and other secondary sources. In (c) the designers must learn about both the users and the context of use through secondary sources only. Unfortunately, situation (c) is not uncommon. The interview study showed that also designers who had several years of experience from designing for the offshore industry had never been to sea and rarely spoke to representative users.

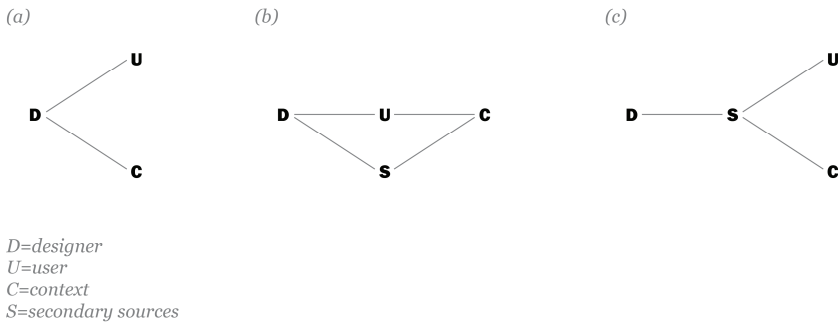


Figure 30: Designers' access to users and context of use. (Figure 3 in Publication 1)

Below, I summarise the challenges that hinder designers in conducting user studies in offshore-specific projects in relation to: 1) hard-to-reach locations, 2) economic barriers, 3) organisational barriers, and 4) designing for rare situations, all of which were identified in the interview study. We also experienced many of these in the UBC project and much effort was put into organising the field studies and workshops with users that we were able to conduct during the project.

Hard-to-reach locations

The field sites of offshore-specific design projects are situated in places that are geographically difficult to access. Further, when the mariners have signed off and gone ashore, it can be difficult to organise interviews and user sessions, as this is their time off. Also, the fact that most of the Norwegian mariners who work on OSVs live on the west coast of Norway, while most of the designers live and work in the southeast, adds to the difficulty of establishing contact with users, as there are few personal connections that could help designers to get in touch with the mariners.

Economic barriers

Conducting field studies at sea usually implies spending several days onboard, and it is expensive for the client to pay for hired designers to conduct field studies. According to the designers we interviewed, many clients are not prepared to accept this cost because they do not see the value of field studies for design. We did not experience this challenge in the UBC project to the same extent.

Organisational barriers

Gaining access to a ship or a rig may be difficult for a range of organisational reasons. The interview study indicated that it is normally

not the shipping companies or operators that hire the designers, but rather the equipment suppliers. Equipment suppliers often do not have direct contact with users and field sites, and have to request access from their clients or even their clients' clients, if they are subcontractors. Some equipment suppliers do provide training courses, however, and some of the designers interviewed had access to users at the training facilities.

Another organisational barrier to gaining access to field sites is that certain safety certificates may be required to enter some installations. Examples include the 'Basic Offshore Safety Course' and 'Helicopter Underwater Escape Training', which may be needed before conducting field studies on rigs.⁹

There are also practical obstacles to conducting field research related to the nature of the offshore ship industry. Because the opportunity to join a vessel can be unpredictable (because ships' schedules are often subject to change on short notice), it may not be possible for designers to go when such an opportunity arises. One of the designers interviewed expressed this challenge rather vividly: 'We have experienced occasions where we arrive at the quay just in time to wave the vessel goodbye because they suddenly had to leave and could not wait for us' (D2 #00:13:46-2#). Because we also experienced this unpredictability in the UBC project, during the periods when we were conducting field studies we were told to 'have our sailor bags ready' at all times.

Designing for rare situations

Designers may also experience the challenge of designing for extremely rare situations that are almost impossible to observe. One of the designers interviewed illustrated an example for us from one of his projects that addressed the design of a system used for oil spill recovery: 'An oil spill at sea occurs once a year. The few beds on a vessel going out when a spill has happened are highly coveted and needed by others' (D4 #00:10:36-9#).

5.1.3 Designing for uncertain and high-risk situations

The maritime and offshore industries are examples of high-risk industries (Perrow 1999). This implies that the consequences of an 'unwanted event' may be disastrous, with potential loss of life and assets, and harm to the environment. The high-risk nature of the maritime and offshore industries implies a strong focus on safety, and as a consequence many of

⁹ Exceptions may be granted for shorter visits.

the designers interviewed had encountered a requirement for ‘evidence’ that a new design would not compromise safety.

The designers’ appreciation of the high-risk nature of the domain they designed for differed among the interviewees. While some were concerned with the risk aspects of the situations they designed for, others were not at all. The latter saw risk considerations as something that was done after the designing stage, and therefore the responsibility of the client. While it is surprising that these experienced designers did not see risk considerations as part of good design craft, there may be systemic reasons for this; it may be related to the tradition in the maritime industry of ensuring safety through regulations (see Section 5.1.5). The same designers stressed that it was the client’s responsibility to make sure that the products satisfied the requirements in the regulations, partly because acquiring a good overview of all the regulations and their relative statuses is a challenging task that could take the focus away from designing good products. In this way, the regulations work as a ‘guarantor-of-design’ (Nelson and Stolterman 2012, 203) to which responsibility can be transferred. Searching for an external guarantor-of-design can be seen as a strategy for escaping the uncertainty of the design situation.

5.1.4 Facing difficulties in understanding advanced technology

The technology on ships is increasingly becoming more advanced (Lützhöft 2004; Røed 2007; Tang 2009) and in the interview study we found that ‘a typical design project for the offshore industry involves developing products based on highly advanced technology to be used in complex operations’ (Publication 1). This implies that the designers in these industries must put considerable effort into understanding the technology used in the products they design.

One example of an advanced technology used in many operations where OSVs are involved is DP, ‘a system which automatically controls a vessel’s position and heading exclusively by means of active thrust’ (Bray 2011, 3). DP is an example of an automation system that relies on feedback control (see Section 3.4.4) and is used in a range of offshore operations, including while discharging at a rig, as shown in figures 27 and 29. DP is not one piece of equipment. Rather, it is a ‘vessel capability’ (Bray 2011), and in addition to the DP computers, the DP system includes all the technical systems onboard that are involved in: 1) identifying the position and heading of the vessels (e.g. GPS, gyro compasses, and relative position reference systems); 2) measurements of factors that influence the position of the vessel (e.g. wind sensors); and 3) technical systems that

provide the vessel with capability of controlling its position (e.g. thrusters, propellers, and power plants).

The design of systems used in DP operations was addressed in several of the interviews, and is also something we worked on in the UBC project (see Section 5.3.2). Gaining a thorough understanding of all the technical systems involved in DP operations is very demanding and requires an in-depth technical understanding. Given that the development of such systems is done by specialised engineers (often with Ph.D. degrees), it is clear that designers cannot expect to fully understand the systems. One of the designers interviewed described a project that involved such technology. The designer said that to really understand what he designed, he would have needed an engineering degree. Yet, he also stressed that ‘The designer must know more than just the user needs, at least if one is considering the whole system and aim at coming up with radical innovations’ (D7 #00:31:35-7#). Later in the interview, he said ‘If I as a designer do not understand the technical information to be displayed, it is very difficult to recognise the real problem’ (D7 #01:14:25-2#). This poses a dilemma for the designers: How much effort should be expended to understand the technology (at the expense of understanding other aspects of the product and its use) and not to neglect generating new designs?

The introduction of advanced technology to ships’ bridges has also resulted in a situation where deck officers do not always fully understand the systems they use, as is the case with ECDIS (Gale 2009). This was confirmed in our field studies, where we observed that deck officers often did not know the functionality of systems such as autopilot and ECDIS (Figure 31) beyond the basics, or could not use them properly.

5.1.5 Organisational factors adding to the complexity

Adding to the above-mentioned complexity of offshore-specific design projects are several organisational factors related to the maritime and offshore domain. Although it is beyond the scope of this thesis to go into detail on these organisational factors, I will try to provide a brief overview to make what designers need to understand visible. The organisational factors are divided into two sections: 1) ship-building and ship operations and 2) regulations.

Ship-building and ship operations

A ship is owned by a ship-owning company and is operated by a ship management company (Grech et al. 2008). Sometimes this can be the same company, and other times they are different companies. Both company types usually have several ships they own or operate as part of a



Figure 31: The electronic charts (ECDIS) stood out in the field studies as a system that the deck officers found hard to use beyond the basic functionality. (Photo: UBC)

fleet. A ship is ‘chartered’, which means that it is hired for a mission, typically moving freight from one part of the world to another (BIMCO 2014). The charterers of OSVs are oil companies, such as Statoil, BP, and ConocoPhillips. A ship can be chartered for a certain period of time, or it can be hired on the ‘spot’ market for a single-voyage charter. The market for ship chartering is volatile, changing quickly depending on supply and demand (ibid.). This means that the situation designers design for is uncertain.

The global nature of the industry also implies that the crews are composed of people from different nationalities. On the smaller OSVs in the Norwegian sector of the North Sea (such as PSVs), crew members are mainly from the Nordic countries. But the larger vessels often have crew members from other parts of the world as well, for example from the Philippines. The potential language and cultural barriers are something interaction designers need to be aware of.

Furthermore, the ship design and ship-building process itself is complex. According to Ulstein and Brett (2012), the project brief from the owner is often short and underspecified, which leads to inefficient ship design processes. It is uncommon that all stakeholders affected by the ship design are involved, and often there are what Ulstein and Brett

refer to as ‘conflict oriented situations’ that arise from differences in the viewpoints, competencies, and experiences of the stakeholders. Shipbuilding also transcends country borders. A ship is designed in one country and the parts built in different parts of the world.

Industrial and interaction designers involved in the industry are normally hired through one of the many subcontractors involved in the building of a ship. The interview study showed that the designers are normally not involved in delivery projects and the development of specific ships. Rather, they are hired to develop generic products, which are then used as building blocks by the engineers involved in the deliveries. All of these issues mean that it is difficult to foresee the situations one designs for in these projects.

Regulations

The overarching regulatory body of activities at sea is the aforementioned International Maritime Organization (IMO). The IMO is ‘the United Nations specialized agency with responsibility for the safety and security of shipping and the prevention of marine pollution by ships’ and ‘the global standard-setting authority for the safety, security and environmental performance of international shipping’ (IMO 2015).

The maritime domain mostly relies on rules and regulations to ensure safety at sea (Lützhöft et al. 2011). The IMO is responsible for different regulations, with different statuses: the regulations may be mandatory or voluntary. *International conventions*, such as the International Convention for the Safety of Life at Sea (SOLAS) (IMO 2009), are mandatory for all flag states (i.e. the state where a vessel is registered whose laws must be followed by the vessel). In addition, IMO publishes *international codes*, such as the ‘Code on Alerts and Indicators’; *resolutions*, such as ‘A.477(XII) Performance Standards for Radar Equipment’; *circulars*, such as ‘MSC.1/Circ.1409—21/11/2011 Revised List of Certificates and Documents Required to be Carried on Board Ships’; and *guidelines*, which address how to implement a regulation. All these documents may contain information and rules relevant to design.

Fundamental in the regulation of shipping are the flag states and classification societies. A shipping company may freely choose which flag state to register its ship under. The situation today is that ‘the owner could be located in one country, the ship management company located in a second country, and the same vessel could be registered in a third country’ (Grech et al. 2008, 9).

‘Classification societies’ are non-governmental institutions with the objective of verifying ships’ compliance with international and/or national statutory regulations on behalf of a flag state, and to verify that

the technical condition of a vessel meets with rules set by the classification society (IACS n.d.). Although classification is in principle voluntary, most of the world's vessels are classified today because of requirements by underwriters and ship registers (Grech et al. 2008).

Adding to the complexity of the regulations is that there may be standards that apply from organisations such as IEC and ISO¹⁰, the ship management company may have rules and procedures that influence the design, and the charterer of the ship may have rules and requirements that influence the design.

While in some design projects the regulations serve as framework conditions that specify what is required, in others the design team can to some extent disregard them: for example, because the product to be designed is completely new, and the existing rules may not apply (as was the case in one project referred to in the interview study), or because the aim of the project is to rethink the product completely without being limited by the existing (such as in the UBC project). In cases where the regulations do apply, the interview study showed that designers take on different strategies. The regulations can be viewed as limitations or, as stressed by one of the designers interviewed, as something one should question. He highlighted that since the regulators develop requirements based on what exists, designers must challenge the existing solutions to contribute to development for the better. In the UBC project, we experienced a positive attitude from many regulators exactly for this reason.

No matter if the rules and regulations apply in a design project or not, it is useful to be familiar with them because they document years of accumulated knowledge. Acquiring an overview of all the possible regulations that may apply, however, and understanding the relationships between these regulations is an overwhelming task for designers, and therefore may result in the described resignation where designers conclude that it is not their responsibility to deal with regulations.

5.1.6 Designing a ship's bridge is a 'wicked' problem

The described challenges of offshore-specific design projects make it clear that such design projects can be seen as 'wicked' problems (Rittel and Webber 1973), as discussed earlier. I will use the design of the ship's

¹⁰ The International Electrotechnical Commission and the International Organization for Standardization, respectively.

bridge as an example. Our design aim in the UBC project was to create a ‘good’ ship’s bridge. However, there is no definitive formulation of how to design such a thing. There is no true-or-false solution to the task of designing the bridge, and no ultimate criteria that can be used to assess the solution. Satisfying regulations gives some indication of what constitutes a good ship’s bridge, but it cannot ensure a good bridge design for the current context. The classification rules, as an example, define what those who made the rules deemed to be a good solution at the time they were defined. Today, the conditions that the rules were based on might have changed in terms of the operations the ships are involved in, the technology available for developing the bridge, and the users’ expectations.

What is a good bridge depends on who is judging the design, their appreciative setting (Vickers 1965), and their context. Thus, designing a good ship’s bridge implicitly means identifying what a good bridge is from the perspectives taken. Our emphasis was to consider the bridge from the users’ perspective, from a design perspective, and from a systemic perspective. We also aimed to utilise possibilities with new technology. This influenced what was (tacitly) considered a good bridge in our project.

Given that there are no ultimate criteria for a good ship’s bridge, we cannot know when we have solved the task of creating a good bridge. In the UBC project, we stopped with individual design tasks when we were satisfied with the solution we had found, or when we decided our efforts were better used on another task. The whole UBC project came to an end when the set timeframe for the project was up.¹¹ We did what Nelson and Stolterman (2012) refer to as ‘search for adequate designs’—that is, we found the best possible design within the time and resources available.

We will not know how good our bridge concept is before it is implemented, because the situation we designed for is dynamic and uncertain. What Rittel and Webber state is true for the design of a ship’s bridge: ‘any solution, after being implemented, will generate waves of consequences over an extended—virtually an unbounded—period of time’ (1973, 163). For these reasons it is impossible to prove that a new design will enhance safety, although we can assert that a new design is

¹¹ Although the work has continued within Ulstein and in other research projects, such as the aforementioned project ONSITE, the form that the work took within UBC was discontinued in April 2013.

better than an existing one based on our judgements and thus argue for our assertion.

Ships are usually ‘one-offs’. Even though experience from the design and building of one ship can be used when designing and building the next ship, the design of an individual ship’s bridge can be seen as a ‘one-shot’ operation. Building a ship is expensive; once a ship is built it is usually not a reversible act. The lifetime of a vessel can be several decades. When a vessel is no longer deemed fit for the North Sea, it will be relocated to other parts of the world and new people will be influenced by its design, defined in and for a completely different context. As an example, *Rig Pilot*, the first Norwegian OSV built in 1971, is still in operation in China today (Norwegian Shipowners’ Association 2014a, 4).

As I have described, designers who work in the offshore industries find themselves in a complex design situation that requires that they make sense of substantial and diverse information. The overall aim of this thesis is to understand how systemic design may be of help to designers faced with such situations. Systemic design has not yet been defined for the offshore and maritime domain, however, and to be able to discuss this, I must first establish what I mean by ‘systemic design’.

5.2 CONCEPTUALISATION AND OPERATIONALISATION OF SYSTEMIC DESIGN IN THE OFFSHORE SHIP INDUSTRY

One presumption for this thesis was that designing for the offshore ship industry is complex, and that systemic design may be of help. The characteristics and challenges presented in the previous section support that working in this domain is complex. In this section I will present the conceptualisation and operationalisation of systemic design of this thesis, and argue why such an approach to systemic design may help industrial and interaction designers working in the offshore ship industry.

5.2.1 A systemic design mindset

In this thesis I conceptualise systemic design through a systemic design mindset that involves, in the words of Pearce (1998), *thinking about systems* and *thinking systemically* when considering one’s design situation. The term ‘mindset’ refers to a way of thinking and a sensitivity that enables people to notice certain aspects of a situation (Nemeth and Klein 2010, 3). Our mindsets are related to our worldviews and mental models (Nelson and Stolterman 2012, 65), and are influenced by our values and appreciative setting (Vickers 1965). Mindsets are born out of experience

but can also be deliberately shaped: for example through the use of models or schemas (Dubberly 2009; Nelson and Stolterman 2012, 64).

In Publication 6, I propose a model that encourages such a mindset: a *systemic model of the design situation*. The starting point for this model, derived from the interview study and the experiences of the UBC project, is that which design teams need to make sense of in offshore-specific design projects. From the previous section, it becomes clear that some of this is related to that which is designed, some of it is related to that which one designs for, and some is related to that which sets the framework conditions for design. Each ‘chunk’ that needs to be made sense of can be seen as a system, in that they consist of several interconnected parts that together form a whole. In the model in Publication 6, I refer to these systems as:

- the system we design
- the system we design for
- the system we design within

The *system we design* can be a traditional physical product, a digital product/user interface, a service, or the design of an organisation. In this thesis, the phrase is used to refer to the physical and digital environments of the ship’s bridge. Considering what we design to be a system is part of thinking about systems, which, as highlighted in Publication 6, invites making boundary judgements.

The *system we design for* includes the *context of use* (ISO 1998), as well as the wider setting of the use situation, for instance the operations that the ship is involved in and the natural surroundings of these operations, such as topographic factors and weather conditions.

The *system we design within* consists of the framework conditions that influence the design project and shape the design team’s performance. This includes industry-specific factors, such as regulations, culture, and traditions, and project specific-factors, such as the project’s scope and role, budgeting and resources, and the distribution of roles and responsibilities within the project. The system we design within is similar to what in SOD is sometimes referred to as the *landscape* of a design project (Sevaldson 2013). Although there is obviously some overlap between the system we design *for* and the system we design *within*, the latter is broader than the former. This system stands out from the other two systems in the model, in that the design team themselves are explicitly part of this system. Acknowledging one’s own position in the system is part of thinking systemically.

The systems of the systemic model of the design situation are interlinked and thus influence each other. In Figure 4 of Publication 6, feedback loops from the design decisions to each of these three systems indicate that we can influence all of them through our designing, while a feedback loop from design decisions to sensemaking makes visible that insight is also gained through designing, as emphasised by numerous scholars (e.g. Schön [1983] through the notion of *seeing-moving-seeing*).

I argue that a good understanding of all of the systems in Publication 6's model is necessary to make good design decisions that will lead to 'adequate designs' (Nelson and Stolterman 2012). An insufficient understanding of the design situation may lead to false assumptions about the conditions for a design project, and could lead designers to place unnecessary constraints on their design work. Conversely, a good understanding of the design situation can help designers make better design judgements, enable them to see opportunities beyond the obvious, and clarify how designers may change their conditions through their design work.

In the next three sections I will discuss operationalisation of this understanding of systemic design in terms of its implications for the design process, design methods, and the design team.

5.2.2 Implications for the design process

The systemic model of the design situation introduced in Publication 6 shows the dynamic nature of the design situations we face. Just as the dynamic nature of the world in general calls for flexible and adaptive approaches (Checkland and Poulter 2006), the dynamic nature of the design situation calls for flexible and adaptive approaches in design. Pre-defined and prescriptive design processes can fail because all design situations are unique, and as a consequence it is difficult to predict how they will evolve.

The systemic model of the design situation invites considering the design process a dynamic system that must respond and react to the design situation in a flexible and adaptive manner. When we learn about the *system we design for* and the *system we design within*, we may expand the boundaries of both the *system we design* and the scope of the project. Similarly, we may find unexpected opportunities as we explore the material qualities of the *system we design*. These new insights may lead to a desire to change the design process.

The model presented in Publication 6 builds on Vickers's theory of appreciative systems (Vickers 1965). Through the model, I argue that we,

by designing, change the world a little, and consequently our design situation also changes. Ideally, we should therefore continuously adapt our design process as the work progresses and the design situation changes. Such a view of the design process means the design team and the client should continuously engage in collaboratively framing of the project.

5.2.3 Implications for design methods

The systemic model of the design situation is generic, and thus does not provide insight needed for particular design projects. Yet, no design situations are the same, and a universal model can never be representative for every design project. We need to inquire into the specific design situation we face in order to learn about its unique characteristics (Nelson and Stolterman 2012). Systemic design methods are useful for such a purpose.

A design method is here understood broadly as anything one does while designing (J. C. Jones 2012, 148). Thus, a systemic design method as defined in this thesis is an activity one engages in while designing that will help the design team think about systems or think systemically. Systemic design methods can be used to consider the design situation as a whole, or to make sense of the individual systems inherent in the design situation. This view is somewhat different to Ryan's (2014) use of the term *systemic design methods*.

In design there is a tendency to apply a pragmatic approach to the use of methods (Harrison et al. 2006). This implies picking and choosing methods from different theoretical traditions, and adapting and inventing methods deemed to be useful in the design process. The rationale for such an approach is that the purpose of using a method in design is not to develop certain knowledge, but to develop better designs. Since design situations are both unique and dynamic, such an approach is understandable. I argue that systemic design methods should be flexible and easily adaptable to the needs of the situated design work. A systemic design method should further support maintaining the proposed systemic design mindset, and help the design team to think about systems and/or think systemically.

Methods that help us think about systems could help us invent boundaries and identify 'chunks' of the design situation that are relevant to consider as systems. The systems of the systemic model of the design situation can be a starting point, and, as stressed in Publication 6, each of these systems can be divided further into sub-systems in a variety of ways.

The systemic design methods may also help us make sense of the defined systems by:

- Providing tools that can be used to identify relevant parts of the system;
- Suggesting techniques for establishing different types of connections and relations among the parts;
- Helping us identify emergent properties of the system, and its goal(s) or purpose(s);
- Helping us identify how the system interacts with its environment and other systems; and
- Helping us consider how the systems may evolve.

SOD provides a few systemic design methods that have some of these features. GIGA-mapping (Sevaldson 2011) can be used to map out the parts of a system and their relationships and connections in a flexible way. In GIGA-mapping, emphasis is placed on acknowledging that there are other types of relations in addition to cause-effect relationships. A checklist of systemic relations is provided that can be used to help identify such relations (Sevaldson 2015). SOD also recommends the use of ZIP-analysis (Sevaldson 2013), which is a technique that can be used to identify intervention points in a system.

We used several systemic design methods in the UBC project. In addition to GIGA-mapping and ZIP-analysis, we adapted existing systemic methods from other disciplines, for example ACTA (Stanton et al. 2005, 374–379; Militello and Hutton 1998) and comms usage diagrams (Stanton et al. 2005, 87–93). We also developed our own systemic design methods, such as design-driven field research, introduced and discussed in publications 3 and 4, and layered scenario mapping, presented in Publication 5.

5.2.4 Implications for the design team

Considering the design situation to be a dynamic system of systems also has implications for the design team. As we learn more about the *system we design*, we may see a need for new competencies within the design team. A change in the scope of the design project as a response to the design situation may also lead to a need for other competencies among the team members. Consequently, just as the design process can be viewed as a dynamic system, the design team can be as well. Further, just

as the design process should be flexible and adaptive, ideally the design team should be too.

The characteristics and challenges of offshore-specific design projects described in Publication 1 and Section 5.1 make it clear that no one person can have a full and in-depth understanding of all relevant aspects of such projects. Hence, multidisciplinary or even transdisciplinary teams are necessary. Multidisciplinarity involves studying a research topic using the viewpoint of several disciplines at the same time (Nicolescu 2002, 42), and goes with the systemic principle of applying multiple perspectives. It is also valuable when design is seen as a balancing act (see Section 3.1), because an in-depth understanding of the different factors is needed to be able to balance them in a good way. Transdisciplinarity, on the other hand, concerns that which is between or across disciplines (ibid., 44). Transdisciplinary approaches often emphasise including laypeople in the knowledge production, such as in what Gibbons et al. refer to as ‘mode 2 knowledge production’ (1994). In the specific case of designing for the offshore ship industry, including laypeople may not be relevant, however, the inclusion of expert users is recommended when designing for professional use (Roesler and Woods 2008).

One consequence of keeping a mindset where one thinks systemically is to acknowledge that the members of the design team will have different appreciative settings (Vickers 1965), which will influence how they judge the design situation and what they deem a good response to be. Thus, a systemic view of the design team should acknowledge the individual designers’ personal focusses and subjective interpretation of a design situation, as described by for example Suri (2011) and Kolko (2011).

Considering the design team as a dynamic system also implies acknowledging that the team members change through their work. As John Chris Jones says, ‘To make or invent something new is to change not only one’s surroundings but to change oneself and the way one perceives: it is to change reality a little’ (J. C. Jones 1992, xxix). Kjetil Nordby, the project manager of the UBC project, similarly used to say that ‘We are not the same team now as we were last year’. This view of designers supports the notion of design as a learning system that is continuously evolving, as suggested by Dubberly (2008; Dubberly and Evenson 2011) and Jonas (2007a; 2014), among others.

In the next section, I present the ship’s bridge design developed by the UBC project, and discuss it in the context of the conceptualisation and operationalisation of systemic design in the offshore industry introduced above.

5.3 THE ULSTEIN BRIDGE VISION™

The Ulstein Bridge Vision™, as mentioned, is the ship's bridge design developed by the UBC project. The design can be seen as a representation of our understanding of the design situation (and the needs, problems, and possibilities within it) and a manifestation of our design decisions.

In the following, I will first present and discuss the Ulstein Bridge Vision™ as a whole, and will then discuss two distinct parts of the bridge that may be seen as systems in themselves: the conning display and the multimodal interaction system. Other parts of the bridge can similarly be seen as distinct sub-systems and could have been discussed here, such as the workstation, the operator chair, the communication system, or the alarm system.

In the discussions of the Ulstein Bridge Vision™ I use the designs presented to the public in 2012 at the ONS trade fair and online (*2012 iteration*), and in 2013 at the Nor-Shipping fair (*2013 iteration*). The design is presented in a 'thick' (Geertz 1973) and informal way (represented here by a different font from the rest of the thesis) to give the reader a sense of what experiencing the bridge is like. I apply the systemic model of the design situation (Publication 6) as an analytical tool for considering the sensemaking that took place in each case.

5.3.1 The concept bridge as a whole

The first thing that might strike you with the Ulstein Bridge Vision™ is how open it is. There are windows almost from floor to ceiling all around the wheelhouse, and there is no funnel or rigging blocking the view. Thus, it allows 360 degrees of vision around the ship.

The forward part of the wheelhouse, referred to as the 'navigational bridge' or 'front bridge', is where the officers navigate the ship. On an osv, the front bridge is mostly used during transit. The front bridge of Ulstein Bridge Vision™ consists of two identical work stations (see Figure 1 from Chapter 1 and Figure 32 next page). The officers have a good view out of the windows from both positions. The chair is designed so that the officers may sit or stand. A foot-rest enables them to sit comfortably. The desk is 1,000 mm above floor level, which is a favoured operation height when standing. In the 2012 iteration, the desktop consists of levers used to control the individual thrusters of the ship, a joystick, multifunctional physical input units ('knobs'), and a generic touch surface. In the middle of the work station is a touchscreen with a keyboard that enables the deck officer to type when needed. The 2013 iteration (Figure 34) has an even cleaner design, where multifunctional knobs are placed just above the touch



Figure 32: The front bridge (2012 iteration). Still images from a film presenting the Ulstein Bridge Vision™ by Frost Media/4grader and UBC, available at: <https://vimeo.com/48453519>.



Figure 33: The aft bridge (2012 iteration). Still images from a film presenting the Ulstein Bridge Vision™ by Frost Media/4grader and UBC, available at: <https://vimeo.com/48453519>.

surfaces on each side, one main multimodal control/joystick is placed to the right, and a physical controller for the autopilot system is located on the primary location on the left side. The desktop also contains a coffee cup holder and a holder for cold drinks, for those rare officers not drinking coffee.

Below the window there is a 9-m-wide screen area, consisting of all the information the deck officers need during navigation. The placement of this screen allows the officers to merely tip their heads down to glance at the screens, which means that they do not need to take their eyes off what is happening outside the window for long periods of time. This is very important for

the tasks performed by the deck officers. As stressed in a post by the blogger 'the Mariner' cited in Publication 2, 'Learn one thing, look out of the windows, and then look again' (Wyles 2013). The middle part of the screen is a shared information space, while the sides include information for the specific work stations. In Figure 32, the screen area portrays RADAR, ECDIS (electronic charts), CCTV (video surveillance), alarm overview, and a conning display (discussed in the next section). The screen below the windows also includes graphics that support you when interacting with the touch surfaces by giving indications of where the user's hand is (a kind of cursor) and indicators when a physical controller is touched.

As you move to the aft, you will pass an office area where the deck officers can do paperwork and a lounge area. The aft part of the bridge of an OSV is often referred to as the 'operational bridge' or the 'aft bridge'. This is the place where the officers control the ship during offshore operations. It is also commonly used for fine manoeuvrings in port, because it gives the officers a good overview and a feeling of control.

The aft bridge design of the 2012 iteration (Figure 33) includes two workstations, and the same operator chair as at the front. Had you been on-board during offshore operations, you would have observed that the deck officers are much more active in the aft than in the front. It is thus more natural to stand here. Since they may spend a lot of time here, however, they will need to rest, and therefore comfortable seating is provided also in the aft.

The head-up display (HUD) on the windows may also catch your attention. This makes key information readily available to the officer while looking outside. The underlying design philosophy for the HUD is that the user can bring up information here as needed. The example of the HUD shown in Figure 33 includes RADAR, standing alarms, heading and position information, and thruster parameters.

Information for the officers is also provided by sound: both speech and composed sounds that contain information. These sounds are nothing like the traditional alarm sounds you would hear on a bridge, which so many deck officers find intrusive. The sounds make you aware that an alarm condition has occurred without disturbing what you are doing. The rhythm, intensity, and speed of repetition convey the urgency of the alarm. Through the sounds, you also get clues about which equipment the alarm is related to. If several alarms occur at once, you can easily distinguish the different alarms based on the sounds. While the alarm condition persists, a non-intrusive sound plays in the background.

In the 2012 iteration there is no screen below the window in the aft, while the 2013 iteration of the bridge (Figure 34) presents a more ambiguous design,

which could be viewed as either front or aft bridge, thus suggesting that a screen below the windows may also be provided in the aft. If so, the screen is used for information that needs to be available all the time. This is contrary to the HUD, which includes restricted information necessary for a shorter timeframe that is related to the specific operation at hand, such as variables that are monitored during an operation.

Sensemaking efforts leading to the concept bridge

In the UBC project, we considered the bridge as one system to be designed as a coherent whole. This, however, is a complex system, consisting of many sub-systems.

We made substantial efforts to understand the typical bridge of an OSV of today. In the UBV pilot study (presented in Section 2.4), an initial field study was conducted where the main functions and all the equipment of the bridge were mapped out (Nordby et al. 2011). The two designers who conducted this field study did not continue in the UBC project. Still, as discussed by Nordby et al. (2012), their report helped the UBC team as newcomers to become familiar with the bridge.

We also used a number of other activities to get acquainted with the ship's bridge and its constituent parts. Mapping played a particularly important role, as described in Section 4.3.4. Designing the 2012 iteration depended to a large extent on mappings of the current bridge environment, and all its equipment. To make these mappings we reviewed many documents, including the report from the UBV field study, regulations, equipment manuals, and the specification of a recent ship delivered by Ulstein Verft. Findings from the field studies of UBC also informed the mappings.

To make sense of and to design the individual sub-systems, the project members did a range of activities, depending on their area of expertise and the task at hand. The team's sound designer made substantial efforts in reviewing the regulations on alarms and research on alarm sounds. The industrial designers made inquiries into ergonomic aspects of workplace design on ships. Sections 5.3.2 and 5.3.3 describe the sensemaking efforts made by the interaction designers when designing the conning display and the multimodal interaction system.

Part of making sense of the system we designed was actually engaging in designing and judging that which we had designed, as described by several scholars, including Schön (1983), through his notion of seeing-moving-seeing, and Alexander (1964), when describing design as judging whether the fit between a form and its context is in fact a misfit. This involved making sketches, CAD models, prototypes, and physical models.

As described in Section 4.3.4, our lab facilities played an important role in this aspect, because it enabled us to make full-scale prototypes.

Making sense of the *system we designed for* included considering the environmental factors, job and task factors, and social factors discussed in Section 5.1.1. It also involved considering the broader operations that the vessel was a part of. Further, we had to understand organisational factors, such as cultural aspects, tradition, economic factors, and the global nature of shipping. This sensemaking relied on making reality judgements (Vickers 1965, 40) and identifying which facts were relevant to a current situation. It also involved making value judgements and considering what we deemed to be a desirable situation (ibid.), and ultimately making design judgements that would lead to our final designs.

In addition to the aforementioned activities for making sense of the system we designed for, we explored the use of mariner workblogs and online forums to gain an initial understanding of the users, their tasks, and the maritime and offshore domain, as described in Publication 2. Although this proved valuable, to be able to get an understanding at the level needed for designing and to develop what in Publication 4 we describe as *designers' sea sense*, we had to go to sea ourselves. The role of field research in gaining the needed insight is thoroughly discussed in publications 3 and 4. Through the substantial amount of field studies we carried out, we developed the model of *design-driven field research at sea* presented in Publication 3, which we based our field studies on. This model was a premise for the generic field study guide presented in Publication 4. The field study approach we developed and used can be seen as a systemic design-method because it encourages using multiple perspectives through the three focus areas of *data mapping*, *experiencing life at sea*, and *on-site design reflection*; and because it is flexible and easily adaptable.

As discussed in Publication 3, the field studies proved crucial to our design work and in getting to know the system we designed for. In particular, the full-body experience we got of the moving environment influenced our designing. We also experienced a few challenges with the field studies, however, the most important of which were making sense of the vast amount of data collected, transferring insights gained from those who had conducted the field studies to the rest of the team, and going from insight to design. To meet such challenges, we developed and used the layered scenario mapping technique presented in Publication 5. This technique was used to map out a scenario along several dimensions and at

different levels of abstraction. It can be seen as a systemic design method for the following reasons:

- It considers the broader context of the scenario mapped out;
- It addresses the whole scenario, as well as the parts;
- It considers relations and connections between the parts;
- It is flexible and easily adaptable to the needs of different kinds of situated design work, as argued in Publication 5.

We used layered scenario mapping to map out the scenario ‘positioning the vessel alongside the rig and doing loading and offloading operations’ from the perspective of the officers on the bridge only, although the layout of the map invites considering the perspectives of other actors in the scenario as well.

As I describe in Section 5.2.1, the *system we design within* includes the organisational factors that set framework conditions for the design project and shape the designers’ performance. Our attempts to gain insights into this system were less structured and focussed than our efforts for understanding the system we designed and the system we designed for. Although we touched upon this in the GIGA-mapping sessions in 2012 (presented in Section 4.3.4), we did not properly define this system until later in the process.

In a paper presented at RSD2, we introduce the notion of the *system we design within* (Lurås and Nordby 2013). We describe the kinds of regulations that influence the design of a ship’s bridge, and also define the system we designed within as constituting the actors that influence and are influenced by our design work. In our case, this included the company Ulstein and the Oslo School of Architecture and Design (in which the UBC project took place), as well as our collaborative partners, the Research Council of Norway and Ulstein’s competitors. We also stressed that the design community is part of the system we design within and an influence on our designing, as well as something that can be influenced by our designing. In Publication 6, I argue that the way in which such parties can be influenced by the Ulstein Bridge Vision™ is because the design changes their appreciative settings (Vickers 1965) and thus what they deem possible and good and bad. The Ulstein Bridge Vision™ can also become part of their repertoire of exemplars (Schön 1983) that they can draw on for future design projects.

Next, I will present the conning display we designed for the Ulstein Bridge Vision™ and discuss the sensemaking efforts that led to this sub-system of our concept bridge.



Figure 34: The Ulstein Bridge Vision™ (2013 iteration). Interactive demonstrator presented at Nor-Shipping 2013. (Photo: UBC)

5.3.2 The conning display

In a prominent position of the screen below the windows of the Ulstein Bridge Vision™ you see the conning display (in Figure 34, slightly to the left of the person operating the console). According to the *Collins English Dictionary*, the nautical meaning of 'to con' is 'to direct the steering of (a vessel)' ('Con' 2015). Walraven (1967, 608) emphasised that when designing the bridge, one must acknowledge that '[t]he officer of the watch requires near him the instruments for determining direction and distance or speed, position finding instruments and other electronic aids, and a good view'. Such information supports the officer in making the decisions of how to steer, and is on modern offshore vessels usually provided by a conning display. Current conning displays are designed to support the deck officers during navigation. In the Ulstein Bridge Vision™, conning displays are available for all modes of operation. Figure 35 shows our design of the conning for manual steering mode, while Figure 36 shows our conning for dynamic positioning (DP) mode. The first thing you may notice is the clean design and modern feel of these conning displays compared to some of the other conning displays available.

You will most often see the conning display for manual steering mode in the front bridge. In the upper left corner of the conning display of the Ulstein Bridge Vision™, you can see who is logged in and the current mode of operation (manual). In the middle top area you find the ship's heading, which is the

direction in which the 'nose' of the ship is pointing, measured in degrees following the compass convention of 0° being north. Below the heading is the speed over ground (SOG) in knots. The size of the heading arrow represents the relative speed (larger arrow = greater speed). Below the speed is the rate of turn (ROT), indicated both visually by an animation (a digital 'slip indicator') and numerically in degrees/minute.

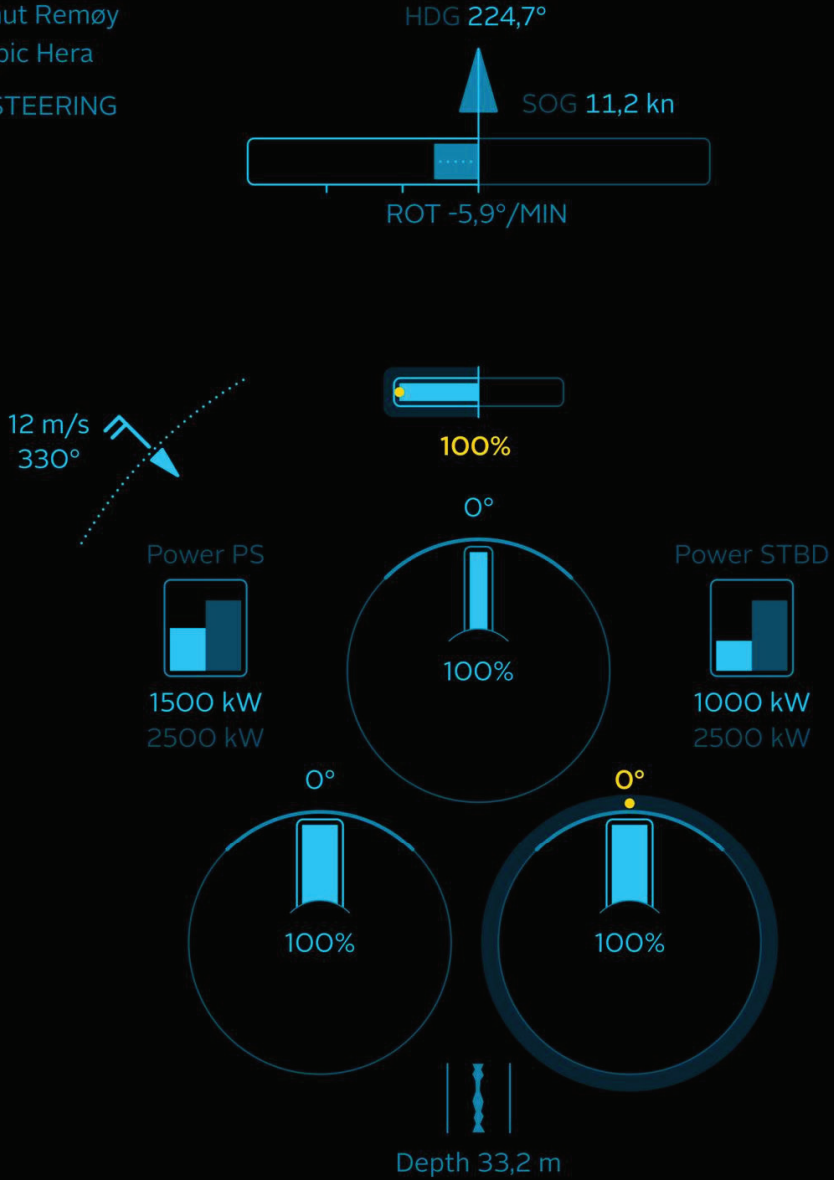
The wind speed/direction is indicated in accordance to actual direction relative to the ship, and visual representations of the thrusters map their placement on the ship. The size of the thruster icon represents the maximum thruster force a thruster may provide. For each thruster, the direction in degrees and thruster force in percentages are included. Indications of applied force and direction are also included when appropriate. Different graphical layouts signal whether a thruster is ready or not, and whether the user is touching the thruster's lever or not. The conning display will probably catch your attention while on the bridge, because the graphical elements of the display will be constantly moving: this is because the ship is moving, the machinery is running, and various environmental factors, such as wind, are constantly changing and acting upon the ship.

The conning for DP mode is meant to be used during offshore operations, and will therefore most often be used in the aft bridge. The DP system was introduced in Section 5.1.4 and its function is to automatically control a vessel's position and heading. There are eight submodes within DP, depending on which degrees of freedom are locked and in control by the DP system and which are free for the DP operator to control. In full DP, all degrees of freedom are locked and the DP system is completely in control of the vessel's position and heading.

This DP conning display contains the information the officers need to be able to judge if they are on set position and heading and whether they will be able to maintain this in the near future. In the upper left-hand corner of the display, below who is logged in, is an icon showing the current DP mode. Below this is the vessel's GPS position and the measured wind and the estimated current in knots, as well as the ship's speed alongship and across in knots. At the centre of the upper part of the display is a visual indicator of the ship and its rotation point relative to the 'set point' (desired position indicated by an orange circle), as well as the warning and alarm limits (indicated by the two dotted circles). The areas with hatched lines provide a visual indication of the external forces applied on the

Figure 35: Ulstein Bridge Vision™ conning display for manual steering mode (next page). (Illustration: UBC)

Captain Knut Remøy
Ship Olympic Hera
MANUAL STEERING



Captain Kjetil Nordby
Ship UBV Innovator

DP



N: 60°51.1744'

E: 005°04.0072'

Wind:

337.1° 19.1 kn

Current:

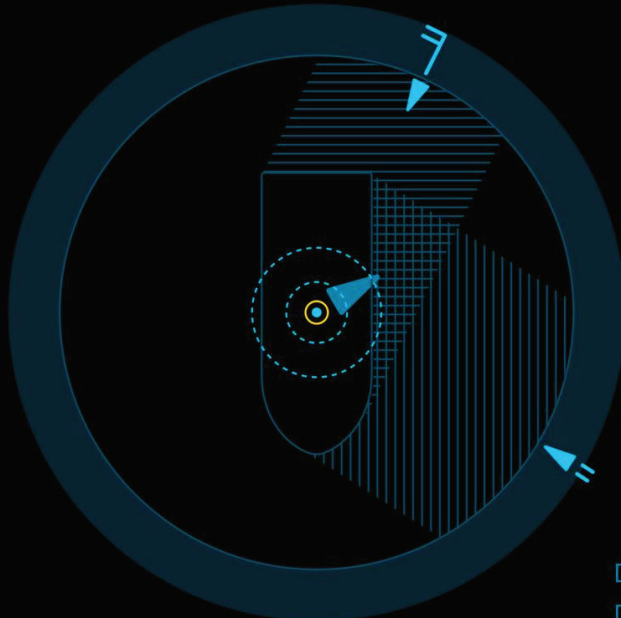
72.3° 2.3 kn

Speed

0.1 kn



0.0 kn



HDG 130,0°

160 150 140 130 120 110 100

ROT 0°/MIN



ship from the wind and current, respectively, and the arrow pointing out from the ship's rotation point gives an indication of the ship's total counter-force used to maintain its position and heading. Below the visual presentation of the ship's position is an indicator of the ship's heading relative to its set heading. In Figure 36, the ship is on the desired position and heading. To the right of this is an overview of the position reference systems in use, with visual indications of their relative weighting as well as the reliability of the signals.

The bottom part of the display shows the main variables of the ship's power system and thrusters, and which generators provide power to which thrusters. At the top is an indication of whether the 'bus-tie' switch between the ship's two switchboard sections is open or closed. During DP operations, the bus-tie switch is open to avoid total blackout on the ship in case there is a fault, thus ensuring that there will still be power for two thrusters to control the vessel (Bray 2011, 29). The example in Figure 36 includes four generators, of which two are in use, as well as four thrusters that are all in use. Both the used and available power and thruster force are displayed. Similarly to the manual mode conning, the elements on the DP conning display are never still.

Sensemaking efforts leading to the conning display

Those who are unfamiliar with the technical outfitting of an OSV may have found that they did not understand much in the previous paragraphs. Most readers will have heard of GPS, but what is the difference between GPS and DGPS, and why is it so important for the officers on a ship's bridge? What are position reference systems? How do the different types of thrusters function? And what is a bus-tie switch? We had to consider such questions in order to be able to design the conning display.

In the DNV's class rules NAUT-OSV (DNV 2012), the conning display is defined as a:

... screen-based information system that clearly presents information from sensor inputs relevant to navigation and manoeuvring, as well as all corresponding and upcoming orders given by an automatic navigation system to steering and propulsion systems if connected. (DNV 2012)

Figure 36: Ulstein Bridge Vision™ conning display for DP mode (previous page). (Illustration: UBC)

The conning display presents data from other technical systems on the ship, and does not generate any data itself. Thus, the *system we design* when designing the conning display is the visual presentation on one screen, but we had to understand all of the systems related to power, propulsion, and positioning to be able to design the display.

DNV's class rules define what should be part of the conning display for manual mode. This served as a starting point for defining the content of the display. We also had to understand the systems that provide the information defined by the class rules. This relied heavily on judging what was relevant to our situated work, and setting boundaries for what we need not understand to avoid facing an overwhelming task.

When designing the DP conning, we had to make substantial efforts to understand the DP technology, such as the basics of the control algorithms and how the position reference systems work. We also made substantial efforts to understand the 'submodes' of DP. A mode confusion while on DP—such as believing an axis is locked when it is in fact free—can lead to an undesired moving of the vessel, which may result in undesired consequences. For this reason, we designed clearly visible icons for the different modes of the DP conning.

In order to gain the necessary level of insight on DP, we read *The DP Operator's Handbook* (Bray 2011) and DNV's class rules for DP (DNV 2011). We also reviewed the user manuals and analysed the user interfaces of DP systems from other vendors. Obviously, the field studies were also paramount in gaining an understanding of DP. While at sea, we could make observations when the ship 'was on DP' and also had the opportunity to discuss the DP system with the users.

Given that we had a broader idea of the conning display than is commonly used, we also had to make judgements to decide what information to include in this system beyond what was defined in the regulations. This depended on the *system we designed for*. We defined the system we designed for when designing the conning as *monitoring* during the different modes of operation. When defining the conning displays, we worked on defining which questions this display should provide answers to while monitoring. The questions were developed based on insights gained during field studies, the information elements defined in DNV's class rules (DNV 2012), and the review of conning displays from other vendors.

The conning for manual mode will most often be used during transit, but also in other circumstances in which manual mode is used, such as

during anchor handling operations. We defined the following questions that the manual mode conning should provide answers to:

- Where are we going and at what speed?
- What factors can make us go in another direction than we would like to? (Wind)
- How deep is the water where we are? (To avoid grounding depth below keel, which is required information in DNV's class rules)
- What are our possibilities for going where we want to go? And for getting away, if we are going in a direction we don't want to go? (Available power, available thruster force)

We defined the following questions that the DP conning should provide answers to:

- Where are we? (Absolute and relative to set position and heading);
- Where are we going? (Desired movement);
- Are we moving when we want to keep a position? (Undesired move/drift);
- Does the vessel know where it is? How much can we trust the position? (Status of the reference systems);
- What are the vessel's possibilities for keeping the desired position and heading? (Available power, available thruster force);
- What are our possibilities for getting away if we are moving in a direction we don't want to go? (Available power, available thruster force).

The sensemaking of the *system we design within* for the bridge as a whole also applies to the design of the conning display.

Next, I will present the multimodal interaction system of the bridge, which is an important subsystem and defining feature of the Ulstein Bridge Vision™.

5.3.3 The multimodal interaction system

Another striking characteristic of the Ulstein Bridge Vision™ is the versatile ways of interacting with the systems it provides. The interaction system utilises several modalities, including touch, voice, and gestures. Direct physical

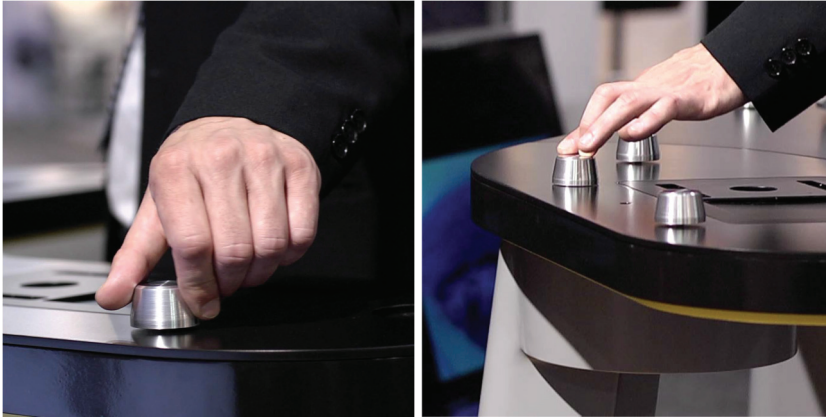


Figure 37: Direct controllers in the 2013 iteration. (Photo: UBC)



Figure 38: The joystick in the 2013 iteration. (Photo: UBC)

controllers (figures 37 and 38) are used for controlling functions that are used frequently, or which have high criticality. Examples include thruster levers, a joystick to control the vessel while on DP, and knobs that, for example, can be used to control the window wipers.

The direct controllers are placed at fixed positions on the desktop so that the user will learn to locate them quickly and operate them efficiently. All of the direct controllers are touch-sensitive, which means that the user gets instant feedback when a controller is touched through the main screens below the windows. The information provided upon touching a controller can be guidance on use or data from different subsystems, such as the latest alarms from the alarm system.



Figure 39: The generic multi-touch surface in the 2012 iteration. (Still image from film by Frost Media/4grader and UBC, available at: <https://vimeo.com/48453519>)

The generic multi-touch surfaces on the sides of the console (Figure 39) allow the user to perform general actions that do not have dedicated controllers. These are used for normal point-and-click in applications, and allow for multi-touch gestures for actions such as scrolling and zooming. The two touch surfaces work as separate input units and can be used simultaneously if needed.

As a supporting and alternative way of providing input to the system, the system can be operated by voice commands through a microphone. Any number of actions can be assigned to voice commands. Audio and voice is also used for output from the technical systems: for example, to provide explanatory alarms. In the 2012 iteration, you can also use gestural commands. This could be used for actions that may need to be done in a hurry, such as muting an alarm sound.

Sensemaking efforts leading to the multimodal interaction system

A multimodal interaction system is a system that integrates different modes of providing input to a computer system (Oviatt 1999). Making sense of the *system we design* when designing the multimodal interaction system implied considering the human and machine as a joint system, and making sense of the characteristics of the human as well as the technology providing the interaction. We had to gain a deep understanding of each interaction mode—including how it worked (technically) from the machine's side, and how it worked (physiologically) from the human's side—and from this understanding judge its advantages and limitations. This relied on a substantial amount of exploratory work in the lab, as described in Section 4.3.4. Further, in

order to define which interaction mode to allocate to which functionality, we mapped out all the necessary input (at a high level) and considered it in terms of frequency, criticality, and use. We also made an effort to understand the functions that needed to be controlled, such as the thruster system. It must be emphasised that more research is needed to conclude which interaction mode is appropriate for which functionality on the bridge.

Considering a multimodal interaction system is completely dependent on an in-depth understanding of the *system we design for*, because the situations in which the interaction takes place is what motivates the use of multimodal interaction in the first place. The system we designed for when designing the multimodal interaction included all situations taking place on the bridge requiring interaction with the ship and its systems.

We found that multimodal interaction systems are particularly relevant on a ship's bridge, because the characteristics of the situations that deck officers find themselves in impose situational impairments on them, thus leading to a need for alternative means of interaction (Nordby and Lurås 2015). *Situational impairment* means that characteristics of the situation saddle the user with temporary disabilities (Sears and Young 2003, 488).

The sensemaking of the system we designed for when developing the multimodal interaction system involved gaining an in-depth understanding of the users' situation and when situational impairments may occur, and thus establishing in which circumstances the users may benefit from different interaction modes. A common example from the ship's bridge that we observed during the field studies was that the officers were required to operate several pieces of equipment by hand simultaneously. As a captain we met said when he had to control three levers with his two arms, 'I am missing an arm'. In such circumstances, other modes of interaction could prove valuable.

Introducing multimodal interaction must be done with care, however, as the introduction of new interaction modes makes the interface more complex and requires that we also judge the possible hazards and error-prone conditions we may introduce (Nordby and Lurås 2015). In the UBC project, we did not do a risk assessment of the multimodal interaction system and did not conclude which interaction mode should be used for which situation from a risk perspective. Thus, further studies are needed before the proposed multimodal interaction system could be implemented in ships in operation. Further, there may be systemic effects from introducing more complex interaction, such as new and increased training needs (ibid.). To meet such a challenge, we decided to use the same type of controllers, which allowed for the same form of interaction

for different systems. This made the interaction system as a whole become simpler and presumably less prone to erroneous use.

The sensemaking of the *system we design within* for the bridge as a whole also applies to the design of the multimodal interaction system. In addition, we had to follow the market for new technologies and make sense of multimodal interaction used in other domains.

5.4 TRANSFERABILITY OF RESULTS

Designing for the offshore ship industry is in many ways unique, and has specific characteristics not found in other domains. Still, I argue that the research presented in this thesis is also relevant to designers taking on design projects in other complex domains. The question of transferability has also been addressed in the publications.

In Publication 1, we discuss the transferability of the findings from the interview study. We refer to the health care and aerospace industries as examples of domains with many of the same characteristics as the offshore domain, and assert that these similar characteristics imply that the findings are transferable.

Publication 2 takes up the use of online workblogs to get to know ‘hard-to-reach’ users, using design for the maritime domain as an example. We conclude the article by posing several questions about the use of online media to get to know and engage users in interaction design in general, and by that suggest that online media can be of use in other design projects where the users are not easily available. One example from another domain where online media has been used to get to know ‘hard-to-reach’ users that was not referred to in the publication is Chapman’s (2010) use of online ethnography when designing an application for chronically ill patients.

In Publication 5, I present the *layered scenario mapping* technique, specifically aimed at the needs of mapping out a detailed scenario when designing the Ulstein Bridge Vision™. In the article I discuss the transferability of the technique, and argue that it can be applied to map out all types of scenarios where the spatial and/or temporal dimensions are important.

Publications 3 and 4 discuss design-driven field research at sea. Although we do not specifically discuss the transferability of these results to other domains, since these papers were presented at marine design and human factors conferences, the proposed approaches to design-driven field research can easily be adapted to other domains. Data mapping and on-site design reflection are obviously relevant in all design-driven field

research, and experiencing life at sea can more generally be referred to as experiencing the users' situation, which also is of importance in other domains. Every domain has its special characteristics that will influence how field studies should be carried out, however. In the maritime domain, for example, the moving environment at sea and the fact that the field studies take place not only in the users' working environment, but also where they live, influence how the field research is conducted. In order for design-driven field research to be truly valuable, such domain-specific characteristics need to be identified and taken into consideration.

The systemic model of the design situation presented in Publication 6 is a generic model, and in the article the UBC project and the maritime/offshore domain are used as an example. Because of the general nature of the model, I argue that it is applicable across domains.

I will now consider the transferability of the results of the thesis as a whole. Using the definition of knowledge as our ability to answer to a situation (Lindseth 2015), I address what we can learn from the thesis that makes us better-prepared for answering to other design situations of similar complexity. *Analytical generalisation*, which 'involves a reasoned judgment about the extent to which the findings of one study can be used as a guide to what might occur in another situation' (Kvale and Brinkmann 2009, 262), is a useful approach to this. Such generalisation is based on judging to what degree there are common attributes between two situations. In the following I will discuss the similarities and differences between the offshore ship domain and other domains designers may work in, using the characteristics of the offshore ship industry presented in Section 5.1 as a basis.

Unfamiliarity is an attribute of the offshore ship domain that introduces a challenge to designers engaged in this industry. Designers will be unfamiliar to a smaller or larger extent with all situations where we design for expert users (Roesler and Woods 2008). What leads to the unfamiliarity may differ, however. Whereas an important aspect of the unfamiliarity of offshore-specific design projects is the moving environment, in other domains there are other characteristics that may make the system we design for unfamiliar. Common for all unfamiliar domains is that designers must be aware of their limited knowledge, set aside sufficient time for gaining insight, and cater for involving users and other stakeholders.

Barriers to gaining insight is a major issue in the offshore ship domain, particularly because of the location of the users and the context of use. There may also be other barriers to gaining insight in domains that are not geographically 'hard-to-reach'. As an example, when designing medical products for young children, Høiseth (2014) found that

conducting research in a hospital setting made it difficult to gain insight for design. In particular, ethical barriers made it challenging because the users were young and seriously ill. A consequence of all such barriers is that designers must consider alternative ways of gaining insight.

As Roesler and Woods (2008) pointed out, expertise is found in many critical domains, and experts often have high-stake functions. Thus, the *high-risk* nature of the offshore ship industry is one that may also be experienced in many other professional domains. *Advanced technology* is further increasingly being used in professional domains, as well as those traditionally seen as ‘manual’. One example is nursing, where technology is used for patient monitoring, taking samples, and in treatments such as medication handling. While the *organisational factors* of the maritime domain may be in a unique position given its complex regulation and global nature (see Section 5.1.5), other professional domains may have other organisational factors that add to the complexity of design projects.

In this thesis, I stress that it is important to be aware of such characteristics and their implications for design projects. I assert that although the characteristics of other domains are not exactly the same, the implications for design practice may be similar. I propose that considering the design situation as a system of systems consisting of the *system we design*, the *system we design for*, and the *system we design within*—and using this taxonomy as a starting point for inquiring into the design situation—may prove useful. This will presumably also hold true for design situations in other domains of similar characteristics. I further argue that an implication of such a view on the design situation may be that one considers the design process and the design team as dynamic systems, and as a consequence sees design as a learning system.

Schön (1983) describes how designers engage in abductive reasoning, in which they look at a situation they face and consider how a solution found in a similar, yet different, situation may apply. A designer’s repertoire of exemplars (ibid., 138) plays an important role in this. The design solutions of the Ulstein Bridge Vision™ can also be transferred to other domains as exemplars that designers may draw upon. The following serves as examples: An aeroplane is also a moving environment, and our solutions addressing this characteristic of the ship bridge may also apply in designing a cockpit. A control tower at an airport or rail yard also depends on having a good view out the windows, and as such our solutions for keeping users’ eyes on what is happening outside is relevant. An operating theatre also has a range of equipment and advanced technology, and therefore the integrated solution of the Ulstein Bridge Vision™ may inspire the design of future operating theatres.

6 CONCLUSIONS AND FINAL REMARKS

Dorst (2008) points out that most design research has focussed on the design process and the object of design (problem and solution), while little attention has been paid to the design team and the context in which the designing takes place. In this thesis I have aimed to address all of these aspects of designing. The overall aim of the thesis is to understand designing for complex, high-risk control environments, such as the offshore ship industry, and how systemic design may be helpful when designing for such contexts. Because one of my intentions was to develop knowledge that will prove useful to practitioners, practise has played an important role in the research. The research approach applied has included research by design, in which I took part in designing a ship's bridge, and an interview study with designers with experience in the maritime and offshore industry. This was supplemented by a literature review.

In this chapter I will summarise the main conclusions of the thesis and present its contributions in terms of design, theory, and methodology. I will also address the strengths and weaknesses of the reported research and point towards possible further research that could build on this thesis.

6.1 MAIN CONCLUSIONS

The conclusions are summarised in the following sections with reference to the research questions presented in Section 1.2.

6.1.1 Research question 1

How do designers find designing for the offshore ship industry, and what challenges do they face?

One presumption for this thesis was that designing for the offshore ship industry is complex and the research presented confirms that designing for this domain is complex and challenging on many fronts. First, the domain is unfamiliar to most designers, and gaining the insights needed for designing requires substantial effort. The unfamiliarity is related to: 1) environmental factors, in particular the movements of the ship; 2) job- and task-related factors, which involves complex operations requiring a high degree of expertise and specially trained users; and 3) social factors, in particular the fact that the people we design for live at their workspace.

The second reason why designing for offshore ships is challenging is that the products to be designed constitute highly advanced technology

that is used in complex, uncertain, and high-risk situations. The advanced technology makes it difficult to understand what one is designing, and introduces a dilemma of how much effort to put into making sense of the technology—possibly at the expense of designing. The fact that one designs for complex, uncertain, and high-risk situations makes it difficult to judge the consequences of a design, and makes it impossible to prove that safety will not be compromised with a new design.

The third reason why designing for offshore ships is challenging is that the industry is global; it has many stakeholders and is highly regulated, thus making the framework conditions of offshore-specific design projects difficult to grasp.

These characteristics of offshore-specific design projects lead to substantial amounts of information that designers need to grasp. Such a volume of information can feel overwhelming. As a consequence, some of the designers interviewed proposed that analytic and systematic techniques for handling the information would be helpful. This finding supports the second presumption for the thesis: that systemic design is valuable when designing a ship's bridge.

6.1.2 Research question 2

How may systemic design be conceptualised and operationalised in offshore-specific design projects?

As established in Section 3.4.3, there are few comparable design projects in the literature where systemic design has been applied. Therefore, considering whether systemic design could be useful relied on conceptualising and operationalising systemic design for such projects.

In this thesis, systemic design is conceptualised through a systemic design mindset that involves, in the words of Pearce (1998), *thinking about systems* and *thinking systemically* when considering one's design situation. Thinking about systems implies considering what kinds of systems may be useful to derive from the design situation faced. Thinking systemically implies considering the design situation from different perspectives, and acknowledging one's own position within the design situation. This implies an eclectic approach to the use of systems thinking, as proposed by Sevaldson (2013) and Peter Jones (2014a), among others, where systems concepts and approaches are drawn from different systems theories as they are deemed useful in one's design situation.

In this thesis, I present a model that aims to help designers develop such a mindset: a *systemic model of the design situation*. This model

describes the design situation as a system of systems, consisting of three partly overlapping and intertwined systems: the *system we design*, the *system we design for*, and the *system we design within*.

Ships' bridges have traditionally not been designed in a holistic manner, which has resulted in fragmented working environments that do not support the deck officers in a satisfactory manner. Systemic design in the UBC project was operationalised through the framing of the project and the systemic design methods developed and applied in the project. Considering the ship's bridge as a whole was important in the systemic framing of the design task of UBC.

Since design situations are both unique and dynamic, I argue in this thesis that systemic design methods should be flexible and easily adaptable to the needs of the situated design work. In UBC, we paid the most attention to getting to know the *system we designed for*. Two systemic design methods have been developed within the Ph.D. research presented in this thesis: *design-driven field research at sea* (introduced in Publication 3 and elaborated on in Publication 4), and *layered scenario mapping* (presented in Publication 5).

In sections 5.2.2 and 5.2.4, I reflect upon what implications a systemic design mindset might have on the design process and the design team. I found that the systemic model of the design situation invites considering both to be dynamic systems. Seeing the design process as a dynamic system means that it should not be pre-defined, but rather that we should continuously adapt our design process as the work progresses and the design situation changes. Considering the design team as a dynamic system means that the team should be flexible and adaptive, and that if necessary new team members with necessary competencies should be brought aboard the project. This also means that we acknowledge that the team continuously changes. The latter supports the notion that design is a learning system.

6.1.3 Research question 3

How can systemic design help a design team make sense of the design situation when designing a ship's bridge, and thus support making design judgements?

Publication 6 argues that the proposed systemic model of the design situation can help designers make sense of the complex and messy nature of the design situations they face by making explicit the relations and connections between the *systems they design*, the *systems they design for*,

and the *systems they design within*. The paper further upholds that such a systemic view of the design situation can aid designers in making design judgements that will lead to ‘adequate designs’ (Nelson and Stolterman 2012, 99).

Having a clear understanding of the design situation, as proposed through the model, can help a design team set boundaries in a design project, and thus apply a *proactive strategy* to boundary setting, ‘which may help the designer see opportunities beyond the original design task given’ (Publication 1).

Publications 2, 3, 4, and 5 provide examples of systemic design methods applied in the UBC project, and argue how these methods helped us gain insights needed for developing the Ulstein Bridge Vision™. Field research at sea was particularly emphasised because of the unfamiliarity of the *system we design for* in offshore-specific design projects. In publications 3 and 4, we argue that our proposed *model for design-driven field research* helps designers gain insight for design and develop *sea sense*, which gives them both an explicit and embodied understanding of life at sea, and which extends the designers’ personal repertoires (Schön 1983, 138) of possible designs for a marine context. As a consequence, designers become better marine designers. Publication 5 presents *layered scenario mapping*, a systemic mapping method used to combine and share data on the *system we designed for* among a design team. This method can help design teams make sense of substantial amounts of data, and be used to make design judgements individually and in collaborative settings.

The emphasis on the *system we design within* of the model of Publication 6 aims to show the factors of the design situation that shape our performance. This includes both the factors that enable the designers and provide possibilities to design, and those factors that limit the designing. The model also shows that designers may influence these factors through their designs by changing the appreciative setting (Vickers 1965): not only their own, but also that of others.

6.2 CONTRIBUTIONS OF THE RESEARCH

In the following section I will highlight the thesis’s contributions to design, theory, and methodology.

6.2.1 Design contributions: Design exemplars for high-risk control environments

The UBC project that this thesis was part of developed a radically new ship's bridge concept called the Ulstein Bridge Vision™. The scope of this design extended from the room layout to the graphical user interfaces and the sound environment, and the design introduced multimodal interaction techniques never seen in the context of a ship's bridge. As described in Section 4.7, this project has received a great deal of positive attention.

The design solutions presented through the Ulstein Bridge Vision™ can serve as design exemplars (Schön 1983), from which other designers can build new designs. Given the scope of the project, exemplars can be found for industrial design, interaction design, graphic design, and sound design. As discussed in Section 5.4, the contribution goes beyond designing a ship's bridge and the offshore ship industry. My contributions to the Ulstein Bridge Vision™ design are discussed in Section 4.3.1.

6.2.2 Theoretical contributions: Towards a systemic design framework for design for complex, high-risk settings

The main theoretical contribution of this thesis is the conceptualisation of systemic design through the systemic model of the design situation presented in Publication 6. This is what Zimmerman et al. (2010) refer to as a 'theory for design', developed with the intention of improving the practise of design. Such a theory aims to help designers be 'prepared-for-action' (Stolterman 2008) and to 'create good [designs]' (Gaver 2012, 940).

The model can be seen as a starting point for a systemic design framework for industrial and interaction design in complex, high-risk settings. While Ryan (2014) has proposed a systemic design framework aimed at those who are not trained in design, as well as professional designers; the framework initiated here is intended specifically for industrial and interaction designers. Further, Ryan's framework is originally intended for organisational design and for the initial stages of a design process (e-mail correspondence, 18 August 2015), while the framework initiated here is aimed at the needs of designers who are creating physical or digital products and throughout the whole design process. Thus, the framework I have in mind would not replace that of Ryan, but rather would complement it. Further work is needed, however, to develop a systemic design framework for industrial and interaction design in complex, high-risk contexts (see Section 6.4).

6.2.3 Methodological contributions: Systemic design methods

This thesis contributes to the methodology of systemic design in many ways. The UBC project in itself can be used as a case for others to learn from; specific methods were also developed within the project. Two of these have been specifically presented in this thesis:

1. Design-driven field research at sea;
2. Layered scenario mapping.

The method for design-driven field research at sea is presented and discussed in publications 3 and 4, while layered scenario mapping is addressed in Publication 5. Because I intended to share these methods, I created guides that can be applied directly in design projects without requiring any previous knowledge.

The generic guide *Design-driven Field Research at Sea* is based on a specific guide to field research that was developed and used internally in the UBC project. The guide emphasises the model for design-driven field research, and how this model can inform the planning and execution of field studies at sea. The motivation for this guide was to share the experiences we had gained from the substantial number of field studies conducted within UBC, and thus make it easier for other designers to conduct field research at sea.

The guide *Layered Scenario Mapping* describes how to make a layered scenario mapping. As discussed in Publication 5, the guide can be applied directly in design projects to sort and map out data that has already been collected, or it may be used to identify information that needs to be mapped out and to prepare for data-collection activities, such as field studies.

Both guides have been published in AHO's digital archives under a creative commons licence (CC BY-SA 4.0) and are publically available through the following URLs:

- The guide for design-driven field research at sea:
<http://hdl.handle.net/11250/294200>
- The layered scenario mapping-guide:
<http://hdl.handle.net/11250/294118>

6.2.4 Note on research by design

Although this thesis did not intend to investigate how to carry out research by design, given that there is no agreed-upon approach to research by design, and the design research literature provides few descriptions of how to conduct such design research in practise, I was forced to develop my own approach. By providing a thorough description of how I conducted the research, I hope that other design researchers can learn from and build upon my approach to research by design. Consequently, this thesis also contributes to the development of the research by design methodology in general.

6.3 STRENGTHS AND LIMITATIONS OF THE RESEARCH

The UBC project is not a typical offshore-specific design project. We found ourselves in a unique position in many ways:

- We had a multidisciplinary design team in which highly specialised professionals collaborated. The disciplines involved were industrial design, interaction design, graphic design, sound design, HFE, and engineering. Such a diverse and highly specialised design team is rare in the offshore ship industry and similar industries.
- We had the opportunity to conduct substantial field research, which has to date not been possible in commercial design projects for the offshore industry. Even designers with years of experience in the industry have not been to sea, as the interview study presented in Publication 1 showed.
- We developed a near-future concept bridge, and were not required to adhere to current regulations, which some designers find restricting (Publication 1).

The uniqueness of the UBC project can be seen as both a strength and a weakness of the research reported. It could be argued that the unique characteristics of the project means that UBC is not a representative case, and that typical design projects for the offshore industry cannot be explained from UBC. For these reasons, I complemented the research by design approach with an interview study. I found, however, that many of the experiences of the members of the UBC design team were similar to those of designers engaged in typical design projects for these industries, such as getting to know a new and unfamiliar field and making sense of a

complex design situation. Still, it is clear that through the UBC project, we did not gain first-hand insights into what it is like to work within the strict framework conditions typical of offshore-specific design projects.

The unique characteristics of the UBC project can also, however, be considered a strength of the research. It can serve as an ‘odd case’, from which we can learn things we would not learn if only attending to ‘normal’ cases (Becker 1998, 86). Because we were able to do several field studies, we could build deep knowledge on design-driven field research at sea. Further, the fact that the UBC team had more time to go into design-specific challenges than is common in the industry enabled us to experiment and to develop new knowledge on what kinds of design solutions may work in maritime settings.

We can also learn from the unanticipated effects that UBC had outside of the project. The UBC project became an intervention within the offshore ship industry, which, as discussed in Section 4.7, caused several ripple effects. The project changed the appreciate setting (Vickers 1965) of members of the offshore ship industry and the design community, and thus created the potential for future design interventions: The offshore ship industry is not the same after the UBC project. These unanticipated effects inspired the systemic design model presented in Publication 6.

6.4 FURTHER RESEARCH

Designers seem to be increasingly engaged in designing for complex, high-risk settings with expert users. This applies not only to the maritime and offshore ship domain. The demand for better user experiences in professional domains, for example, led Eclipse Aviation to hire the design consultancy IDEO to design the flight deck of the Eclipse 500 business jet (Scanlon 2007). As established in this thesis, however, designing for such environments is challenging to designers on many fronts. For these reasons, it is important that the design research community continues to investigate how designers may be best prepared for taking on such design projects.

The conceptualisation and operationalisation of systemic design presented in this thesis can serve as a starting point for a systemic design framework for industrial and interaction designers engaged in such contexts. More research is needed to develop such a framework, however. The systemic model of the design situation presented in this thesis was developed towards the end of the UBC project and thus did not inform the project from the start. One relevant topic for future research therefore is

to investigate what kinds of effects such a mindset could have on designing if it is employed from the onset of a project.

A framework for systemic design in complex, high-risk settings should include design principles, methods, and tools that designers can use to cope with the challenges they face in such projects. One example of a challenge that this thesis did not pay sufficient attention to is how designers may cope with the high-risk aspects of the situation they design for. The designs we make for such settings may have high consequences; good or bad. As mentioned in the introduction of the thesis, a bad design may be a contributing factor of accidents. Conversely, a good design may support the users so that they avoid accidents or are able to diminish the consequences of an undesired event.

The systemic design methods presented in this thesis mainly addressed making sense of the *system we design for*. Future research should further address flexible systemic design methods and tools that can support designers in understanding all aspects of the design situations; the *system we design*, the *system we design for*, and last but not least, the *system we design within*.

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APPENDICES

I. TERMS AND DEFINITIONS

The following defines and describes selected terms used in this thesis.

Aft bridge: The aft part of the ship's bridge. The place from where offshore operations normally are carried out. Also referred to as 'operational bridge' (DNV 2012).

AHO: The Oslo School of Architecture and Design (Arkitektur- og designhøgskolen i Oslo). The research institution where the research reported in the thesis took place.

Alarm: See alert.

Alert: Announcement of abnormal situations and conditions requiring attention (IMO 2009).

Bridge: See ship's bridge.

Captain: The person in command of a ship. Also referred to as master.

CCTV: Closed-circuit television. Video surveillance.

Class rules/notations: Rules defined by a class society which must be met to be classified according to a notation.

Classification/class society: Non-governmental institutions with the objective to verify a ship's compliance with international and/or national statutory regulations on behalf of a flag state and to verify that the technical condition of a vessel is according to rules set by the classification society (IACS n.d.).

Conning display: A display on the ship's bridge that presents key information from different technical systems.

CST: Critical systems thinking (see section 3.4.1).

Deck officer: An officer working on the ship's bridge.

DNV GL: Classification society and provider of risk management services (a merger of the former companies DNV and GL).

DP: Dynamic positioning. ‘A system which automatically controls a vessel’s position and heading exclusively by means of active thrust’ (Bray 2011, 3).

ECDIS: Electronic Chart Display and Information System.

Feedback: Systemic concept from cybernetics. An effect on the input by the output (see section 3.4.4).

Flag state: The state where a vessel is registered and under whose laws the vessel must follow (see section 5.1.5).

Front bridge: The forward part of the ship’s bridge where the officers navigate and manoeuvre the ship during transit. Also referred to as the ‘navigational bridge’ (DNV 2012).

Heading: The direction in which the ship's nose is pointing measured in degrees following the compass convention of 0° being north.

HCI: Human-computer interaction. Discipline originating from computer science and psychology addressing the research of interaction between humans and computers.

HFE: Human factors and ergonomics. Discipline concerned with understanding human’s behaviour, abilities, limitations, and other characteristics.

HUD: Head-up display. Presentation of information without requiring users to look away from their viewpoints. Usually displayed on windows.

IEC: The International Electrotechnical Commission. A standardisation body.

IMO: The International Maritime Organization. The United Nations agency concerned with the safety of shipping and cleaner oceans.

ISO: The International Organization for Standardization. A standardisation body.

Lever: Handle, for example used to control a thruster on a ship.

Mariner: Person working at a ship. Also referred to as seafarer.

Model: A representation of a system (see section 3.4.4).

Multimodal interaction: Interaction using different modes (e.g. touch, voice, gestures) of providing input to a computer system (Oviatt 1999).

Ocean Industries Concept Lab: The research group situated at AHO who took part in the UBC project.

Operation: A mission. A set of tasks carried out with a common purpose. Not to be confused with operations as is used in hierarchical task analysis, where the operations are the actions carried out by people in the systems (Kirwan and Ainsworth 1992).

Operator: Another term for user, commonly used in control environments because the users in such settings operate the things they control through human-machine interfaces (HMIs).

OSV: Offshore service vessel. General term for vessels supporting the offshore industry (see section 2.1).

PS: Port side of the vessel. The left hand side if faced towards the front of the vessel.

PSV: Platform supply vessel. OSV used for transporting cargo to and from the offshore rigs.

Risk: The consequence of an event multiplied by the probability of the event occurring (Aven 2007, 41).

RSD: Relating Systems Thinking and Design. Annual symposia on systemic design.

Ship's bridge: The place from whence the captain and the deck officers control the ship (see Section 2.2). Also referred to as wheelhouse.

SOD: Systems oriented design. A systemic design approach developed at AHO (see section 3.4.3).

SSM: Soft systems methodology (see section 3.4.1)

Stbd: Starboard side of the vessel. The right hand side if faced towards the front of the vessel.

System: A whole that consists of interacting parts (see section 3.4.4).

Systemic design: Umbrella term for the attempts to merge systems thinking and design in recent years (see section 3.4.3). The

conceptualisation and operationalisation of systemic design developed in this thesis is presented in Section 5.2.

System of system: In systems engineering a ‘system of systems’ refers to a complex system that constitutes several independently operating systems with a common mission (Held 2008). In this thesis it merely refers to a system that consists of several systems.

Thruster: An auxiliary propeller on a ship.

UBC: Ulstein Bridge Concept. The design research project this thesis originates from (see section 2.4).

UBV: Ulstein Bridge Visions. The pilot study taking place in 2010 which lead to the UBC project (see section 2.4).

Ulstein Bridge Vision™: The bridge concept designed by the UBC project.

Wheelhouse: See ship’s bridge.

2012 iteration: The bridge concept developed by the UBC project and presented publically at the ONS fair and online in 2012.

2013 iteration: The bridge concept developed by the UBC project and presented publically at the Nor-Shipping fair in 2013.

II. PUBLICATIONS AND PRESENTATIONS NOT INCLUDED IN THE THESIS

The following is an overview of publications written and presentations given as a Ph.D. research fellow not included in the thesis.

Publications

Lurås, Sigrun. 2012. "A different systems approach to designing for sensemaking on the vessel bridge." In *The Systems Engineering Conference, 28–29 March 2012, 89–96*. London: The Royal Institution of Naval Architects (RINA).

Lurås, Sigrun, and Kjetil Nordby. 2013. "Radical design processes for systemic change." (working paper) In *Relating Systems Thinking & Design 2013. Emerging Contexts for Systemic Design. Relating Systems Thinking & Design Symposium*. Oslo: The Oslo School of Architecture and Design.

McCartan, Sean, Don Harris, Bob Verheijden, Monica Lundh, Margareta Lützhöft, Dario Boote, Hans (J. J.) Hopman, Frido E. H. M. Smulders, Sigrun Lurås, and Kjetil Nordby. 2014. 'European Boat Design Innovation Group: The Marine Design Manifesto.' *The Transactions of the Royal Institution of Naval Architects: International Journal of Marine Design*, 156 Part C: 1–28. doi:10.3940/rina.ijmd.2014.cl.23.

Nordby, Kjetil, and Sigrun Lurås. 2015. "Multimodal Interaction for Marine Workplaces Used as Strategy to Limit Effect of Situational Impairment in Demanding Maritime Operations." In *Marine Design 2015, 2–3 September 2015, London, 73-77*. London: RINA.

Presentations

"A different systems approach to designing for sensemaking on the vessel bridge." Paper presentation given at *The Systems Engineering Conference*, London 28–29 March 2012.

"The difficulty of designing when safety is at stake. A systems approach." Presentation given at the *Relating Systems Thinking and Design symposium (RSD1)*, Oslo 3-4 October 2012.

"Designing for the offshore ship industry – HMI design concepts for offshore service vessels of the future." Lecture given at the *Human Factors for Naval Architects summer course*. Department of Shipping and Marine Technology, Chalmers University of Technology. Gothenburg, Sweden 17 June 2013.

“Reaching the hard to reach users—Data collection in the offshore ship industry.” Lecture given at the *Human Factors for Naval Architects summer course*. Department of Shipping and Marine Technology, Chalmers University of Technology. Gothenburg, Sweden 17 June 2013.

“Alarm representation and HMI design concepts for offshore service vessels of the future.” Presentation given at the *Alarm management and HMI conference* organised by Informa Energy and IBC Energy Events. London 19-20 June 2013.

‘Radical design processes for systemic change.’ Presentation given at the *Relating Systems Thinking and Design symposium (RSD2)*. Oslo 9-11 October 2013.

“En designers møte med alarmstandarder.” [A designer’s encounter with alarm standards] Presentation given at *Fagdag om alarmdesign på skip* [Seminar on alarm design on ships] organised by DNV GL. Høvik, Norway 23 October 2014.

“Design på menneskets premisser.” [Design on human’s terms]. Presentation given at *Innovasjonskonferansen e-nav.no 2015* [The innovation conference e-nav.no 2015] organised by the Norwegian Coastal Administration, the Oslo School of Architecture and Design, and ITS Norway. Oslo 5-6 May 2015.

III. INTERVIEW GUIDE FROM THE INTERVIEW STUDY

The interview guide is translated from Norwegian.

1. Introduction

Tell me briefly about yourself and your background

2. Specific design project

Think of a specific project you have carried out for the maritime or offshore industry. This may be a typical project, a particularly good example or one you think is important for some reason. Can you tell me about this project?

- **Background on the project:** What kind of project was this? How was it initiated? What was the design brief? Framework conditions? Who was the client? Project organization? The designer's role? Collaboration with other disciplines?
- **Approach:** How did you plan the project and how was it conducted in practice? What strategies do you have to learn about user and use situation? Framing/reframing? Brief? Methods and techniques used? Intention: Who did you design for?
- **Building knowledge:** Was this the first project you did for the maritime or offshore industry? What did you do to get acquainted with the domain and the project's problem area? Did knowledge developed in previous projects matter? If so, how
- **Competence:** What skills were needed? Did you use any theoretical knowledge in the project? If so, what? How?
- **Systems perspective/holistic approach:** To what extent did you consider the larger system which what you designed was a part of? Did you consider other means to achieve this system's goals than the designed object? Do you use systems thinking consciously?
- **Contributions and designers' role:** What were the specific contributions of the designers?

3. Imagined project

It is a well-known issue that lightning can ruin officers' night vision on a ship's bridge. Imagine that you have been hired to design an intelligent dimming system for the bridge. How would you proceed to take on this task?

What would you do differently to the project you described before? What would you do the same way? (Approach, building knowledge, theory, systems perspective.)

4. Dream project

Think of a dream project for maritime or offshore industry: If you had all the power and unlimited resources, what would be your dream situation? How would you have wanted to carry out such a project? How does the dream project differ from the typical project discussed earlier?

5. Designing for maritime and offshore vs. traditional design projects

What sorts of design projects have you done for the maritime and offshore industry? (Make a list)

What are the common denominators of these projects? Generalise: What are the characteristics of projects for the offshore industry?

Are these projects different from traditional industrial/interaction design projects? If so, how? (What you work with? Design Process? Approach? Use of theory? Time spent? Project organization? Cooperation with other professions? Other challenges? Risk assessment?)

How do you typically get hired for a design projects for the maritime or offshore industry?

6. Summary

(Sum up the main things that have been said in the interview.) Have I understood everything correctly?

7. Supplementary

Have we covered everything you think is important, or is there anything else you wish to say related to that which we have talked about today?

PART 2

PUBLICATION 1

Lurås, Sigrun, Margareta Lützhöft, and Birger Sevaldson. 2015. "Meeting the Complex and Unfamiliar: Lessons from Design in the Offshore Industry." *International Journal of Design* 9 (2): 141–154.

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Meeting the Complex and Unfamiliar: *Lessons from Design in the Offshore Industry*

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Designers increasingly find themselves working in unfamiliar fields with high levels of complexity. One such field is the offshore industry. Through qualitative research interviews with eight industrial and interaction designers, we have investigated how designers experience designing for the Norwegian offshore industry, identified the challenges designers face, and examined strategies used for meeting the challenges they experience. The study shows that offshore-specific design projects are found to be complex at many levels, and the designers interviewed described a number of challenges that make it difficult to gain the insight needed to develop adequate designs. They employ different strategies for coping with these challenges. Systemic approaches, which have proven valuable when designing for other complex issues, are used to differing degrees by the designers interviewed. We propose that systemic approaches could help designers in this field get a better understanding of both the system they design *for* and the system they design *within*.

Keywords – Designing for Unfamiliar Fields, Complexity, Offshore Industry, Systems Thinking.

Relevance to Design Practice – The study presented addresses designers' experience with designing for the offshore industry, a complex high-risk field normally unfamiliar to designers. The research results are considered relevant to designing for other fields of similar complexity.

Citation: Lurås, L., Lützhöft, M., & Sevaldson, B. (2015). Meeting the complex and unfamiliar: Lessons from design in the offshore industry. *International Journal of Design*, 9(2), 141-154.

Introduction

Design is expanding into new areas with high levels of complexity. As a result, industrial designers and interaction designers often find themselves in unfamiliar fields—fields that designers are not traditionally trained to design for and where designers have limited personal experience to draw upon. Examples include designing for professional and expert users, designing for industrial settings, designing for hard-to-reach populations, and designing for different kinds of organisational and societal issues. By “complexity” we refer to systems that contain a large number of parts interacting with each other and their environments on multiple levels, making it difficult to understand cause-and-effect relationships. One such complex and unfamiliar field is the offshore (petroleum) industry. In the study presented in this article, eight professional industrial and interaction designers with experience with the Norwegian offshore industry were interviewed. The objectives of the study were to investigate how industrial and interaction designers experience designing for the offshore industry, to identify the challenges designers face, and to examine the strategies used to meet these challenges. We have also initiated a discussion on *if* and *how* systems thinking could be of relevance in offshore-specific design projects.

Background

The Norwegian offshore industry has been involved in exploration activities, field development, infrastructure creation, and production of oil and gas on the Norwegian continental shelf

since the 1960s (Norwegian Ministry of Petroleum and Energy, 2014). The industry consists of owners and operators of the fields, as well as partners, service providers, and other actors providing support for these activities, e.g., offshore shipping companies. This industry is a typical example of a complex, high-risk industry (Perrow, 1999). The focus of such industries is on efficient and reliable production without compromising either human safety or the environment. The offshore industry depends on continuous innovation in order to achieve these goals in a high-cost country such as Norway. Naval architects and engineers traditionally have been in charge of these innovations, while industrial designers and interaction designers (in the tradition of industrial design, as described by Moggridge, 2007) have not played a role.

Over the last ten years, however, the Norwegian offshore industry has seen a change in attitude towards the use of designers. The Norwegian Design Council has observed an increase in interest from the design field (K. Bang, the Norwegian Design Council, personal communication, August 29, 2013). Not only does the council see more companies from the offshore industry

Received March 20, 2014; **Accepted** March 29, 2015; **Published** August 30, 2015.

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using designers, they also see that the nature of the design assignments has changed. Previously, if designers were engaged they were mostly hired late in the process to “style” individual equipment, while now designers are more often involved earlier in the process and in projects with a wider scope: even the design of whole vessels and entire ship bridges. Further, in the last ten years some Norwegian design consultancies have started promoting their services more actively towards the offshore industry, and some Norwegian providers of maritime and offshore products and services have started employing in-house designers. The designers interviewed in the study presented here work at such companies.



Figure 1. Example of a setting to design for in the offshore industry: The ship's bridge of an offshore service vessel discharging cargo at an oil rig. Photo: Sigrun Lurås.

Despite this tendency, little research has been conducted on the use of industrial and interaction designers in the offshore industry. Linder (2008) has discussed how industrial designers can contribute to innovation in the Norwegian offshore ship industry; Lurås (2012) and Sevaldson, Paulsen, Stokke, Magnus, and Strømsnes (2012) have initiated a discussion of how

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Margareta Lützhöft is a master mariner, trained at Kalmar Maritime Academy in Sweden. After leaving the sea, she studied for a Bachelor's degree in Cognitive Science and a Master's in Computer Science. In December 2004 she received a PhD in Human-Machine Interaction. Between 2006 and 2013 she worked as Associate Professor at Chalmers University of Technology, leading the research in the Maritime Human Factors research group at the Department of Shipping and Marine Technology, within the Lighthouse Competence Center. Presently she is holding a position as Professor of Nautical Studies at the Australian Maritime College. Her research interests include human-centred design, the effects of new technology, and resilience engineering.

Birger Sevaldson is a Professor at the Oslo School of Architecture and Design. He is a member of the OCEAN design research association. He is trained as an interior architect and furniture designer, and has practiced in various fields of design, including architecture and interior design, furniture design, industrial design, and art based projects. He has a PhD in creative design computing, and has been researching systems thinking in design for the last ten years. His work centers on the development of Systems Oriented Design, and his research focuses on developing systems oriented design thinking and practice for meeting the increased challenges of globalisation and the need for sustainability. He publishes on various themes including Systems Oriented Design, creativity, and research by design.

designers can cope with complexity when designing for this field; and Lurås and Nordby (2014) have discussed the role of field research when designing a ship's bridge. Looking at maritime research in general, little attention has been paid to industrial and interaction design, even though the maritime human factors research community has argued since the 1970s that it is not the technology that needs improvement on ships, but rather the design of equipment (Lützhöft & Nyce, 2008). Several studies have concluded that the design of the technology on ships does not support the mariners in a satisfactory manner (e.g., King, 2000; Lützhöft & Nyce, 2008; Mills, 2006; Olsson & Jansson, 2006). A common assumption in the maritime domain, however, has been that user-friendly systems are not necessary since the users are experts (Grech, Horberry, & Koester, 2008). This assumption has been challenged in recent years, and more human-centred approaches in maritime product development have been proposed. Koester (2001), Mills (2006), and Petersen, Porathe, and Lützhöft (2011) discussed the importance of domain knowledge and a thorough understanding of the context of use when designing for marine settings, and Petersen (2012) has suggested that usability standards should be implemented in the maritime domain. Within the field of human-computer interaction, we can find some research related to design for the oil and gas sector. Heyer and Husøy (2012) discussed the uniqueness of designing for an oil and gas workplace, as this industry is outside most people's everyday experience, and Husøy, Gaver, and Enkerud (2010) emphasised the importance of having a good understanding of the work of control room operators.

Systems Thinking

Given the complex nature of the offshore field and the level of insight needed in offshore-specific design projects, it is natural to think that systems thinking could be of value to designers entering this field. Systems thinking involves a holistic view of the world and a consideration of parts as components of a whole—that is, the *system*.

Characteristics of Systems Thinking

Systems thinking evolved as an alternative to the dominant “mechanistic” view of the world, which sees the material universe as a machine, and holds that all aspects of complex structures can be understood by reducing them to their smallest parts (Capra & Luisi, 2014). Throughout the twentieth century several systems theories and approaches were developed. Systems thinking is therefore not one single theory or approach but rather a conglomerate of theories and approaches. Some competing systems theories and approaches exist, while others, such as Critical Systems Thinking, propose an eclectic approach where methods from different systems approaches are chosen based on the nature of the problem at hand (e.g., Jackson, 2003; Midgley, 2000). Despite the diversity of types of systems thinking, there are some common characteristics that distinguish systems thinking from the traditional mechanistic worldview. First and foremost, systems thinking implies a shift of perspectives *from the parts to the whole* and *from objects to relationships* (Capra & Luisi,

2014). The components are still important, but systems thinking stresses the importance of the relationships and the emergent properties that follow from the pattern or structure formed by the relationships: “The whole is greater than the sum of its parts” (pointed out already by Aristotle in his *Metaphysics* [Aristotle, 350 B.C.E.], and also formulated by Hegel in the 18th century in his statements concerning the nature of systems [Skyttner, 2005, pp. 49-50]).

Given that relationships cannot be measured and weighed, as is the ideal of the mechanistic tradition, systems thinking also implies a shift *from measuring to mapping* (and modelling) (Capra & Luisi, 2014). The purpose of a model is to organise, clarify, and unify knowledge in order to give people a better understanding of a system (Forrester, 1991). “Models are ideas about the world—how it might be organized and how it might work. Models describe relationships: parts that make up wholes; structures that bind them; and how parts behave in relation to one another” (Dubberly, 2009, p. 54). Mapping and modelling can be based on mathematical equations, as in Complexity Science (Holland, 2014), System Dynamics (Forrester, 1991), and Cybernetics (Ashby, 1956), which all use modelling and simulation to gain insight into nonlinear dynamic systems. Maps and models can also be visual representations of the system, such as Concept Maps (Novak & Cañas, 2008); Rich Pictures, used in Soft Systems Methodology (Checkland & Poulter, 2006); and GIGA-mapping, used in Systems Oriented Design (Sevaldson et al., 2012; Sevaldson, 2013).

Multidisciplinarity and the application of *multiple perspectives* are also inherent in systems thinking (Capra & Luisi, 2014). Considering a phenomena through multiple perspectives is important to gain a rich picture of a situation, because complex phenomena are impossible to understand by “seeing” them from one point only (Nelson & Stolterman, 2012).

The last important aspect of systems thinking emphasised here is *boundary setting*, in which *boundary critique* is a core idea. This involves “judgments as to what ‘facts’ (observations) and ‘norms’ (valuation standards) are to be considered relevant, and what others are to be left out, or considered less important” (Ulrich, 2002). Such judgement-making can also be referred to as making *appreciative judgements* (Vickers, 1965). In a design project, boundary setting implies judging what should be in the foreground of the design process and addressed actively, and what is in the background and part of the context. Churchman (1971) used the design of a family home to exemplify how boundaries can be set broadly or narrowly. He suggested that the architect in a narrow manner can choose to address the design of the physical house, with its rooms and floor plans, only. Applying a broader perspective, the architect can choose to consider “whether the house is not a component of a larger system, consisting of the family (or its activities) and the house. When he does ask himself this question, he may wonder whether his design task should include the design of a part of the family’s activities” (Churchman, 1971, p. 7). Thus, boundary setting is inherent in making framing judgements used for “defining and embracing the space of potential design outcomes” (Nelson & Stolterman, 2012, p. 148).

Systemic Approaches in Design

The development of the design methods movement in the 1960s, which sought to make design more scientific, was influenced by the systems theories and approaches (Bayazit, 2004; Buchanan, 1992; Cross, 2001). Some claimed, however, that this attempt to incorporate systems thinking into design led to illegitimate simplifications (Bayazit, 2004). In the 1970s, Rittel’s introduction of the concept of “wicked problems” (Rittel & Webber, 1973) marked a shift in how design problems were viewed and called for other systemic approaches in design (Jonas, 2005). As design in recent years has increasingly been used to tackle larger and more complex issues, designers have given renewed attention to systems thinking: see, for example, Jonas (2005), Valtonen (2010), Nelson and Stolterman (2012), Sevaldson (2013), and Jones (2014). Jones (2014) proposed systemic design as a common term for these recent attempts to merge systems thinking and design:

Systemic design is concerned with higher order systems that encompass multiple subsystems. By integrating systems thinking and its methods, systemic design brings human-centered design to complex, multi-stakeholder service systems as those found in industrial networks, transportation, medicine and healthcare. It adapts from known design competencies—form and process reasoning, social and generative research methods, and sketching and visualization practices—to describe, map, propose and reconfigure complex services and systems. (p. 93)

Much of the research into using systemic approaches in design has focussed on designing for societal challenges, such as that of Manzini, Vezzoli, and Clark (2001), who used the concept of Product-Service Systems in designing for sustainability, and Jones (2013), who discussed systemic design-approaches to deal with design issues facing healthcare. The design research community has not addressed the use of systemic approaches when designing for high-risk industrial settings such as the offshore industry to the same extent. Sevaldson et al. (2012) provided examples of how Systems Oriented Design has helped design students embrace and understand the complexity of the offshore industry, while Lurås (2012) has suggested that the design process needs to be rethought using systemic approaches when designing a ship’s bridge. Still, more research is needed on this area given the increased use of designers in such areas. To consider if and how systemic approaches are of relevance when designing for the offshore industry, it is necessary to understand both the nature of the design projects carried out in this area and the experiences of designers working for the industry.

Research Method

An interview study was carried out to meet the research objectives of this article. The Norwegian offshore industry was chosen as a prime example of a field that designers perceive as being complex and unfamiliar, but one in which designers are increasingly being hired. Qualitative research interviewing was chosen as a research method because it allows interviewees to share their experiences and understanding of their world, and because it facilitates mutual knowledge construction between the interviewer and the interviewee (Kvale, 2007).

Data Collection

We conducted research interviews with eight professional industrial and interaction designers. The interviews lasted 1 - 1 1/2 hours, and were based on a semi-structured interview guide (Kvale & Brinkmann, 2009). A semi-structured interview resembles a conversation and centres around predefined topics. The interview guide of this study was developed around a narrative where a specific project that the interviewed designers had worked on was used as the starting point. The topics of the interview guide included the following:

- The designer's general experience with designing for the offshore industry;
- How projects for the offshore industry differ from other design projects;
- The challenges designers face in offshore-specific design projects;
- The design process, methods, and techniques applied in the projects;
- The designer's role and relationship with people from other professions in the projects;
- The designer's skills that were considered important in this kind of project;
- The designer's dream project for the offshore industry.

The interviews were conducted from May to June 2013. All interviews were audio recorded and transcribed in Norwegian. Quotes used in this article have been translated into English by the researchers, and the translations have been approved by the designers who made the statements.

Sampling

The sampling for the study aimed to find people with relevant experience. We wanted diversity, yet with some common background to enable comparison across the interviews. Thus, our sampling criteria were that the participants should have a master's or similar degree in industrial design and should have had at least two years of experience working in the offshore industry. They should also have had experience in other fields. Further, the participants had to work at design consultancies that serve the offshore industry or as in-house designers at equipment suppliers. To ensure diversity, we wanted designers working at different workplaces; in total, six design offices / equipment suppliers are represented in the interviews. Given that the use of designers in the Norwegian offshore industry has been limited until recent years, it was a challenge to find potential interviewees with more than ten years' experience in this field. As Table 1 shows, the participants had from two to more than twenty years of experience as designers at the time of the interviews, and they had from two to ten years of experience with designing for the offshore industry. The interview study has been approved by the Data Protection Official for Research in Norway and informed consent was obtained from all participants.

There are no general recommendations for the sample size in qualitative research interviews (Guest, Bunce, & Johnson, 2006; Marshall, Cardon, Poddar, & Fontenot, 2013). Some propose purposive sampling and suggest that one should stop

interviewing when "theoretical saturation" is reached (e.g., Coyne, 1997; Miles & Huberman, 1994). A more general notion of data saturation are proposed by some and described as the point in data collection and analysis when further interviewing gives no new information (e.g., Guest et al., 2006). In our case, with a fairly homogeneous group of participants, we gained little new insight after six interviews, and decided to stop interviewing after having conducted eight interviews.

Table 1. Profiles of the designers interviewed.

ID	Design field	Total years of experience	Years of experience in offshore industry
D1	Industrial and interaction design	10	10
D2	Industrial and interaction design	8	8
D3	Industrial design	8	8
D4	Industrial and interaction design	9	9
D5	Industrial design	>20	2
D6	Industrial design	8	8
D7	Interaction design	2	2
D8	Interaction design	5	3

Data Analysis and Interpretation

The interview analysis focussed on meaning interpretation, where we sought to go beyond what was said directly and tried to identify meaning that was not immediately apparent. We used systems thinking in our analysis, which meant that we did not merely reduce the interview data to "meaning units" that were individually analysed, but that the different meaning units were also considered in relation to the rest of the interview data. We also viewed the issues that came to light in the interviews as reflecting a wider context, and drew from our own experience. This experience involves, in addition to several years of research on and design for offshore and other complex settings, an ongoing practice-based design research project addressing the design of a ship's bridge ("Ulstein Bridge Concept," n.d.).

The interpretation of the interview data was carried out at several levels, as suggested by Kvale and Brinkmann (2009). A first interpretation was made together with the interviewee as part of the interview. Immediately following the interview, a second interpretation was carried out by the researcher who had conducted the interview. After the interviews had been transcribed and anonymised, the transcriptions were shared with the other two researchers. Before meeting to discuss the interviews, each researcher interpreted the interviews individually. A more formal analysis was also conducted using coding of the transcriptions, which is a way of defining what the data are about and easing the analytical process across several cases (Gibbs, 2007). The topics used for coding were partly defined before the interviews were conducted, based on the aims of the study and the interview guide, and partly developed inductively while going through the interview data. To assign codes and develop additional codes, we first performed "meaning condensation" on three of the

interviews, which involves rephrasing the meanings expressed by the interviewees into shorter formulations and meaning units; based on these condensed meaning units, we then identified central themes that could be transformed into thematic codes (Kvale & Brinkmann, 2009). This resulted in forty-nine thematic codes which were categorised into the following groups: the industry, the projects, client relationship, challenges, designers' role, strategies and approaches, complexity and systems thinking, insight, user involvement, focus in the design process, design practice, collaboration with other disciplines, and other framework conditions. All eight interviews were coded using the QDA Miner Lite software.

The final interpretation of the data focussed on identifying relations and patterns based on the coded meaning units across the interviews and considering the findings in relation to the objectives of the study. This interpretation relied heavily on synthesis, using different clustering and visualisation techniques. Figure 2 shows the final map developed to understand the relationships between the challenges the designers faced when seeking to develop "adequate designs" (Nelson & Stolterman, 2012, p. 99). Other visualisation techniques were used for other parts of the data analysis.

Validity

Validity in qualitative research implies that what is reported is a credible description of the phenomena studied (Lützhöft, Nyce, & Petersen, 2010). Throughout the interviews, we validated our understanding by summarising our interpretation of what was said and giving the interviewees the opportunity to come forward with corrections. The final results were validated by giving the interviewees the possibility of reading through a draft version of the article and giving their feedback.

In the analysis, validity was increased by the fact that all three researchers interpreted the interviews individually before we discussed the results as a group. The final results were validated by having a colleague not involved in the study go through all the anonymised transcriptions and then assess whether or not the final article reflected the interview data.

Results

Based on our analysis of the interviews, we divide the main findings of the study into: 1) characteristics of offshore-specific design projects, 2) challenges in designing for the Norwegian offshore industry, and 3) the designers' strategies for addressing the challenges.

Characteristics of Offshore-Specific Design Projects

A typical design project for the offshore industry involves developing products based on highly advanced technology to be used in complex operations. The term "product" here includes both physical and digital products. Projects that the interviewees have conducted for this industry include interaction design of sensor technologies, charts, positioning systems, radar

systems, and communication and automation systems, as well as interaction and industrial design of consoles and operator chairs. Most of the products designed are highly interactive, although some of the design projects discussed involve products that are less often operated by human beings, such as component parts of the onboard machinery on ships or rigs. A couple of examples where the designer was involved in the client's strategy-setting were also discussed in the interviews.

When asked whether design projects for the offshore industry differ from generic design projects, all the interviewed designers stated that there was a clear difference. By "generic design" projects, we mean the type of projects for which industrial designers are traditionally trained in Norwegian design schools. For industrial design, this could be mass-produced consumer products, such as furniture or consumer electronics. Examples from interaction design include websites, application software, and mobile apps.

The designers used several ways to describe the differences, as shown in Table 2. One of the designers stated that the most important difference was whether or not one was designing for professional users, who will use the product to perform work-related tasks. He saw little difference in designing a product to support, for example, accountants and designing products for deck officers onboard a ship. In both cases, his experience was that there were many stakeholders, that the designer was normally unfamiliar with the field and user tasks, and that there was often a great deal of complex data that needed to be understood by the designer. Another designer made an important distinction between designing "lifestyle products" that are developed to meet the emotional needs of users and designing "critical products" that are developed to fulfil functional needs for industrial settings. Several designers said that it is common to focus on functionality and technology in the offshore industry, and that the design profession's traditional focus on aesthetics and the users' emotional experiences of a product are paid little attention in this industry. Another distinguishing factor the interviewees suggested was the difference in potential consequences when bad design resulted in erroneous use. One designer pointed out that the consequences of a bad design in the offshore industry can be catastrophic, using the Deepwater Horizon disaster as an example, while the consequences of a bad design in consumer products can be serious yet rarely will affect more than the individuals involved. Other factors mentioned were that the products of the offshore industry are designed for a business-to-business market, which means that the end-user is not the one making the purchase decisions; that offshore products may be more complex and more technically advanced than consumer products; and that the offshore industry is highly regulated.

Challenges in Designing for the Norwegian Offshore Industry

While the designers interviewed had all been involved in successful design projects for the Norwegian offshore industry, they still reported that they faced challenges when working in this area. Figure 2 presents a visual map of the challenges they mentioned that add to the complexity of designing for this field.

Table 2. Differences between designing for the offshore industry and generic design projects, as suggested in the interviews.

<i>Generic design projects</i>	<i>Design projects specific to the offshore industry</i>
Fewer stakeholders and fewer factors to consider than offshore-specific design projects	Projects with many stakeholders and different goals involved; contradictory factors to consider
May involve design for both non-professional and professional users	Design for professional users who use the product to carry out work-related tasks
Design objects are often lifestyle products fulfilling emotional needs of individuals	Design objects are critical products developed to fulfil functional needs in the industry
Greater focus on aesthetics and emotional factors	Greater focus on functionality and technical factors
The consequences of a bad design can influence individuals negatively, but will seldom be catastrophic	Safety-critical products used in high-risk contexts; the consequences of bad designs can be catastrophic
Design for the consumer market, where the end-user is often involved in the purchase decision	Design for business-to-business markets where the end-user usually is not making the purchase decisions
Can be technically advanced, but normally to a more limited degree than offshore projects	Products usually highly technically advanced
Sources of insight on use often easily accessible	Sources of insight on use difficult to access
Normally not as highly regulated by legislation, rules, and standards as offshore-specific design projects	Highly regulated by legislation, rules, and standards

These challenges make it difficult to achieve designers' goals to "develop adequate designs"—that is, the best possible design within the time and resources available (Nelson & Stolterman, 2012, p. 99). The placement of the individual challenges on the vertical axis of Figure 2 suggests whether it is an industry-specific challenge or a project- and design-specific challenge. The challenges emphasised in **bold** were those stressed the most in the interviews, and the ones with an increased font size were the ones suggested as the most important in our interpretation. The map also suggests relationships between the challenges identified in the analysis of the interviews. One may start reading the map at any point.

Based on what the designers emphasised in the interviews, we have divided the challenges mentioned into: 1) designing for a high-risk domain with a strong focus on safety, 2) barriers to gaining an understanding of the systems, 3) grasping the volume of information needed to gain insight, and 4) working broadly and holistically.

Designing for a High-risk Domain with a Strong Focus on Safety

One important characteristic of the offshore industry is that it is a high-risk domain where the consequences of an accident can be catastrophic. There is thus a strong focus on safety in this industry. The designers interviewed stressed that this makes it particularly important to gain insights into the users and context of use, and several stated that they would not take on projects where there was no potential for gaining that insight. The necessary insight as described in the interviews is both related to the domain and project organisation—which we refer to as the system one designs *within*—and the system one designs *for*, which covers the operation for which to design, the context of use, and user tasks. The system one designs *within* influences the possibilities in designing the product for the system one designs *for*. As shown in the upper left quadrant of Figure 2, our interpretation is that understanding these partly overlapping systems involves: 1) understanding the industry; 2) understanding the operation and context in which

the designed product will be used; 3) understanding the actors involved (both the users and other actors involved in the operation itself, as well as other stakeholders in the development process); 4) understanding the functions and tasks the product supports; and 5) understanding the technology and functionality involved.

The fact that the offshore industry is a high-risk domain with a strong focus on safety has resulted in the industry being highly regulated by legislation, rules, and standards. These regulations often prescribe specific design solutions, and some of the designers interviewed saw them as limiting factors that narrowed the space for possible solutions. This, they said, adds to the difficulty of developing novel designs. In order not to increase the risk level, there is a demand for proof that a new design is as good as, or better than, the old design. As one of the designers interviewed said, "To say 'I just feel this is right' does not hold in these industries" (D4 #00:36:06-8#). The requirements for evidence can make some designers reluctant to think beyond the known, and makes it difficult to maintain what one designer referred to as "the magic of design." Several of the designers stated, however, that they considered getting the design approved by regulatory bodies to be the responsibility of the client, not the designer.

The regulations were not viewed as a detrimental restriction by all of the interviewed designers, however. One designer saw the requirements as something that designers were obliged to question, and as a starting point for creativity. In his opinion, designers need to understand the purposes of the requirements and consider whether there are other ways of achieving these same purposes. The regulators develop requirements based on what exists, and if designers do not question the existing solutions, he feared that there would be no development or change for the better. Studies in design expertise have shown that other expert designers have similar approaches to the role of regulations in a design project, as for example the Formula One car designer Gordon Murray (Cross, 2011). Still, no matter how the designer treats the regulations, they are a framework condition that adds to the complexity of projects.

DEVELOP ADEQUATE DESIGNS

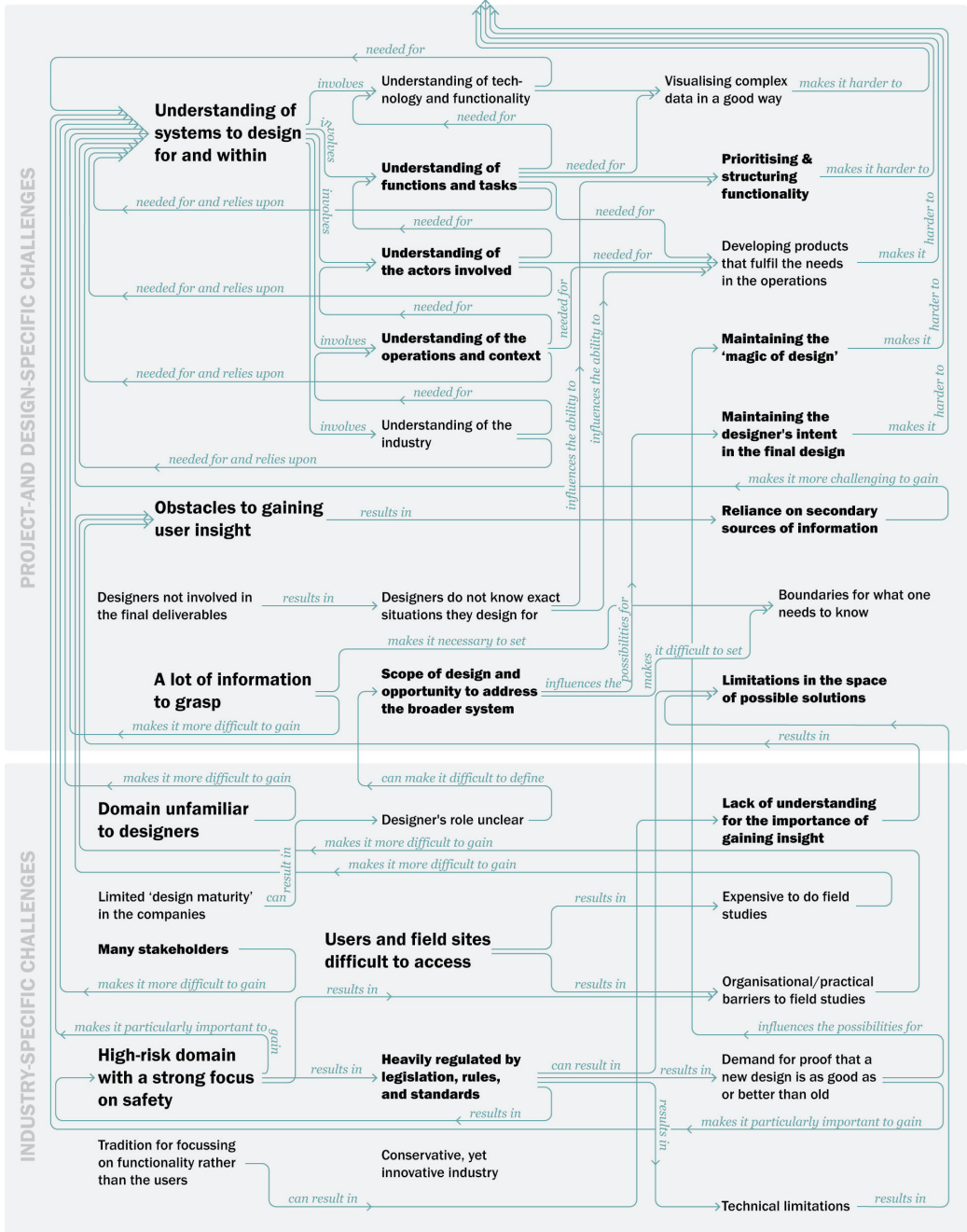


Figure 2. The challenges designers faced in the offshore industry, as described in the interviews.

Barriers to Gaining an Understanding of the Systems

As Figure 2 illustrates, many of the challenges mentioned in the interviews are related to understanding the systems to design for and within: either because the suggested challenge makes it particularly important to understand the systems to design for and within, or because they are barriers that make it more difficult to gain the necessary understanding of the project. One challenge that adds to the difficulties is that the field is normally unfamiliar to designers. Of the eight designers interviewed, no one had experience in the offshore industry before they first became engaged as designers. Thus, the designers stressed that visiting the field sites and observing the product in use was necessary in these projects. As one of the designers interviewed said, “Seafarers’ brains work differently than a landlubber’s. Seafarers know instinctively the heading of the ship and which way is north. Such dimensions are difficult to pick up without being at sea” (D4 #00:12:53-3#).

Several of the designers, however, emphasised that gaining access to users and field sites was a major challenge. Only three of the designers interviewed had taken part in field studies offshore. As shown in Figure 2, the industry-specific challenge “Users and field sites difficult to access” results in other challenges. One major challenge is that doing field studies becomes expensive: and in the experience of the designers, this is a cost that many clients are not prepared to accept. Other challenges are of a more practical nature, such as that the opportunity for joining a vessel can be unpredictable and that it may not always be possible for the designers to go when such an opportunity arises. The designers also described how the location of the field sites, together with the industry’s focus on safety, introduces organisational barriers to conducting field research. In some cases, certain safety certificates are required; in other cases, the contractor operating the vessel or rig needs to obtain approval from the oil company in order to bring designers aboard. When designing for the offshore industry, one may also experience the challenge of designing for extremely rare situations that are almost impossible to observe. One of the designers gave an example from one of his projects: “An oil spill at sea occurs once a year. The few beds on a vessel going out when a spill has happened are highly coveted and needed by others” (D4 #00:10:36-9#). As indicated in Figure 2,

the challenges related to gaining access to users and field sites makes it more difficult to gain an understanding of the systems to design for and within.

All of the designers interviewed had experienced challenges to doing field studies and also to meeting users onshore. As one designer put it, “It is incredible how difficult it has proved to do what you thought, while being a student and a fresh designer, was the most important part of a project, and the most natural thing to do as a designer” (D8 #00:46:41-8#). In many projects this had forced the designer to rely on secondary sources of information, which may include people such as clients who are familiar with the field, or written material and online media. Figure 3 shows the different situations the designers interviewed experienced when seeking to understand the user (U) and the context of use (C). In the ideal situation (a), the designer had direct access to users and the context. In the less desirable situation (b), the designer had access to users onshore but needed to learn about the context through the users or other secondary sources. In the least desirable—but not uncommon, according to the designers—situation (c), the designer needed to learn about both the users and the context of use through secondary sources.

Grasping the Volume of Information Needed to Gain Insight

No matter if one gets direct access to users and the context of use or must rely on secondary sources of information, the information available about the systems to design for and within is fragmented and the amount of information substantial. The designers interviewed described how grasping the volume of information can be both challenging and time-consuming. One of the designers suggested that a designer new to the field needs about six months before getting a grip on what the industry is about. This implies that being patient and persistent are important qualities for a designer in this field.

As indicated in Figure 2, the challenge “A lot of information to grasp” makes it necessary to set boundaries for what one needs to know. One of the interviewed designers stated, “I do not think we ever will reach the stage where we understand everything. This is such a big world, and you have to focus on grasping just what is relevant to what you are supposed to do” (D8 #00:24:47-6#). The

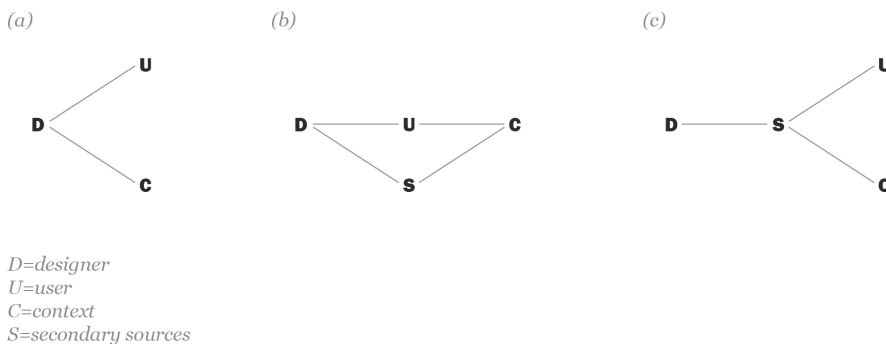


Figure 3. Designers’ access to users and context of use.

challenge of grasping the volume of information makes it more challenging to gain the necessary understanding of the systems to design for and within.

Working Broadly and Holistically

The offshore industry has traditionally developed products without involving industrial and interaction designers. As shown in the lower left quadrant of Figure 2, the designers have experienced “Limited ‘design maturity’ in the companies” of the offshore industry. This challenge can lead to the designer’s role being unclear, which can make it difficult to define the scope of the design project. This can limit the designer’s opportunity to address the broader system. The designers interviewed described that this challenge can make it difficult to set boundaries for what one needs to know as a designer, and may influence the designers’ possibilities for maintaining his or her intent in the final design.

As designers do not have an established role in this field, the designer’s role in the projects addressed in the interviews varied. The designers described sometimes being hired to perform a specific predefined task, such as to redesign a piece of equipment or a user interface. Other times they were hired because of their competence, provided with a less well-defined brief, and given the role of the driver of the development process. This is similar to a role of the designer as *collaborator*, which results in a situation where “both the client and the designer mutually work on framing the project in terms of both problem and solution spaces” (Paton & Dorst, 2011, p. 579). Such a role was identified as the most desirable by many of the interviewees. They indicated, however, that there were many reasons why designers rarely got this kind of role in the offshore industry.

The level in the client’s organisation at which the design project is run influences the designer’s role. In some of the projects discussed, the designers reported to top-level management. In most of the projects, though, the designers were involved only in the development of specific products and were hired at a lower level in the client organisation, such as by a product development department.

The client’s role in the industry’s “ecosystem” also affects the scope of the design project and the designer’s role. In many cases, the client is an equipment supplier with little opportunity to influence the whole working environment their products will be part of. When suppliers are involved in concrete deliverables and may influence the whole, the designers interviewed had not been involved. The fact that designers are normally not involved in delivery projects means that the product they design will be used in a variety of configurations, on different types of ships or rigs, and sometimes can be used for different purposes. As indicated in Figure 2, this introduces further design challenges, such as that it can be more difficult to prioritise functionality in the detailed design.

The designers interviewed would like to be involved more often in framing the projects, and all stated that they would like the opportunity to work more holistically, even though they varied on where they drew the line in relation to thinking holistically. While one designer drew the line within the client’s organisation and suggested being able to address the total product portfolio

of the client, another dreamed of being able to question more fundamental issues, such as which mode of transportation to use for transporting cargo between onshore and offshore.

The Designers’ Strategies for Addressing the Challenges

Through the interviews we saw that the designers employed different strategies for coping with the challenges experienced when designing for the offshore industry. The strategies they described are related to 1) strategies for gaining insight, and 2) strategies for boundary setting.

Strategies for Gaining Insight

All the designers interviewed stressed that having an in-depth understanding of the users’ tasks and context of use is particularly important when designing for the offshore industry, and that conducting field studies at sea is the best strategy for gaining such an understanding. Access to users and context of use is limited in these projects, however. Those who had conducted field studies placed great emphasis on the insights that they gained from this but also stressed that one trip at sea does not make one an expert. Thus, both those designers who had done field studies and those who had not described a diverse range of alternative ways to gain the needed insight throughout a project, including interviewing, conducting sessions with users, and observing training sessions onshore when access to users was granted; and, when gaining access to users was more difficult, reading documentation such as industry standards and accessing material shared by users through social media. Some of the designers stressed that using scenario methods in sessions with users is a successful way to gain a deeper understanding of the system to design for.

A couple of the designers described how they use designing to gain insight. One designer emphasised how one does not always need a thorough understanding of the situation to make the first sketch: a lot can be developed based on good design practice and previous experience. Another designer explained how he starts designing early, based on gut feelings and with very little insight, and then uses these first designs as starting points for discussion with users. The designer repeats these user sessions as often as possible throughout the design process. Through this approach, this designer said he more quickly gains better quality insights, and reaches a good design solution earlier. This is preferable to the traditional design process he described, where the designer first conducts an insight phase, and only then develops designs. “Insight is not a phase,” he stressed throughout the interview. A significant body of research indicates that developing solutions to understanding a problem is a common strategy among expert designers (Cross, 2004).

Several of the designers interviewed stressed that structured and analytical approaches are needed in order to grasp all the information necessary for understanding the system one designs for and within. “The somewhat unstructured artist-like designer will not necessarily be right for these professional settings. When designing for these environments, the designers have to be able

to structure large amounts of information and delve deep into functionality. They need to understand the everyday lives of users within a domain that they have no previous knowledge of. This simply doesn't suit every designer" (D1 #01:00:54-4#). None of the designers interviewed described particular methods for handling the large amount of information they needed to grasp, although several stressed that strategies for filtering and structuring the information were necessary. When asked specifically whether they used systemic approaches as an aid for this, none confirmed that they had consciously done that, even though some of them described using systemic approaches, such as scenarios and different activity mapping techniques.

Strategies for Boundary Setting

The designers interviewed acknowledged that due to the complexity of offshore-specific design projects, one cannot fully understand the systems to design for and within. Thus, the designers have to set boundaries for what is within the scope of the design project and what is not. The designers had different approaches to this. One designer put it this way: "The strategy is rather to understand what you don't need to understand" (D3 #00:24:08-3#). Another interviewee said that a designer should pay close attention to what the client specifically mentions in meetings, and that what is not mentioned is of lesser importance. Yet another designer stressed that in these kinds of projects, the designer needs to "accept functionality"—that is, to accept that there are certain functions that are set and cannot be changed. This designer's approach was to identify what was possible to alter and what needed to be considered as fundamental. Nelson and Stolterman (2012) claim that the skill of making such appreciative judgements is fundamental to design judgements.

In one of the interviews a good example of how a different approach to boundary setting proved valuable in a project was brought up: The office of the designer interviewed helped a client develop a new system to be used for oil spill detection on offshore service vessels. Using scenarios to gain a deeper understanding of the operational context and the users' tasks, they quickly realised that the greatest advantage of the product would be if several vessels could use it to collaborate in a network. Rather than attempting to start with the whole network, however, they started with designing a really good operator station to be used onboard one vessel. Once that was in place, they addressed the broader system. "You have to start with something that is very focussed, something that is based on clear needs. But as a designer, you must also have the ability to look ahead and create solutions that one can grow into, and not grow out of" (D4 #00:20:08-2#). This way, the product evolved from being a tool enabling an individual user to detect an oil spill to becoming a system of collaboration for oil spill response including many ships, a lot of people, and completely new ways of handling oil spills.

Through the interviews we have gained an understanding of the characteristics of offshore-specific design projects and how the designers interviewed experienced designing for this industry. Now it is appropriate to ask: Could systemic approaches that

have proven valuable when designing for other complex issues be relevant and of value when designing for the offshore industry? If so, in which ways can systemic approaches help?

Discussion

The designers interviewed described both the systems they designed *for* and the systems they designed *within* to be highly complex, and that gaining the necessary understanding of these systems can be challenging for several reasons. In the following we will discuss the relevance of systems thinking in offshore-specific design projects in the light of the designers' experience in: 1) coping with complexity, 2) boundary setting, and 3) ensuring a holistic approach. We also discuss the generalisability of the results of our study.

Coping with Complexity

The challenge of coping with complexity and grasping a substantial amount of information is not unique to design projects for the offshore industry. Weick (2004) suggested using the concept of "thrownness" to indicate that designers are thrown into situations characterised by "limited options, unreflective submission, continuous acting, occasional interruption, unquestioned answers, ready-made categories for expression and interpretation, and disjunction between understanding and explanation" (p. 77). He also claimed that "what separates good design from bad design may be determined more by how people deal with the experience of thrownness and interruption than by the substance of the design itself" (p. 74). A similar observation was made by the designer interviewed who claimed that designing for complex domains such as offshore "simply doesn't suit every designer" because these projects require that designers "structure large amounts of information and delve deep into functionality" (D1 #01:00:54-4#).

The designers interviewed said that they were faced with a large volume of information they needed to make sense of to gain the necessary insights, and that getting a grip on the offshore industry is time-consuming. This implies that designers in this field would benefit from more rapid learning processes. Further, the designers interviewed described how the information they got came from many sources and was fragmented. Experience indicates that having taken part in field studies makes it easier to grasp such fragmented information (Lurås & Nordby, 2014), presumably because field research helps the designer develop "ideas in cognitive structure" (often referred to as a frame), which then makes it easier to assimilate new information (Ausubel, 2000). The interviews showed that access to field sites and users was limited, however, and that conducting field research is a major challenge in offshore-specific field studies. Thus, other ways of developing such a frame will prove valuable in these circumstances.

Experiences with recently suggested systemic design techniques imply that systems thinking can help designers grasp more of the problem field than is normally conceived and more quickly gain the insight needed (e.g., Jones, 2014; Sevaldson,

2013). Scenarios and activity mapping techniques, which some of the designers interviewed described using, are examples of systemic approaches valuable in gaining insight and that presumably can help designers develop a frame of reference useful in making sense of new information. We propose that other systemic techniques, such as Rich Pictures (Checkland & Poulter, 2006), Concept Maps (Novak & Cañas, 2008), and GIGA-mapping (Sevaldson et al., 2012; Sevaldson, 2013) could be valuable in offshore-specific design projects in addition to the ones described in the interviews, because they emphasise relationships and help those developing them get a better understanding of how parts of the system are connected and influence each other. While scenarios usually only focus on the system one designs *for*, techniques such as GIGA-mapping can also be used to “create a detailed overview of the landscape in which a design project will play out” (Sevaldson et al., 2012, p. 14)—that is, the system one designs *within*.

Some of the designers interviewed described how they used designing to gain insight. An interesting observation is that the designers’ reason for developing and presenting their not-yet-thought-through designs to users and stakeholders early was not only to develop new designs, but also to learn about the current situation. This approach thus had a validation purpose: correcting the designers’ interpretation of the system they were designing for. In this sense, early sketches and prototypes serve the purpose of being what Capjon calls “negotiotypes,” used to negotiate understanding (Capjon, 2004, p. 292). In a similar manner, system models and maps could be developed early with limited information and used to negotiate understanding. Rather than specifying everything in advance, a map or model of the system can be developed based on what the designer currently knows and assumes, and then be assessed together with users or other stakeholders. Experience from master’s-level student projects suggests that GIGA-mapping can serve such a purpose and work “as a fundament for communicating ideas and findings and at the same time arguing for decisions made. During this debate various root definitions and conceptual models were put forward, modified, and developed until a desirable model was achieved by consensus” (Sevaldson et al., 2012, p. 19). A strategy of designing early and using preliminary designs to negotiate understanding can help the designers avoid becoming overwhelmed by this system that they describe as impossible to get a complete grip of, and can help them avoid “analysis paralysis.”

Nelson and Stolterman (2012) described that framing categories are needed in order to examine and understand systems. None of the designers reported having explicit training in the field of systems thinking, and most were not familiar with the systems vocabulary. To be better prepared for developing system models and maps of value in the offshore-specific design projects, we encourage designers to get an understanding of the core concepts of systems thinking. We propose an eclectic approach to systems thinking, as stressed in Critical Systems Thinking (e.g., Jackson, 2003; Midgley, 2000), and suggest that concepts derived from different systems theories and approaches can be of value to designers. Examples include *connections*, which define how casual power is transferred between things, and *relations*, which

define how things compare and contrast with one another (Nelson & Stolterman, 2012), both of which can help the designer identify not only which parts of the system are interconnected but how they influence each other. The concepts of *tightly coupled systems*, in which parts of the system are highly interdependent, and *loosely coupled systems*, where the parts are not very dependent on each other (Perrow, 1999), can help the designer assess the criticality of the different parts of the system, while the concepts of *leverage points* and *systemic interventions* (Meadows, 2009; Midgley, 2000) can prove valuable in considering where in the system making changes will have the greatest impact.

Boundary Setting

The boundary or frame of a design project defines what is part of the system to be addressed by the designers and what is out of their scope. The interview study shows that the boundaries of offshore-specific design projects vary and can be unclear. But the study also shows that the designers to some degree can influence the boundaries of a project, and that different approaches to boundary setting were used by the designers interviewed. When the designers make the client fully responsible for setting the boundaries of the project, we interpret this as employing a passive strategy to boundary setting. The opposite is a *proactive strategy*, where the designers themselves are involved in setting the boundaries of the design project based on what they know about the systems they design for and within. As the project addressing design for oil spill response shows, such a proactive approach can prove valuable.

We believe that one reason why designers apply passive strategies to boundary setting is that designers traditionally are not trained in working consciously with boundaries. Mapping and modelling techniques can be useful in setting the boundaries of a design project for several reasons. They can help designers get a better understanding of the system one designs *within*, which makes it easier to identify what types of changes will be possible in the system one designs *for* and what kinds of designs (interventions) will have a significant impact. These techniques can also help designers gain a better understanding of the systems they design *for*, which may enable the designer to see new opportunities beyond the original task. Such opportunities could result in improvements of the use situation, which for example could contribute to enhanced safety; or it could result in new product ideas, which could then result in business opportunities for the client. In recent years some systemic techniques within design have been proposed that can help the designer in making such judgements, e.g., ZIP-analysis, which is used to find potential areas for interventions and innovations in a system (Sevaldson, 2013).

Ensuring a Holistic Approach

The interviews have shown that offshore-specific design projects involve understanding and balancing multiple perspectives. The complexity of such projects suggests that multidisciplinary development teams are needed. Majer and Rechlin (2009) have

pointed to the problem of ensuring a holistic view in complex projects where many disciplines are involved. They suggested a new role responsible for ensuring a holistic approach, parallel to project management: the role of the *systems architect*. The term “architect” refers to architects’ assumed ability to handle complex problems in a holistic way.

The designers interviewed believed that designers are well-suited for taking on such a role and being responsible for holistic thinking in the project teams. We propose that systemic approaches, such as visual modelling and mapping, can help designers both to grasp the complexity of the system they design *for* and *within* and to obtain the role they would like in the system they design *within*. Because designers are trained in visualisation they are well qualified for taking responsibility for mapping and modelling tasks of a project. However, the use of designers in the Norwegian offshore domain is relatively new, both to the design profession and to the offshore industry, and a broader study is needed to conclude whether designers really are in a unique position to take on a role similar to a systems architect in such projects.

Generalisability of the Research

According to Flick, “the focus of interview research is (mostly) the individual experience of the participant, which is seen as relevant for understanding the experience of people in a similar situation” (Flick, 2007, p. 79). In qualitative research, the traditional quantitative concept of generalisation is normally not of interest (e.g., Flick, 2007; Kvale & Brinkmann, 2009; Lützhöft et al., 2010). “If we are interested in generalizing, however, we may ask not whether interview findings can be generalized globally, but whether the knowledge produced in a specific interview situation may be transferred to other relevant situations” (Kvale & Brinkmann, 2009, pp. 261-262). Kvale and Brinkmann described different ways to consider the generalisability of qualitative interview studies. Most relevant to the study presented here is considering *analytical generalisation*, which “involves a reasoned judgment about the extent to which the findings of one study can be used as a guide to what might occur in another situation” (Kvale & Brinkmann, 2009, p. 262). By comparing the characteristics of the Norwegian offshore industry identified in this study with characteristics of other fields, we can gain some indications of whether the findings and conclusions of this study are relevant when designing for other complex and unfamiliar fields.

The Norwegian offshore industry is presumably not very different from the offshore industry in other countries. The industry is, to a large degree, global, with many similarities in regulations and the operations carried out. Thus, we assume that designers engaged in the offshore industries in other countries face similar issues and that the research results of our study are therefore of relevance.

Health care is an example of a different field which presumably holds many of the same characteristics as the offshore industry, and where the designer could meet similar challenges. Similar to the offshore industry, the health care field is characterised by many stakeholders, professional users carrying out complex

tasks, high-risk contexts of use where human safety is at stake, and an increasing use of technically advanced products. Even though hospitals are not geographically situated in hard-to-reach locations, it can be difficult for designers to gain access to users and the field (such as an operating theatre) due to organisational barriers. The aerospace industry is another example of a field with similar characteristics. Given the similarities between these domains and the offshore industry, we assert that the research results of our study are relevant when designing for these and other similar fields. More research is needed to conclude whether this assumption holds, however.

Conclusion

In this article we have presented an interview study investigating how industrial and interaction designers experience designing for the Norwegian offshore industry, what challenges they face, and the strategies they use for meeting these challenges. The interview study gave us a thorough understanding of designing for the offshore industry, and based on this understanding we have initiated a discussion on *if* and *how* systemic approaches can be of relevance when designing for this field.

The designers interviewed placed emphasis on gaining insight on the users and the context of use, which we refer to as the system one designs *for*, and described a range of approaches used to overcome barriers to gaining such insight. We stress that designers also need techniques to gain an understanding of the system one designs *within*—the domain and project organisation. Understanding both is important because the system one designs *within* both introduces limiting factors and provides possibilities related to the system one designs *for*.

Based on experiences from recent developments within systemic design, we propose that systemic approaches such as *mapping and modelling* and *boundary critique* could be valuable in offshore-specific design projects. Maps and models can be used to develop a frame that makes it easier to assimilate new information, and to more quickly gain an in-depth understanding of the systems to design *for* and *within*. They can be developed early and used to negotiate understanding with users and other stakeholders, similar to the strategy of designing a product early in the design process to gain insight. Furthermore, systemic approaches can be useful in employing a *proactive strategy* to boundary setting, which may help the designer see opportunities beyond the original design task given. We propose that such approaches also could help designers to get closer to the roles they would like in the systems they design *within* because it can help them gain a better understanding both of the system they design *for* and the system they design *within*.

Acknowledgments

The research presented in this article was funded by the Research Council of Norway, Ulstein Power & Control, and Kwant Controls. We would like to give special thanks to the designers who were willing to participate in this study. We would also like to thank Kjetil Nordby and Marianne Støren Berg at the Oslo School of Architecture and Design for valuable feedback on the article.

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PUBLICATION 2

Lurås, Sigrun, and Henry Mainsah. 2013. "Reaching Hard-to-Reach Users. Using Online Media to Get a Glimpse of Work in Marine Contexts." *Interactions*, 20 (6): 32–35. doi:10.1145/2530539.

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Reaching Hard-to-Reach Users Using Online Media to Get a Glimpse of Work in Marine Contexts

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The wind was 75kts give or take and I was on watch at the time but had just been relieved by the other DP operator. Suddenly the wind shifted just enough to push the bow from the required heading. This is fairly common during these extreme conditions but at the time this happened a 15-meter wave hit the bow in such a way that the ship was pushed off significantly and we were pushed astern and sideways in a horrific swell causing the vessel to roll violently. Not a second was spared by myself or my colleague as he switched to manual control—we were moving very quickly towards the Normad Neptune. He regained our position and steadied up quickly as I paid out ... additional wire, gave distances to the vessels and reported our situation to the Tow Master. We spent the following two days on manual control, which is incredibly difficult in such atrocious weather, and once the weather improved we switched back to DP control.
—the Mariner, February 1, 2013 [1]

Offshore service vessels are unfamiliar to many designers. Sailing the seas can seem mystical; the life of mariners is one most of us do not know much about. We can probably all imagine that a ship is a chal-

lenging place to work and live, but it is not that well known that ships have become advanced technological environments. In such places, traditional seamanship is no longer sufficient to do a good job. Mariners also need to understand how the advanced technology works. Yet several studies report that understanding and using this technology is a difficult task, and that the design of the working environment and equipment does not support the mariners in a satisfactory manner [2].

In a design research project called the Ulstein Bridge Concept (UBC), we are designing the future ship's bridge of offshore service vessels. The bridge is the place from which the captain and the deck officers control the ship. Offshore service vessels are ships that support the oil industry, for example platform supply vessels, specially designed to bring cargo to and from offshore oil platforms, and anchor-handling tug supply vessels, mainly used to tow rigs to a location and anchor them up. The aim of the UBC project is to take a completely new look at the bridge environment of such vessels and redesign everything from the

room layout to furniture design, and from fundamental interaction techniques to detailed screen layouts.

To design for marine contexts like this, the designer needs to know the domain, understand the work carried out and the technology used, and appreciate the experiences of workers on the site. An obvious approach to gain such insights is fieldwork involving on-site observation and interviews with users [3]. However, doing fieldwork in these kinds of environments is a challenge. Sites are often situated in far-away places, and access to them can be stringently controlled and may require specific safety certificates that designers normally do not have.

New Avenues for Inquiry into the Maritime Workplace

Faced with these limitations, the designers and researchers in the UBC project have begun conceiving of new ways of getting the inside story on ship's bridge environments and the people working there. Online media, such as blogs, forums, and social networking sites, allow anyone with access to the Internet to write about their work. This has

created new spaces for researchers and designers to gain insight into the workplaces for which they design. One example of such spaces is mariner workblogs, which are Internet-based employee diaries containing accounts of the writer's experiences, observations, and opinions related to the work environment [4]. These accounts can offer an interesting avenue for learning about hard-to-reach environments like a ship's bridge. Designers interested in mariners' work experiences are now able to read years of archived material from these blogs, following work-related dramas as they unfold and tracing responses from readers through their comments.

Most research on workblogs has focused on how employees use them as a means of challenging workplace power structures and how they give employees a voice on workplace issues [4,5]. There is still little research on using workblogs as a tool of design inquiry. Here we discuss how mariner workblogs and online forums can offer a rich glimpse into the world of work on offshore service vessels, and how the insight gained from these sources can be of value in the design process. We draw on the long tradition within design of engaging with users to understand the contexts for which we design. But we also draw on more recent research fields, such as cyberethnography, which challenges the boundaries of fieldwork and looks at how the Web can be viewed as a field where one can do participant observation using text as the means of interaction [6].

Developing Domain Knowledge

Domain knowledge is one of the most important competences of a designer of systems for maritime workplaces [2,7]. A ship is a high-risk environment where an incident may

have disastrous consequences for human life, property, or the environment. Domain knowledge gives insight both on the greater systems in which the designs will function, and on the detailed parts of the systems one develops. This systemic understanding is important in forming the risk awareness needed when designing for such workspaces.

It is difficult to gain this domain knowledge and to envision what work and life on a ship are like without having been at sea. Through the workblogs, mariners express in publishable form insights on their domain and the operations in which they are involved. One such blog is Rigmover [8], authored by a mariner who works with moving and positioning drilling platforms. As an example, in a blog post titled "Rig move for dummies" (January 23, 2013), he provides a description of rig-moving operations starting with why rigs are moved, continuing with a description of the operation and the actors involved. He accompanies the text with close-up pictures that show the process of rig moving. This allows the reader to examine the operation in a concrete manner.

We find similar accounts of operations in other blogs, for example the shipping company Maersk Line's Officers Blog [9]. In a post published July 18, 2012, a Maersk officer provides an in-depth description of how he and his colleagues aboard an anchor-handling tug supply vessel spent two weeks towing a jack-up rig from Esbjerg in Denmark to the Gorm Field in the North Sea. A few months later, on September 12, the same officer tells us that he is on his way to Africa:

"Lots of things have changed in the past 2 weeks, in my last blog I was preparing to spend another winter in the North Sea, but it looks like we may be spending it some-

where slightly warmer. The Maersk Puncher has been chartered to support an oil rig in Equatorial Guinea for over half a year ... So, at the moment, our vessel is busy ordering spare parts and stocking up on plenty of stores, as well as trying to fix any outstanding problems we have with the vessel so that it is in prime condition to start the charter."

Here we see an example of the unpredictable life at sea. Preparing for going to a different part of the world, the ship is in a completely different mode of operation and the functions of the bridge and the tasks of the deck officers change.

In the UBC project, we find these blog posts help us get a better understanding of the domain for which we design. Through reading such posts, one can get an understanding of the purpose of the operations carried out, the potential versatility of life as a mariner, and the vast variety of operations that must be considered.

Familiarization with an Unfamiliar Working Environment

In the workblogs the mariners also write about their working environment and the tools they use. In a blog called the Mariner [1], authored by a second officer onboard an anchor-handling tug supply vessel, there are a number of posts aimed at cadets (officers in training) and those considering a maritime career. In these posts the Mariner describes the tasks and responsibilities of the deck officer in detail. In a post from January 24, 2013, he describes what is expected while on deck watch:

"Learn one thing, look out of the windows, and then look again. Reliance on technology has no place at sea, everything on the bridge is an aid, you are the one who makes decisions. When asked, 'What's that ship doing?' your first instinct should be to pick up a pair of binoculars, look



► The bridge of an offshore service vessel (photograph by Ulstein Group).

through them and figure it out with your brain. Then you can look into the radar and add to the mess of fingerprints all over the screens.”

Other blogs we have read give details on the technical equipment controlled from the bridge, for example thrusters (part of the ship's propulsion system) and winches.

These descriptions, although not aimed at designers, enhance our comprehension of the bridge environment and can inform our designs directly. The fact that looking out of the windows, for example, is more important than looking at the screens can affect where one positions the screens in a bridge design. Understanding how the thrusters work is paramount when designing levers that control the thrusters. We must know how the physical systems are affected by the user actions we design.

Getting to Know the Person Beyond Use

Figure 1 shows a picture of Rigmove's dog (published January 11, 2013). The picture shows that Rigmove shares not only his professional life on his blog, but also

aspects of his personal life. As we read through Rigmove's different blog posts, our preconceptions of the traditional seaman are challenged. Through a personal narrative style, he shares his passion for photography, cars, travel, and family life. When he describes how he in one year missed his son's birthday, his 20th wedding anniversary, Christmas day, Boxing Day, his own birthday, New Year's Eve, and New Year's day (December 29, 2012), we feel for him. From the Rigmove's next comment, “The worst thing was, the weather was so bad we didn't do anything,” we learn that it is important the mariners feel their stay onboard is worthwhile and that they do something productive with their time.

In the UBC project, having a diverse understanding of the people for whom we design is important because our motivation is not only to design an effective and efficient working environment that supports safe operations; we also strive for designing an innovative bridge that the mariners can be proud of and look forward to coming back to after a period onshore. Knowing and

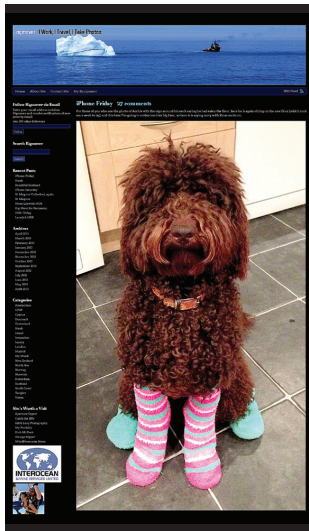
understanding the people we design for is vital in achieving this. As June Fulton Suri puts it, “It is much easier to get excited about designing for people once we know them and understand their situation” [10].

Gaining intimate knowledge of mariners can serve as a catalyst in our idea-generation process. In fact, we have found out that online content produced by mariners sometimes constitutes a source of direct inspiration. One example is a poem that was posted by smudgerthesailor on the gCaptain Forum:

*Give me a boat that works mate
Where the electrics don't spark out
And a big batt
that doesn't go flat
And leaves us all in doubt ...*

*Give me a boat without paperwork mate
Most of which I don't really need
They go on for miles
my library of files
And it's not what I normally read [11]*

In user studies, for example, during field studies, it is common practice to ask the users to describe their ideal workplace. Through posts



such as the one by smudgerthesailor, one can get an eloquent idea of what this ideal workspace could be like. The poem can serve as a verbal vision that designers can translate into new designs. When we read the poem, we might ask ourselves: How can we design systems that do not leave the users "all in doubt"? And what would "a boat without paperwork" look and feel like?

Possibilities Yet to Be Explored

The maritime domain can be difficult to grasp, and gaining access to users and context of use is a common challenge when designing for environments like a ship's bridge. In the UBC project we use several sources for understanding the mariners and the complex environment of the bridge. In addition to reading mariners' online narratives, we have carried out seven field studies at sea, consulted technical documentation, attended courses, read training material, and conducted sessions with users and subject-matter experts. Through this process, we have discovered that studying mariners online can be a useful supplementary way of gain-

ing insight on the maritime workplace. Here we have discussed how online media, such as blogs, forums, and social networking sites, can provide insight into the work and life of mariners onboard offshore service vessels. Similar approaches can be used when designing for other hard-to-reach environments, for example the aviation or space industry, an industrial plant, and other faraway locations. Online media could also be used when designing for closed communities such as chronically ill people and communities where the social distance between the designer and the user is great.

However, there may still be ways not addressed here of using online media in the interaction design process. In August 2012 the UBC project launched its first bridge concept, the Ulstein Bridge Vision. Two videos describing the concept were published online; the new design got attention on news websites. Without our intervention, mariners started discussing our design in the comment fields of news articles, in online forums, and on Twitter. This implies that the online user communities are interested in the work of designers.

Many questions remain unanswered when it comes to taking full advantage of new online field sites in the interaction design process. How could online media be used for co-creation, exploration, experimentation, and evaluation, as in the context of living labs? Could meeting users online be an alternative to personas or cultural probes? Could we contact users directly through online media when we need answers to specific questions? Could we use online media to get evaluations of design proposals? These and other new ways of engaging with users through online media are yet to be fully explored.

Acknowledgments

The work presented in this article was funded by the Research Council of Norway and the Ulstein Group. We would like to thank all the mariners who generously share aspects of their professional and personal lives through online media.

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DOI: 10.1145/2530539

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► Figure 1. A picture of the blogger Rigmoover's dog with the following caption: "For those of you who saw the photo of Archie with the sign around his neck saying he had eaten the floor, here he is again sitting on the new floor (which took me a week to lay) and this time I'm going to embarrass him big time, so here he is saying sorry with Xmas socks on" [8].

PUBLICATION 3

Lurås, Sigrun, and Kjetil Nordby. 2014. "Field Studies Informing Ship's Bridge Design at the Ocean Industries Concept Lab". In *Human Factors in Ship Design and Operation, 26–27 February 2014, London, UK, 27–35*. London: The Royal Institution of Naval Architects.

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FIELD STUDIES INFORMING SHIP'S BRIDGE DESIGN AT THE OCEAN INDUSTRIES CONCEPT LAB

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SUMMARY

In this paper we discuss the use of field research in multidisciplinary design processes when designing the ship's bridge of offshore service vessels. From carrying out ten field studies at sea over a three year period we have gained considerable insight into the role which field research may play in design projects for the offshore ship industry. We have found that allowing the designers to experience the onboard environment first hand is vital when designing for such a complex domain. Building on the experience we have gained, we have developed a *model for design-driven field research* relevant for these kinds of design projects. Our model encourages designers to engage in design reflection while in the field. This we believe is particularly important when designing for use situations unfamiliar to most designers, like a ship's bridge.

1. INTRODUCTION

Industrial, interaction, sound and graphic designers are increasingly involved in the development of marine product, and it is important that they have sufficient insight into the marine working environment. Field studies are an effective way of gaining such insights. One designer, after conducting a field study at sea, had the following to say:

The field study represents an important juncture to me. Now I know what I need to relate to and can avoid a lot of assumptions in my design work. I know how offshore operations are carried out, how the mariners perform their tasks and how they communicate. I have seen the humour they may have in the midst of demanding operations and I have got to know them as human beings. The field study gave me an embodied experience. It let the experience of being at sea get under my skin. (Designer in the Ulstein Bridge Concept project)

Despite the importance of field-related knowledge, designers of products and systems used at sea frequently have difficulty in gaining access to the field sites. It is therefore particularly important that field research is well conducted whenever access to the field is granted.

At the Ocean Industries Concept Lab of the Oslo School of Architecture and Design, over a three year period, we have conducted ten field studies as part of the Ulstein Bridge Concept (UBC) design research project. In this paper we discuss our experiences of field studies done at sea as part of the design process when developing a new ship's bridge. The paper is based on the authors' own experiences when conducting field studies, the field study experiences of other project members, and also on the experiences of sharing insight from the field within the project team and attempts to incorporate this insights into the design process. Input from other members of the UBC project were captured through short, semi-structured interviews.

1.1 THE ULSTEIN BRIDGE CONCEPT DESIGN RESEARCH PROJECT

The Ulstein Bridge Concept (UBC) is a design research project which aims to redefine the bridge environment of offshore service vessels. The scope of the project includes all functions of the bridge, and extends from room layout to graphical user interfaces. The UBC project is a collaborative project funded by the Research Council of Norway's MAROFF programme and the Ulstein Group, with participants from the Oslo School of Architecture and Design (AHO), the Ulstein Group, Kwant Controls, and Aalesund University College (HiALS). The multidisciplinary project team consists of researchers and designers from the fields of interaction, industrial, sound and graphic design, as well as experts in human factors and engineering.



Figure 1: Future ship bridge design developed by the Ulstein Bridge Concept design research project, and presented at Nor-Shipping 2013.

1.2 FIELD RESEARCH IN DESIGN

To design usable products and systems it is necessary to have a comprehensive understanding of the users, their tasks and the context of use. Conducting field studies is an acknowledged approach for gaining such understanding,

as designers can seldom rely on their own prior experiences as a guide to design [1]. Going to the field to learn about a product's users and the context of use is not new in design practice. In Europe socially-oriented design can be traced back to the Bauhaus school operating in the interwar period [2]. In the USA, already in the 1940s and 50s, the famous industrial designer Henry Dreyfuss and his colleagues went out into the field and collected data to inform and inspire their designs [3]. Since 1965 some industrial designers in the USA continued to incorporate field research into the design process, and from this has emerged a call for integrating the social sciences into design research [4]. In the 1970s and 80s the participatory design movement evolved in Scandinavia with the aim of involving workers in work- place designs. Participatory design requires the designers to have a deep understanding of the situation they design for, which makes visits to the work-place an important early activity in the design process [5, p. 57]. Around the same time, Xerox PARC and other research labs, working with human-computer interaction in the USA, started carrying out user studies, applying ethnographic methods [1], [2]. In recent years, the practice of observing and interviewing users in their natural surroundings has become common in design [6]. In commercial design projects this approach is often referred to as design ethnography [7]. However, Button states that not all field-work is ethnographic, and claims that real ethnography is something designers of collaborative work systems rarely do [8]. Arnold has defined the more general term 'field research' in the context of design as: 'activities during the product development process where the designer gathers information about the user while in the user's environment - which can then be used to influence design' [4]. As Arnold points out, this may include methods similar to those used in ethnography, but it also involves other approaches.

1.3 THE IMPORTANCE OF FIELD RESEARCH WHEN DESIGNING A SHIP'S BRIDGE

The aim of the UBC project is to improve the bridges of offshore service vessels. In order to create such changes through good design, designers have to make sense of, and frame, the situation they design for. Sensemaking and framing are needed to judge what it is possible to change in the situation, and what means are available to accomplish the desired changes. Nelson and Stolterman stress how judgement making is essential in design [9]. They describe design judgements as a unique form of judgement, and explain how these are necessary in order to create 'that-which-is-not-yet', i.e. design solutions that are fit for the future. Schön describes this judgement process through the concept of *reflection-in-action*, where designers move between doing design work and reflecting on the outcomes [10].

Although reflection-in-action, to some degree, explains the designer's practical approach to designing, it does not

deal with the complexity of design requirements in situations such as the marine and offshore environments. In the UBC project we approached this complexity by using systems thinking. This implies a consideration of the parts as components of the whole, i.e. of a system, with an emphasis on the relationships and connections between the parts of the system. A ship's bridge does not function in isolation, and there are many systems that influence the design of the bridge, which need to be understood by the designers [11]. As Nelson and Stolterman state, designers 'must be able to create essential relationships and critical connections in their designs and between their designs and the larger systems in which they are embedded' [9, p. 57]

We suggest that there are two partially overlapping systems of which one needs to make sense when designing for complex domains like the offshore ship industry: 1) The system one designs within, which we refer to as *the design situation*. This includes domain specific aspects, organisational issues of the industry, the client and project organisation, as well as the means (e.g. technology) available for designing. 2) The system one designs for, i.e. *the use situation*. This includes the users, their roles, the operations they are part of, their tasks, the equipment used, and other human, technical, organisational and environmental factors relevant during use. As suggested by Figure 2, we view the use situation as making up a substantial part of the design situation.

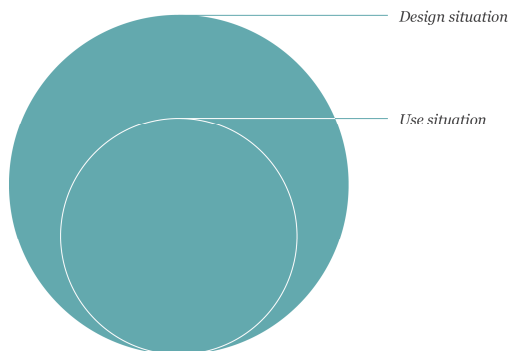


Figure 2: The use situation is a substantial part of the design situation.

When designing a ship's bridge this use situation is unfamiliar to most designers, and is very different from use situations the designer knows onshore. Given this uniqueness of the use situation at sea, we believe that it is particularly important to conduct field studies when designing a ship's bridge.

2. FIELD STUDIES AT THE OCEAN INDUSTRIES CONCEPT LAB

As shown in Table 1, we have conducted a total of ten field studies as part of the UBC project. The first field study was conducted in January 2010 and the last three were conducted in the summer of 2013. All field studies were carried out on board offshore service vessels serving the oil industry in the North Sea. Eight of the studies were carried out on board platform supply vessels (PSVs), one was carried out on a well simulation vessel, and one on an anchor handling tug supply vessel (AHTS). Three of the studies were conducted by individual designers, while seven were carried out by a team of two designers. A total of twelve designers were involved in the field studies, and three of these were involved in more than one field study. The field studies lasted from 2-8 days, and the total number of hours spent on board was 1800. In addition to the field studies conducted as part of the UBC project, the reflections in this paper are based on three field studies conducted by Masters level students at the Oslo School of Architecture and Design in Norway in 2011 and 2013.

Anonymity of participants was ensured in the field studies. The field studies were approved by the Data Protection Official for Research in Norway, and informed consent of participants was obtained.

No.	Type of vessel	Conducted by	When	Days
1	Platform Supply Vessel	2 designers	Jan 2010	3
2	Well simulation vessel	1 designer	Sept 2011	2
3	Platform Supply Vessel	1 designer	Oct 2011	5
4	Platform Supply Vessel	1 designer	July 2012	3
5	Platform Supply Vessel	2 designers	Sept 2012	8
6	Platform Supply Vessel	2 designers	Dec 2012	6
7	Anchor Handling Tug Supply	2 designers	Feb 2013	4
8	Platform Supply Vessel	2 designers	July 2013	3
9	Platform Supply Vessel	2 designers	July 2013	4
10	Platform Supply Vessel	2 designers	Aug 2013	4

Table 1: Overview of field studies carried out from the Ocean Industries Concept Lab.

2.1 AIMS OF THE FIELD STUDIES

The field studies in our project had three partially overlapping focus areas, as indicated in Figure 3: Data mapping, experiencing life at sea, and design reflection. We refer to this kind of focused field study as *design-driven field research*.

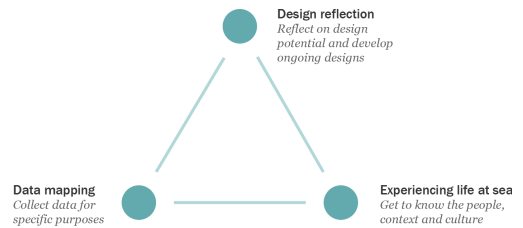


Figure 3: Focus areas in the UBC field studies, important in our *model for design-driven field research*.

Data mapping involves collecting the specific data designers need in order to develop relevant designs. This can include recognising the user groups, documenting functions and tasks, identifying the equipment used to conduct the different tasks, mapping out the physical working environment etc. *Experiencing life at sea* suggests an ethnographic-inspired approach. The purpose of ethnography is to get a deep, detailed understanding of how a group of people experience and make sense of what they do [2]. It deals with people in the collective sense, and involves an examination of the culture of the group, i.e. their learned and shared behaviours, customs and beliefs [12]. For us, the ethnographic-inspired approach involves becoming familiar with life on board the vessel, gaining insights into the offshore culture, and getting to know 'the men behind the users', i.e. what kind of people choose to work at sea, how they experience their life at sea, and what their needs are, beyond those of their work performance. Another important aspect of experiencing life at sea is to understand the environmental, temporal and bodily aspects of staying on board. *Design reflection* involves reflecting on possible design opportunities and on the potential of design ideas while in the field. It also concerns being conscious of using the field study to create a basis for generating ideas and for getting 'aha-moments' later in the design process. This involves being curious, not setting strict boundaries for the scope of the field study, and seeing everything on board as interesting. It also relies on documentation of conceptual thinking while on board.

The field studies we have carried out have had different objectives in relation to these focus areas. The aim of the first study, conducted in 2010, was to get an overall understanding of what happens on board a platform supply vessel, to identify the main functions and tasks of the deck officers, and to map out the physical environment and the systems used to conduct these tasks. The report and images from this field study were used by the other designers to prepare for subsequent field studies to make sure that we did not start again from scratch on each field study, but rather built on the insights gained by others in the project. The second field study was a less formal, familiarisation trip to a well simulation vessel. The third field study was carried out by the sound designer in the project, and looked, particularly, at the alarm situation and the sound environment on the bridge. Field studies 3-7

placed particular emphasis on the operators' sensemaking of the situation at sea, the operations the vessels were part of, and the communication between the actors involved in these operations. In field study 5, in-depth interviews with all crew members were also carried out in order to learn more about the people on the whole ship and their roles and tasks. A typical scenario for platform supply vessels, based on these observations, were mapped out in detail in field studies 3-6. Field study 7 aimed to document as much as possible of anchor handling operations. Field studies 8-10 aimed at an in-depth understanding of the use of the integrated automation system, both on the bridge and in the engine control room. Important in all field studies was not only to understand and assess the current situation, but also to generate new design ideas.

2.2 APPROACH

Our approach to carrying out field studies has evolved over the course of these three years. Building on the experience we have gained, we have developed an approach to planning, conducting and reporting on the field studies. From field study no. 6 onward we used the guide shown in Figure 4 to prepare for the field studies. This guide has also been provided to Master level students doing field studies.

Since the aims of the field studies differed, we used a mix of methods and approaches. We have conducted pre-planned activities while on board, but also kept our eyes open and sought opportunities as they presented themselves. Our ethnographic-inspired approach meant that we tried to see everything as interesting and potentially of significance.

On all field studies we relied heavily on note-taking, sketches and photography of what we saw. We have consulted human factors literature for formal methods, and tested out the Comms Usage Diagram in documenting the communication taking place; and used the Applied Cognitive Task Analysis interviews to analyse cognitive demands and the expertise needed to carry out particular tasks [13, pp. 87-93, 374-379]. On some of the field studies we presented the users with designs and ideas from the project in order to get their feedback to guide our designs. On other field studies we developed new ideas with the users in co-design sessions on board. In the later field studies we started using ZIP-analysis as a design-oriented technique to analyse what we had observed. In the ZIP-analysis we identified areas that need more research and which we need to zoom in on (Z-points); points where we have a design idea (I-points); and problem areas or areas with a potential for improvement (P-points)

Field studies in UBC

Planning & preparation

Define the purpose of the trip, what you will do to achieve that purpose and how you will document it.

It is useful to prepare as much as possible in advance, e.g. observation forms, interview guides, design proposals you want to discuss, list of what to photograph etc. During the field study one gets quite tired, so having a plan to follow is helpful. **Note:** The plan should not restrict you onboard! Familiarise yourself as much as possible with the ship and types of operations before going. This includes technical design of ship, equipment onboard, type of operations etc. Consult books, the Internet, reports from previous studies, information provided by Ulstein etc.

What to pack?

- Passport
- Comfort casual clothes
- Indoor shoes (sandals)
- Drinking bottle (the air is quite dry)
- Motion sickness pills
- Consent forms and everything you need for the studies. Minimum a sketchbook and a camera.

Bed linen, towels and soap will normally be provided.

Once out there

One of the first things to do onboard is to inform the captain that you need to go through the consent forms with him and all the officers on the bridge. Ask when is the best time to go do it. During transit may be a good choice.

Safety is important onboard. Pay attention to the information provided during the safety instructions. Pay particular attention to muster stations and safety zones. During an exercise or if an emergency situation occurs, do as told by the captain or officer in charge.

Empathy takes you a long way, and some humour never hurts. Always keep your social antenna out. Be courteous and respectful, but at the same time interested in what goes on. Be honest about your intentions. Ask questions if the situation allows for it, but accept it if the users don't want to talk. Note customs onboard, for example fixed seating arrangement in the mess and whether you are expected to clean the cabin before departing the ship.

Be explorative! Everything is interesting, it's just a matter of recognising the value. Use all your senses when observing. Pay attention to details in the situation without being critical. Look for patterns and make connections. Notice things that puzzles you and are not as expected. And be conscious about what is just as you thought it would be. Document anything, also trivial stuff.

Ask the captain on a general basis if it is ok to take photos and/or make video/audio recordings. Always ask the individual users before taking any photos of them or if you want to make video/audio recordings. If the users accept it, be clear on when you start and stop the recording. Respect it if the users say no.

Beware of "photo & documentation fatigue". The users may think you are too eager, always using your camera or writing in your book. Being open and telling them why you do the things you do is good for increased understanding and acceptance.

Make notes and sketches while doing observation most of the time, but also allow yourself to hang out with the crew with no special purpose in mind. Remember that these notes may be read by others, e.g. over your shoulder or while you are out if you leave your book on the bridge. It is a good idea to tag the notes with where you got the information from, e.g.:

- Something someone said
- Something you observed
- An idea you got

After each observation session (day) make a summary of the most important things the users said or you observed, and reflect on how that is important for the purpose of the field study and your design work. This may be tough to do after long hours doing observation studies, but is very important for later. Remember: You cannot rely on your memory!

You may want to keep a separate account of these summaries, e.g. on your computer. This way you can reflect openly about what you have observed without being afraid of others reading it.

Before you depart the ship, ask the participants if they want information about how the project evolves. If so, note down the email address.

Back home

Back home you need to finalise the analysis and communicate your findings and ideas to the rest of the UBC project. The more analysis you've been able to do onboard, the easier this will be. Do this as soon as possible, it gets more difficult the longer you wait. See own guidelines.

Field studies in UBC v2
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Figure 4: Guide used to prepare for field studies in the UBC project.

[14]. We are currently testing communicating insights gained during field research by authoring a detailed scenario, based on multiple field studies.

The field studies have been documented and reported to the rest of the team using different means, as shown in Table 2.

Approach	Field studies no.
Written report	1, 2, 3, 4, 5, 6, 8, 9, 10
Images	1, 2, 4, 5, 6, 8, 9, 10
Video recordings	5, 7
Audio recordings	3, 7
Spoken reports (informal)	1, 2, 3, 4, 5, 6, 7, 8, 9, 10
Spoken reports (formal 10 mins presentations)	2, 3, 4, 5, 6, 7
Spoken reports (formal 1 hr presentation)	8, 9, 10
Personas	4, 5, 6, student projects

Table 2: Approaches used for documenting and reporting on field studies to the rest of the project team. Personas is a technique for modelling typical users that is frequently used in software design [15].

3. GAINING AND SHARING INSIGHT

Through the ten field studies carried out in the UBC project we have gained considerable understanding of life and work on board offshore service vessels. This has served as an important basis for developing our new ship's bridge design. In order to incorporate the diverse insights gained into the final ship's bridge design, it has been necessary for the individual designers to share their insights with the rest of the design team effectively. Not all members of our team have been to sea, and of the twelve designers who have conducted field studies, a number have only been involved in the project for a relatively short period of time. Five designers who have been to sea are currently working on the UBC project. The twelve designers who have conducted field studies have been on board nine different vessels at different times of year, meeting 40-50 different deck officers. Factors like weather, crew culture and vessel type have given the designers different onboard experiences.

3.1 THE DESIGNER IN THE FIELD

Our experiences indicate that to really understand the situation on the bridge of an offshore service vessel, the individual designer benefits greatly from taking part in field studies. However, a ship is a challenging place to do field studies for a person who does not have sea legs. Many will experience motion sickness to a lesser or greater degree. Even if you are not nauseous, you may be physically affected and become tired, get a headache and experience poor concentration. These effects from the motion will affect your ability to conduct good

observational studies. Another factor influencing the designer's ability to do good field research is that being on board an offshore service vessel in the North Sea is an overwhelming experience for those unfamiliar with such settings. There is a lot to take in. We have recognised the need to compensate for these factors by doing comprehensive pre-planning for the field studies. Our guidelines for planning (Figure 4) have proved useful for this. Also, we have seen that, before going, it is important to talk to other designers who have done field studies.

We consider the observer to be an interpreter, and acknowledge that the different designers who carry out the field studies will interpret what they see in different ways, based on their previous experiences, and the focus of their design practice and research. This finding corresponds with Suri's conclusion that designers observe the world in a personal way, and that designers have a habit of paying attention to selected elements that help them generate new solutions according to their personal focus [6]. In the UBC project we have seen that different designers take different things back from their field studies, and that their insights gained may not always be relevant to the other team members from different fields of design. As an example, our sound designer placed great emphasise on the audio environment on the bridge, something which may be of lesser importance to the graphic designer. Also, product designers may not get all the information they need about the spatial environment from an interaction designer focusing on human-machine issues.

The designers of the UBC project who have been to sea stress that the field study has been vital in their understanding of the ship's bridge. We have experienced the following benefits from doing field studies:

- Getting a holistic understanding of the bridge as one system, rather than just an assembly of individual parts.
- Gaining insight into the operations, users and tasks at a level which is difficult to obtain without observing for oneself.
- Understanding how the crew communicates and interacts, both in work-related and social situations.
- Getting a spatial understanding of the bridge environment, and seeing the users' movement patterns on the bridge.
- Understanding temporal aspects of operations and tasks.
- Getting an embodied understanding of what being on board a vessel is like.
- Identifying the appropriateness of emerging designs in the context of current use.

Among these benefits the temporal and embodied aspects seem to hold a unique position. Someone can tell you about the duration of an operation and the waiting times, but the understanding you get it is very different if you have actually experienced it for yourself. Likewise, you can imagine that operating equipment in rough seas is

challenging, but, if you observe it first hand, you will have a completely different insight into what rough seas really mean. Another unique insight obtained from the field studies, which is difficult to gain onshore, is getting a holistic and systemic understanding of the situation we design for. Information about the use situation as made available to designers onshore is fragmented, and it can be difficult to see how the parts are connected in the larger system without having been on the bridge.

These factors suggest that getting a personal sense of what life and work at sea is like is valuable for designers. Not only does a field study give the designer unique insights in itself, we have also experienced how the field studies have made it easier to grasp information about the use situation coming from other sources. This can be reports from other designers' field studies, spoken accounts from users or subject matter experts, and written material, e.g. manuals and accident reports. It seems that by having been at sea the designers develop a tacit understanding of the situation on the bridge, which enables them to add missing pieces of information which aid the process of making sense of new information. As Polanyi has explained it, tacit knowledge implies that we know more than we can tell [16]. Polanyi describes how tacit knowledge is an integral part of true understanding. The body plays an important part in forming this knowledge, which can only be achieved by 'indwelling'. In our case the indwelling involves going to sea. Such an understanding is particularly important in design, since it can also be used to connect field-related insight to emerging designs. However, the personal perspectives of the individual designers also introduce challenges, e.g. the designer develops biases and heuristics that are employed in making design judgements, and which may be used erroneously. Design judgements are usually made under uncertainty, i.e. we do not know how our proposed design will actually work in a future situation. In the context of probability assessments, Kahneman and Tversky have suggested three heuristics leading to biases that are employed in making judgements under uncertainty, and which sometimes lead to severe and systematic errors: 1) Representativeness, 2) Availability of instances or scenarios and 3) Adjustment from an anchor (an initial value or starting point) [17]. Referring to Kahneman and Tversky's examples, we have for example experienced biases and heuristics based on representativeness including 'insensitivity to sample size', i.e. the designer generalises, based on one field study; 'insensitivity to predictability', i.e. the designer makes predictions regarding what will or will not work; and 'illusion of validity', the designer does not critically question the representativeness of the field site visited. We have strived to address these biases and heuristics by being aware of their potential occurrence, and by allowing several team members to do field research on different vessels, and at different times of the year.

3.2 FROM INDIVIDUAL INSIGHT TO TEAM INSIGHT

In the UBC project we have experienced that sharing individual insights with the rest of the team can be challenging. There are two main reasons for this: 1) Urgent tasks and project deadlines may keep the focus away from analysing and reporting to the rest of the project team. 2) It is difficult to share the individual's insights and to communicate the full richness of the use situation because of the tacit aspects of the insights gained.

The first challenge can be considered a project management issue. It may also be related to the fact that designers are not trained in doing observational studies and are therefore not as focused as they might be on analysing the field data. We acknowledge that interpretations are carried out in different ways, and that every field study has different needs when it comes to analysis. Still, we have experienced that sharing insights with the project team has been most successful when the designers doing the field study have set aside sufficient time to consciously analyse what they have observed in the context of the ongoing design project.

As Table 2 shows, the field studies conducted in the UBC project have been reported to the rest of the project team through a number of techniques. Written reports have proved valuable in communicating selected parts of the field studies, and project members have emphasised that they are valuable in understanding very focused topics. However, it has been difficult to convey the richness of the insights gained through text alone. The overwhelming experience of being on board an offshore service vessel can also make the designers focus more than necessary on their own experience, potentially at the expense of reporting on users' experiences.

Images have proved valuable in communicating the physical environment and the equipment used on the bridge, and to some degree, issues of the use situation. We have used images in a structured manner to help new designers in the team to quickly become familiar with the bridge environment, as reported in a previous paper [18]. However, it is difficult to convey the holistic, dynamic and interactive aspects of a situation by using still images. For this purpose video has proved more appropriate, and we have used this in different ways. In one case, the designer who had been at sea edited a film, with written explanations, of 30 minutes of a common operation. This gave the team detailed insight into what happened during this specific sequence. On another occasion, the designer who had been on the field study made a film with a high playback rate, which showed the broader use patterns on the bridge over a longer time span. This proved to be particularly useful in assessing ergonomic issues, and informing the design of the physical working environment.

Informal spoken reports were given after all field studies, and during the design work relevant observations and design ideas emerging from the field studies were put forward. In such discussions interesting issues were raised that went beyond the photo-factual documentation. Short, formal spoken presentations proved to be an efficient way of conveying clear findings and considering patterns across the field studies carried out by different designers, while longer spoken presentations enabled deeper discussions on specific issues. The process of developing personas was valuable for those involved because it made us realise that we had met the same kind of people while at sea. However, the resulting personas have not played an important role in our design work.

To sum up, we have seen that sharing factual information about users, tasks and equipment has proved considerably easier than sharing insights on the less concrete aspects of the use situation. The issues most difficult to convey seem to be the tacit knowledge related to environmental, temporal and bodily aspects, which in our experience should be felt by designers in order to be fully understood.

3.3 FROM INSIGHT TO DESIGN

We have seen that offshore ship design processes accelerate after designers have been to sea. In particular, we noticed a change in the designers' ability to efficiently and confidently make choices in the design process, which is dependent on good design judgements. Nelson and Stolterman address the complexity of such judgements, and suggest that they involve ten different categories [9]. Since designing for the offshore ship domain differs significantly from the design situations that are familiar to designers on shore, it can be particularly challenging for designers in this domain to make efficient design judgements. Our experience suggests that designers who have been to sea acquire a more holistic and systemic understanding of use situations, which makes them better at several of Nelson and Stolterman's categories of design judgement. In particular, they improve at 'appreciative judgement', which involves determining what should be considered as the foreground of a design situation, and thus requires specific attention, and what is to be considered as the background. They also seem to be better at 'compositional judgement' and 'connective judgement'. Compositional judgement 'is about bringing things together in a rational whole', while connective judgement involves making 'binding connections and interconnections between and among things so that they form functional assemblies transmitting their influences, energy, and power to one another, creating synergies and emergent qualities that transcend the nature of the individual things that are being connected' [9, p. 153].

As we have described in section 2.1, our field studies follow a *model for design-driven field research*, in which we focus on data mapping, experiencing life at sea and design reflection (Figure 3). Through our model, we urge

designers to engage in design reflection while in the field. In our experience, it can be hard to carry out actual design production while in the moving environment at sea. However, we have found it useful to bring emerging design proposals to the field to discuss and expand on the ideas with users. Also, we have found it useful for designers to actively reflect on their current design issues while at sea.

Our model reflects the multifaceted needs of designers, and implies a view of field research in design that differs slightly from that represented in Arnold's definition [4]. We regard field research as integrated into the design process in a manner that encourages the conception of and reflection on designs while still in the field. This means that field research is not something that has to precede design, and instead suggests a more direct link between insights from the field and design.

Regarding field research as integrated into design reflection in this way builds on Schön's concept of reflection-in-action [10]. Schön's model of reflection draws on the designer's previous experience and internalised knowledge, and describes the designer's ability to reflect on new designs as they are developed. In the offshore ship industry, the field is environmentally and culturally very different from the contexts that designers normally design for. As such, we suggest that designers in offshore ship design contexts can benefit from an expansion of reflection-in-action, involving design reflection as part of field studies. We suggest that field research in design can be a means of documenting existing use situations, and can provide spaces for reflecting on possible changes in these situations through design. This makes it possible to create a better basis both for generating new designs and for assessing the appropriateness of the designs that we come up with.

4. CONCLUSIONS

In the UBC project carried out at the Ocean Industries Concept Lab, we used field research to inform multidisciplinary design processes when designing the ship's bridges of offshore service vessels. In this paper, we have described how field research was conducted for the UBC project, and have shared key lessons from our work. Our emphasis has been on the role of field studies in the context of design processes. Our main conclusion is that conducting field studies is vital when designing for a complex domain like the offshore ship industry, as this domain is normally unfamiliar to designers, and is environmentally and culturally very different from the contexts that most designers work with onshore.

In design projects like the UBC project, which addresses several design fields, including industrial, interaction, sound and graphic design, the necessary understanding of the use situation is multifaceted and dependent on the focus of the individual designer. In our work, we have seen

that designers who carry out field studies develop a personal sense of the use situation that enables them to make better design judgements. Therefore, we suggest that crucial members of design teams be allowed the possibility to conduct field research. However, we have also seen that personal understandings of use situations can lead to biases and heuristics that may be inappropriately applied in making judgements. It is thus important to be aware of these tendencies within a design team.

The multifaceted needs for insight into use situations also suggest that a versatile approach should be applied to communicating insights gained through field studies within design teams. Textual reports, images, videos and spoken accounts provide different kinds of insight and should be used in a complementary manner. We also acknowledge that generating new designs is a way of interpreting the use situations observed during field studies, and that reporting on field studies is a continuous process that occurs throughout a design project.

We propose that field research in design for the complex domains of the offshore ship industry should have three areas of focus: 1) data mapping, 2) experiencing life at sea, and 3) on-site design reflection. We refer to this as a *model for design-driven field research*. Our model explicitly encourages the designer to engage in design reflection while in the field, in order to accelerate the process of interpreting use situations and more quickly arrive at appropriate designs. In this way, the model expands on the more traditional concept of field research in design, which emphasises field studies as efforts that take place before designing. Our experiences have led us to consider whether designing for environments that designers are less familiar with can generally benefit from on-site design reflection, as a means of decreasing the contextual gap between the field and design. Our future research will involve developing a general model for design-driven field research that is applicable to other domains, in addition to the offshore and maritime industries, and investigating how this model can be used to incorporate field studies into design processes in industrial, interaction, sound and graphic design.

5. ACKNOWLEDGEMENTS

The research presented in this paper was funded by the Research Council of Norway and the Ulstein Group. We would like to thank the project team of the Ulstein Bridge Concept design research project, who provided invaluable input into this article. We also give special thanks to the crew members who shared their insights and thoughts during our field studies, and to the shipping companies that allowed us on board their vessels.

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PUBLICATION 4

Lurås, Sigrun, and Kjetil Nordby. 2015. "Shaping Designers' Sea Sense: A Guide for Design-Driven Field Research at Sea". In *Marine Design 2015, 2-3 September 2015, London, UK*, 53-63. London: The Royal Institution of Naval Architects.

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SHAPING DESIGNERS' SEA SENSE: A GUIDE FOR DESIGN-DRIVEN FIELD RESEARCH AT SEA

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SUMMARY

Designers taking on marine design projects need an in-depth understanding of the context for which they design to be able to make good design judgements. This paper suggests that such an understanding can be referred to as 'designers' sea sense', and argues that field research is paramount for designers to develop such a sense. Building on experiences with field research at the Ocean Industries Concept Lab at the Oslo School of Architecture and Design, a guide for design-driven field research has been developed. This guide can help designers prepare for and make the most of field studies at sea. In this paper, we introduce the guide and discuss the rationale behind it.

1. INTRODUCTION

The seaman must develop sea sense, just as the driver of a motor vehicle develops 'road sense'. He must be alert continually to visualize what is happening, and to anticipate what might happen next. A true seaman is always ready to act in time to avoid injury to his ship or to his shipmates, or to himself. He does the right thing because he has learned how the sea behaves, and how it affects a ship afloat, and how she can be kept under control in spite of it [1].

The above quote is from 'A seaman's pocket-book', published by the Lords Commissioners of the Admiralty in 1943. This book provided an introduction to seamanship to the many men who, because of the Second World War, had entered the navy with little or no experience at sea [2]. Already on the first page of the book the notion of 'sea sense' is introduced; the authors emphasise its importance and urge the seaman to 'lose no time in acquiring sea sense'. Sea sense is what makes the seaman able to do what is right in the situations he faces at sea.¹

In recent years, designers have been increasingly engaged by the maritime industry. This trend has even resulted in the recognition of a separate field of design referred to as marine design, i.e., design within the maritime domain based on the principles of industrial design [5]. To be able to make good design judgements, a good understanding of the situation of users and their needs is necessary. Thus, marine designers need to develop their own kind of 'sea sense' which, just as a seaman's sea sense enables him to effectively do his job, enables the designers to theirs.

An assumption and starting point for this paper is that, in order to develop sea sense, designers need to go to sea. There has, however, been little use of field research to inform design in the maritime industries [6]. For this

reason, little practical advice can be found about how to carry out field research to inform marine design projects. In this paper, we introduce a guide for design-driven field research at sea, building on the experiences of field studies carried out at the Ocean Industries Concept Lab at the Oslo School of Architecture and Design, most of which were conducted within the Ulstein Bridge Concept (UBC) design research project from 2011 to 2014 [7]. The aim of the UBC project was to design a completely new ship's bridge for offshore service vessels. To be able to do this, we needed to devote considerable time and effort to understanding offshore operations and the work of the deck officers as well as the maritime and offshore context in general. Field studies have played an important role in our gaining this understanding. The motivation for developing the guide for design-driven field research presented in this paper was to share the experiences we have gained from these field studies and make it easier for other designers to carry out field studies at sea.

2. DESIGN-DRIVEN FIELD RESEARCH TO SHAPE DESIGNERS' SEA SENSE

Before we present the guide, we will describe what is meant by design-driven field research and discuss what role it can play in shaping designers' sea sense.

2.1 A MODEL FOR DESIGN-DRIVEN FIELD RESEARCH

The model for design-driven field research (Figure 1) emphasises three focus areas we believe should be considered during field studies at sea:

- Data mapping
- Experiencing life at sea
- Design reflection

¹ Prison suggests the related concept of mariners' 'ship sense'. Ship sense refers to mariners' ability to obtain harmony between a ship and the environment in which it is operating [3, 4].

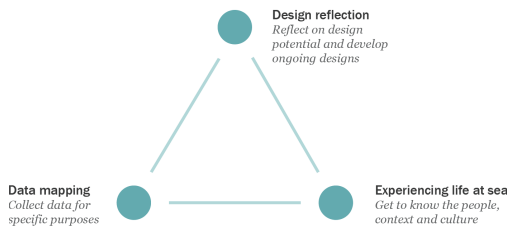


Figure 1: The model for design-driven field research introduced in [7].

As described in [7, p. 29]: ‘*Data mapping* involves collecting the specific data designers need in order to develop relevant designs. This can include recognising the user groups, documenting functions and tasks, identifying the equipment used to conduct the different tasks, mapping out the physical working environment etc. *Experiencing life at sea* suggests an ethnographic-inspired approach. [...] For us, the ethnographic-inspired approach involves becoming familiar with life on board the vessel, gaining insights into the offshore culture, and getting to know ‘the men behind the users’, i.e. what kind of people choose to work at sea, how they experience their life at sea, and what their needs are, beyond those of their work performance. Another important aspect of experiencing life at sea is to understand the environmental, temporal and bodily aspects of staying on board. *Design reflection* involves reflecting on possible design opportunities and on the potential of design ideas while in the field. It also concerns being conscious of using the field study to create a basis for generating ideas and for getting ‘aha-moments’ later in the design process. This involves being curious, not setting strict boundaries for the scope of the field study, and seeing everything on board as interesting. It also relies on documentation of conceptual thinking while on board.’

Through the model for design-driven field research, we highlight that field studies in design differ from those of other disciplines. Whereas, for example, biologists conduct field research to collect samples [8] and the intention of the fieldwork of ethnographers is to understand and give a detailed description of a unique case [9], the purpose of field studies in design is to gain insight and inspiration that enables designers to create better designs. This aspect of field research in design is acknowledged although, in the literature, field research is commonly seen as something taking place before designing [10]. By emphasising design reflection as part of field research, we encourage designers to engage in designing while in the field. As becomes apparent from the guide presented in this paper, we even encourage the making of design reflections and engaging in designing before the field study takes place as part of the preparation.

2.2 DESIGNERS’ SEA SENSE

Designers’ sea sense deals with tacit and explicit knowledge about work and life at sea. Such knowledge is part of a designers’ maritime domain knowledge which Mills, among others, states is a prerequisite for successful designing of marine equipment [11] and, thus, specifically supports designers’ judgement making when designing for marine environments. The concept of sea sense is connected to sensemaking, which can be seen as a continuous process of making sense of situations, events and data [12, 13]. Just as a mariner cannot develop sea sense without going to sea, neither can a designer. Tacit knowledge of a situation can only be achieved by ‘indwelling’, [14] which is difficult to gain without taking part in the situation one aims at understanding. Also, explicit knowledge is more easily formed at sea because access to users (the most important source of information) is limited onshore [15].

We can extract some of the characteristics of designers’ sea sense by drawing on the model for design-driven field research. With regards to data, designers’ sea sense implies having a general insight into maritime operations, what they consist of, and what demands they place on the crew. Further, it implies having an understanding of fundamental marine data that would affect most marine design processes within their field. For instance, interaction designers should have fundamental knowledge about regulations, crew, operations, and ship functionality that commonly affect the design of marine equipment.

In experiencing life at sea, the designer needs to get an embodied understanding of what it is like to be a mariner. Such experiences can help develop a tacit understanding of physical and mental aspects of being in a ship environment as well as enhance the designer’s ability to empathise with the mariners. Empathy is a strong driver in design [16]. ‘It is much easier to get excited about designing for people once we know them and understand their situation’ [17, p. 54].

Carrying out design reflection within the situation one designs for at sea is also necessary to develop a designer’s sea sense. This is important since design reflections help designers situate and activate their embodied experiences and knowledge of maritime-related data to design projects. This way, domain knowledge is connected with design practice. In carrying out design reflection, designers extend their personal *repertoire* [18, p. 138] of possible designs for a marine context and, thus, become better marine designers.

3. PRESENTING A GUIDE FOR DESIGN-DRIVEN FIELD RESEARCH AT SEA

The guide for design-driven field research addressed in this paper is included in the appendix and is also available online at <http://hdl.handle.net/11250/294200>. The guide

builds on and expands a specific guide developed for and used within the UBC project (see Figure 4 in [7]), and experiences drawn from the field studies carried out by design researchers and students in which this version of the guide was used. The guide aims at helping designers develop sea sense and emphasises all three areas of focus of the model for design-driven field research. In the following, we will introduce the sections of the guide and discuss the rationale for that which is included in each section.

3.1 PLANNING AND PREPARING THE FIELD STUDY

A successful field study relies on good planning. Once out at sea, things may get overwhelming, taking the focus away from the purpose of the trip, or one may experience motion sickness which, even if one does not feel nauseous, may influence one's concentration [7]. For these reasons, planning is given a lot of attention in the guide.

The guide stresses the necessity of familiarisation with the context and of getting acquainted with the ship one will visit. This provides the designers with a frame of reference to use when making sense of what happens at sea. In addition to using standard written documentation, the guide suggests consulting online blogs kept by mariners. Such blogs provide concrete descriptions of life and work at sea and can help designers gain an initial understanding of the marine context and get to know the kinds of people who choose to work at sea [19].

Familiarisation makes it easier to define the purpose of the field study. The purpose informs the choice of methods and techniques, as well as the means of reporting from the field study, which we advise designers to decide on before going to sea because it can help them stay focussed and ensure that all needed data is collected. The guide stresses identifying data sources as part of planning because this influences the choice of methods and techniques. One should consider other data sources in addition to the human users, including capturing data from technical systems. At the Ocean Industries Concept Lab initial studies suggest that when such quantitative data is combined with data of a more qualitative nature, designers may get new insights valuable to the design process.

Designers often have an urge to do things from scratch. However, there are a lot of resources to draw on in planning a design-driven field study. The guide encourages looking to the design and human factors literature for methods and techniques to use during the field study and provides some examples of methods which we found useful in the field studies of UBC. However, the guide also emphasises that the methods chosen should be adapted as needed.

Both observation sessions and interviews to be carried out in context should be planned prior to the field study.

Designers are normally not trained in such methods, as social scientists are; for that reason, the guide gives concrete advice on how to plan observations and how to prepare questions to ask the users. These suggestions are based on the experiences of the members of the UBC team as well as literature used to prepare for the field studies carried out within UBC (e.g. [20–23]).

An important part of the guide is encouraging designers to start working with design ideas as a part of planning. To start designing 'without insight' may feel disagreeable to some. There are, however, several reasons why we stress this in the guide. First, the act of designing leads to insight (as pointed out by Schön, [18] among others) and also elicits what we do not know. Second, by engaging in design reflection as part of planning, we can develop design proposals to discuss with users at sea. In our experience, many mariners do not question why things are as they are and how things could be improved and, therefore, find it difficult to give concrete input on what could be different. Providing them with some suggestions may spark their imagination. Even if there are several flaws in the proposed designs, our experience indicates that concrete design ideas are good starting points for discussions with users (see Figure 2). The design proposals can thus serve as 'boundary objects' [24] that both designers and users can refer to. During one field study, the users referred to the design proposals a day or two after being presented with them, during a specific situation, and described how the ideas would and would not work in those circumstances.



Figure 2: Presenting design proposals from the UBC project to a user during a field study, December 2012 (Photo: UBC).

Finally, as part of planning, the guide highlights the importance of practical preparations. Attention is given to ensuring the privacy of the crew members and preparing information for the crew because designers are usually not used to considering such issues. The guide also gives concrete advice on what to bring based on experiences from the field studies we have conducted. For example, readers are advised to bring a water bottle because the

water in the cabins cannot be drunk and we have found that it can be very difficult to bring a glass of water from the mess to one's cabin in rough seas. This is especially helpful if one experiences motion sickness, when the need for drinking water in one's cabin may be particularly strong.

3.2 CONDUCTING THE FIELD STUDY

Most designers are landlubbers [15] and may not know what to expect and how to behave on a ship. The guide covers signing on and off as well as observing and on-site design reflection.

With regards to observation, an underlying assumption of the guide is that observation is 'interpretation rather than recording' [20]. This is why the guide stresses reflecting on that which is observed. Emphasis is placed on not restricting what is considered and on seeing everything as interesting, as suggested by, for example, Smith [21]. To designers, part of observing is normally to try to experience what it feels like 'to be in the user's shoes'. Though gaining first-hand experience of use may be difficult on a ship because operating the equipment requires being a certified seafarer, the guide encourages readers to try experiencing what it feels like to operate the equipment when it is not 'in command'² (Figure 3).



Figure 3: Testing what it feels like to sit in the DP (dynamic positioning) operator chair at a field study, September 2012 (Photo: UBC).

The guide provides concrete advice on how to engage with the crew. Showing respect is emphasised. There are two main reasons respecting the users is particularly important when doing field studies on a ship:

- The ship is not only the users' workplace but also their home.

- It may be difficult for users to refuse to take part in the field study, even if they are offered the possibility of not participating, given the restricted space on a ship.

In our experience, sometimes designers may be so focussed on the task of gaining insight that they forget to consider the people they encounter. Respecting the crew, as written in the guide, implies being honest about intentions, acknowledging that it may feel uncomfortable to be observed, and accepting if users do not want to talk or be photographed. The guide encourages openness: for the crew to learn about what the designers do. It even suggests 'forgetting' one's notebook in public spaces to give the users the opportunity to take peek at what is documented.

3.3 INTERPRETATION AND ANALYSIS

It is well established that one cannot rely on one's memory [25]. The guide builds on the assumption that if you forget what you observed, the field study will be of limited value to your design work. Given that it is difficult to get access to the field in marine design projects, one must make the most of it when one gets the opportunity to conduct a field study [15]. For this reason, the guide stresses documenting and interpreting as much as possible while in the field (Figure 4). The guide also emphasises that the designer should set aside sufficient time after each observation session to debrief and interpret what was observed. This involves identifying the most important things observed and reflecting upon what they mean for one's situated design work. It also implies identifying what one should focus on in the next observation session. The guide suggests ZIP-analysis [26] as a framework for the debriefing session.

The ethnographer Fetterman says: 'Fieldwork ends when the researcher leaves the village or site, but ethnography continues' [22, p. 10]. In the UBC project, we found that it was, at times, difficult to set aside sufficient time for analysing the field study when back at the office [7]. For this reason, what happens after the field study has ended is given attention in the guide. The topic of analysis in design-driven field research, however, is vast and deserves its own guide, and thus the guide presented here merely aims at pointing out the importance of analysis following a field study and suggests some starting points for the designer. The guide also makes the point that designing based on the insight gained normally leads to further questions, which means that it is a good idea to plan for several field studies, if possible. Often designers cannot expect to be given the opportunity to conduct several field studies, though, let alone one [15]. This fact is another reason for the emphasis on on-site design reflections in the guide.

² The equipment (e.g., an operator chair) is 'in command' when it is controlling the ship's technical systems.



Figure 4: Designer documenting and interpreting what is observed during a field study, December 2012 (Photo: UBC).

4. DISCUSSION

The guide for design-driven field research is intended as a tool to help design practitioners and researchers planning field research at sea and, thus, to help designers shape their sea sense. The guide does not require any prerequisite knowledge and can instantly be picked up and put into use. Furthermore, it emphasises the practical aspects of field research and designers' personal needs, such as what to bring on board, since these kinds of details are sometimes overlooked in method descriptions.

This generic guide for design-driven field research has not yet been put into use and is presented for the first time here. However, it builds directly upon the specific guide for field research developed within the UBC project, which has proved valuable in planning and conducting field studies informing the design of a ship's bridge. The former guide has also been used by students at the Oslo School of Architecture and Design who are doing marine design projects. There are a lot of things to consider when planning a field study, and our experiences with this specific guide suggest that such a guide makes it easier to conduct field research for design.

With regards to our proposed focus area of design-driven field research, we found that field studies helped us acquire the sort of knowledge that can be seen as part of

the designers' sea sense. As described in [7], the field studies helped us get a holistic understanding of the situation we were designing for and specific insight into the operations, users, and tasks involved. We also found that going to sea gave us a spatial understanding of the bridge environment and an embodied understanding of what being on board a vessel is like. Finally, field studies helped us assess the appropriateness of emerging designs in the context of current use.

The research objectives of the UBC project were not originally centred on the role of field research in marine design projects. However, during the course of the project, we experienced the explicit need to conduct field research and to be able to do so in an efficient manner. The main reason for this was our unfamiliarity with the situation we were designing for, particularly the environmental and cultural differences between the situation on board an offshore service vessel and life onshore [7]. Through our work, we discovered that the field studies we had conducted were valuable outside the scope of the UBC project. We also experienced a need to develop field research practices for design in order to make field studies more useful and more efficient in marine design settings. We have, therefore, started a new three-year research project named 'ONSITE' which is picking up on the work of UBC in design-driven field research at sea. ONSITE will develop knowledge about how to collect, process, store and share field data for human-centred marine design processes.

5. CONCLUSIONS

In this paper, we have presented a guide for design-driven field research at sea, which aims at helping designers develop what we refer to as *designer's sea sense*—that is, the tacit and explicit knowledge designers need to make good design judgements in marine design projects. The guide is included in the appendix and is available online at: <http://hdl.handle.net/11250/294200>.

6. ACKNOWLEDGEMENTS

The research presented in this paper was funded by the Research Council of Norway and the Ulstein Group. We would like to thank the project team of the Ulstein Bridge Concept design research project for their input on the former version of the guide for design-driven field research presented in this paper. We would also like to thank Snorre Hjelseth and Margareta Lützhöft for giving input on the guide. Finally, we would like to express our sincere gratitude to the shipping companies and crew members who welcomed us on board their vessels and, thus, made it possible to carry out the field studies leading to the insight that informed the guide presented in this paper.

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9. APPENDIX: GUIDE: DESIGN-DRIVEN FIELD RESEARCH AT SEA

Design-driven field research at sea

Design-driven field research



Design-driven field research¹ is an approach to field research specifically aimed at the needs of designers. The approach focusses on three areas:

- **Data mapping:** Collecting data for specific purposes in the design project. Examples include data related to users and their distribution of roles and responsibilities, user tasks, equipment used, and the users' information needs.
- **Experiencing life at sea:** Addressing social and cultural aspects of sea life as well as understanding its environmental, spatial, temporal and bodily aspects.
- **Design reflection:** Reflecting on design potential, developing ideas in the field, and using the field study to create a basis for generating ideas and 'aha moments' later in the design process.

These focus areas are considered throughout the planning, conducting, and analysing of the field study.

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Version 1.0 | 1 August 2015
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Planning and preparing the field study

It is useful to prepare as much as possible before carrying out a field study. While at sea, one gets quite tired due to the constant motion and because observing is, itself, demanding. A detailed plan can help you stay focussed and cover all that you have planned.

Familiarisation

Familiarise yourself as much as possible with the ship you will be visiting. Identify its technical outfitting and equipment. This can often be found online. Search for the ship's name at: www.marinetraffic.com and in Google. Identify what kinds of operations the ship normally takes part in. Consult written documentation, such as training material, guidelines, books and online material. The Nautical Institute² publishes a range of specialist maritime books. gCaptain.com is a valuable online resource. There are also mariners keeping useful online blogs.

Define the study's purpose

Define the purpose of the field study. This purpose depends on your situated design work. Will it be a narrow study focusing on specific operations, user tasks or equipment, or a broad study aiming at identifying possibilities without a specific design object in mind?

Decide what to do

Decide which methods and techniques to use to achieve your purpose. Different methods are needed for different focus areas of design-driven field research. It can be helpful to consult literature on design and

human factors methods to identify approaches. Methods that may prove useful include the following: shadowing,³ hierarchical task analysis and link analysis⁴, com usage diagrams⁵ and applied cognitive task analysis.⁶ Adapt the methods to suit for your specific needs. The sources you choose will influence your choice of methods. The users are an obvious source. It may also be helpful to retrieve data from other sources, such as log data from technical systems on board.

Plan the observation sessions. Although it is useful to have a clear idea about what to observe, once in the field you should have an open mind and also consider that which is not planned for. It is useful to prepare some questions that can be used during interviews and as a starting point for discussions with users. Some type of questions, and ways of phrasing

¹ Lurås, S. & K. Nordby (2014). Field studies informing ship's bridge design at the Ocean Industries Concept Lab. In *Human Factors in Ship Design & Operation*, 26-27 February 2014, London, UK (pp. 27–35). London: RINA.

² <http://www.nautinst.org/en/shop/>

³ Design Council. 2015 *Design Methods for Developing Services*. Available at: <http://www.designcouncil.org.uk/resources/>

⁴ Kirwan B. & L. K. Ainsworth (1992). *A Guide to task analysis*. London: Taylor & Francis; Stanton E. al (2005). *Human factors methods: a practical guide for engineering and design*. Aldershot: Ashgate.

⁵ Stanton N. A. et. al (2005). *Human factors methods: a practical guide for engineering and design*. Aldershot: Ashgate.

⁶ Militello L. G. & R. J. B. Hutton (1998). Applied cognitive task analysis (ACTA): a practitioner's toolkit for understanding cognitive task demands. *Ergonomics*, 41(11), 1518–1541;



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questions, are better than others. Things to consider when preparing questions:

- Using a narrative to make people start talking is a good strategy. You can, for example, use 'a day at work' as a starting point, saying, 'tell me about a typical day at work. What do you do?' You can also use a specific operation or task as a basis for discussion: 'Think about the operation of interest -> Can you describe what you do?' To shed light on the diversity of the task, you may ask, 'How does your task differ in different circumstances? What about at different times of year? What if the weather turns bad? What if you are chartered by a different company? What if you are performing the operation in a different country? What if you are on a different ship?' etc.
- Consider using 'how' or 'what' rather than 'why' to avoid being perceived as confrontational and making the people you ask defensive. You can ask, 'How did you end up as a mariner?' rather than 'Why did you become a mariner?' to avoid the person feeling that he must have a specific reason for his career choice. If you observed the use of a system during an operation, and you want more information on the user's actions, ask, 'What made you use this system?' rather than 'Why did you use this system?' The latter might imply that the choice of system was wrong, while the former assumes that there was a good reason for the user's action.
- To encourage the user to talk about what works well and not, you can ask, 'Are things better or worse around here than they used to be?'
- To identify what the users consider the most important information, you can ask questions like,

'If you were to go away for a minute to get a cup of coffee, and I was to keep watch for you, what should I pay attention to?' **Note:** The mariners may not accept such a question because it would be against the procedures and compromise safety, but if they accept the question, it can give valuable insight.

- If you are interested in the risk aspects of the mariners' work, you can ask 'What possible occurrence on watch do you fear the most?' to get an understanding of what is the worst event that they find plausible and 'What do you expect will be the nature of the next accident: that occurs?' to gain insight on what they consider most likely.
- To elicit the users' strategies for coping with incidents, you may ask: 'If an event happened now, what would you do?'

Design reflection during planning

Design reflection should start before you enter the field, and you should consider making some design proposals that can be presented to the mariners on board to serve as a starting point for discussions. Presenting design ideas is a great way to involve the users in the design process as many find it easier to comment on concrete design proposals than to come up with design ideas themselves

Decide on the format of reporting

It is a good idea to plan how to document and communicate regarding the field study even in the planning stage as this will help you to capture the data you need in the field. If you plan to make a written report, make an outline for it before entering the field. If you plan to use video, consider what to record and which

views may provide useful information. If you plan to develop personas or make other types of maps or models, identify what kind of data you will need. Layered scenario mapping⁷ is a technique that can be used to map out a scenario on several layers—along several dimensions and at different levels of abstraction. If you plan to make such a map, it is useful to identify the scenario to map out: before going to sea.

Practical preparations

Find a shipping company and captain that will allow you on board. Note that this may be difficult and time consuming. Personal contacts are helpful. Once a shipping company has approved the field study and you know which ship you will be visiting, try to contact the captain directly to make practical arrangements.

Consider how to ensure the privacy of the crew. If you would like to take photos and video recordings, decide if you want to include identifiable people and ask for their permission; otherwise, stick to taking photos and videos where people can't be recognised or anonymise them afterwards. Consider also if the material will be used only within the design project or if you would like to use it externally as well.

Prepare information about the field study for the crew. Consider whether you need to obtain 'informed consent', which means that the crew signs off that they have been informed about the study, its purpose, and how the data collected will be used. Informed consent is normally obligatory for student and research projects. Whether informed consent is required or not, you should make a written sheet including the following: information about the project, which insti-

⁷ Guide: Layered scenario mapping. Available at: <http://hdl.handle.net/11250/294418>



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Conducting the field study

Signing on

When you arrive at the port, there may be a gate where you will need to identify yourself. The guard may contact the ship for you, or you may have to call the ship yourself. You may be told to walk to the quay where the ship is moored, or someone may come and collect you. Note that a port can be a hazardous area. Always do as you are told and keep within restricted zones.

Once on board, report to the bridge. Tell the captain that, as soon as is convenient for him, you would like to tell him and relevant crew members about your research. Ask when the best time for this is. During transit may be a good choice. This does not need to be a plenary session, and it need not be formal. You may also have one-on-one sessions with individual crew members at times that suit them. If you use a consent form, make sure you go through it with all relevant crew members; which crew members are relevant depends on the purpose of the study.

Before observation sessions take place, ask the captain on a general basis if it is okay to take photos and/or make video and audio recordings, if you plan to do so.

Safety is important on board. Pay attention to safety instructions, particularly location of muster stations and safety zones. During an exercise or an actual emergency, do as the captain or officer in charge tells you.

Observing

Document what you observe using notes, sketches, photos, and recordings (if relevant and allowed). Make sure to reflect on what you document, particularly on problem areas and design potential. It is a good idea to tag your notes with where they originate from.

What to pack?

- Passport.
- Comfort, casual clothes. Warm clothes if it may be cold.
- Indoor shoes (sandals).
- Water bottle.
- Motion sickness pills.
- Equipment needed for the study, such as sketchbook notebook, observation forms, camera and audio recorder.
- Chargers and/or batteries for technical equipment.
- A hard drive to make backups of digital data.

Note: Acknowledge sailor superstitions: consider not packing in a rucksack or bringing an umbrella on board.

tution is responsible, and contact information to the project manager and/or yourself.

Develop the material necessary to carry out the planned activities, such as observation forms, interview guides, design proposals to discuss, a list of what to photograph, etc. Obtain the equipment you need, such as a camera, an audio recorder, and a sketchbook.

Be all set to go!

Life at sea can be unpredictable, and the opportunity to join a vessel may come suddenly. Be prepared to leave on short notice and have your bag packed with all the equipment and materials needed.

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If possible, try out what it's like to be in 'the user's shoes': Be aware that you must be a certified seafarer to operate some of the equipment; thus, it may need to be tested while it is not 'in command', i.e., when it is not controlling the ship. Always ask before touching the equipment!

Be explorative, and see everything as interesting. Use all your senses when observing. Pay attention to details, look for patterns and make connections. Notice things that puzzle you and that are not as expected. Be conscious of what things are just as you thought they would be. Document everything, even trivial stuff. When you observe, keep as a mantra that 'something is always happening'. Look for what is happening, even when 'nothing is happening'. What are the mariners doing when it seems like they are doing nothing? What are they paying attention to?

Stick to your plan if possible, but do not let it restrict you while on board. Allow time to hang out with the crew without your notebook and with no special purpose in mind.

On-site design reflection

Work with ideas while on board. It may be difficult to conduct focussed sessions with the users for longer periods of time, however, so take advantage of periods when the crew is less busy. Present the users with design ideas developed prior to or during the field study. While on board, work on design ideas based on what you see and keep the users in the loop.

On a personal level

Always keep your social antenna up. Be courteous and respectful but, at the same time, interested in what goes on. Be honest about your intentions. Ask ques-



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Interpretation and analysis

To make the most of the field study, what you have seen must be interpreted in relation to your situated design work.

Interpretation while on board

After each observation session, do a debriefing. This implies making a summary of the most important observations and reflecting on how they are important for the study's purpose and for your design work. You may want to keep a separate account for these summaries, e.g. on your computer. This way, you can reflect openly about what you have observed without being afraid of others reading it. Consider using Z/IP-analysis⁸ as a probe for reflector: on and interpretation of your observations:

- **Z = Zoom.** Used to identify areas or points where you need to do more research.
- **P = Potential.** Used to identify areas with potential for improvement.
- **I = Innovation/intervention.** Used to identify ideas or solutions to a problem.

After long hours of observing, debriefing may be tough, but it is very important to do it while the observations are fresh. Remember: You cannot rely on your memory!

Back home

After the field study, you need to finalise the analysis and document your findings and ideas. The more analysis you've been able to do on board, the easier this will be. Do this as soon as possible—it gets more difficult the longer you wait! Focus the analysis on interpreting the findings in relation to your situated design work. If others will be using the analysis, strive

tions if the situation allows for it, but accept it if the users don't want to talk. Note customs on board: for example, fixed seating arrangements in the mess and whether you are expected to clean the cabin before departing the ship. Empathy takes you a long way, and some humour never hurts.

Remember that your notes may be read by others—for example, over your shoulder or if you walk away and leave your book. You may even want to leave your book out intentionally to let people have a look and, thus, avoid suspicion. Notes of a more personal nature can be made on your computer or in a different book while in your cabin. Being open and telling the users why you do the things that you do is good for increased acceptance.

Beware of photo and documentation fatigue. The users may find it annoying or intrusive if you are too eager, always using your camera or writing in your book. Always ask before taking photos of people or if you want to make video/audio recordings. If the users accept it, be clear on when you start and stop the recording. If the users say no, respect their wishes.

Be prepared for sea sickness. It can happen to anyone. Even mariners get sea sick at times. Make sure you eat and drink properly during your stay. Bring motion sickness pills, and if you know that you get sea sick easily, consider taking one before you board the ship.

Signing off

Before you depart the ship, ask the captain and the crew members if they want to be informed about how the project evolves. If so, record their contact information. You may also consider offering the captain and the shipping company a report of the field study.

Further reading for inspiration

About observation:

- Lipshitz, R. (2005). There is more to seeing than meets the eyeball: the art and science of observation. In B. Brehmer, I. Montgomery, & R. Lipshitz (Eds.), *How professionals make decisions* (pp. 365–378). Mahwah, N.J.: Lawrence Erlbaum.
- Smith, K. (2008) *How to be an explorer of the world*. New York: Penguin books.
- Suri, J. F. (2011). Poetic observation: what designers make of what they see. In A. J. Clarke (Ed.), *Design anthropology: object culture in the 21st Century* (pp. 16–32). Wien: Springer-Verlag.

Practical advice on ethnographic field research:

- Fetterman, D. M. (1998). *Ethnography: step by step*. 2nd ed. Thousand Oaks, CA: Sage.
- Hutchins, E. (1995). *Cognition in the wild*. Cambridge, MA: MIT Press.

On going to sea to learn about the work on the ship's bridge:

- Hutchins, E. (1995). *Cognition in the wild*. Cambridge, MA: MIT Press.

to communicate the experience in ways that enable others to gain the needed insight. Reflect on the field study and make notes of lessons learned.

Designing based on field study insight often leads to further questions. For this reason, it can be a good idea to plan several field studies in a given design project, if possible.

⁸ <http://www.systemsonlinedesign.net/index.php/giga-mapping/zip-analysis>



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PUBLICATION 5

Lurås, Sigrun. 2015. "Layered Scenario Mapping: A Multidimensional Mapping Technique for Collaborative Design". *CoDesign*.
doi:10.1080/15710882.2015.1072221.

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Layered Scenario Mapping: A Multidimensional Mapping Technique for Collaborative Design

Making use of insights gained through field research in design can be challenging. Some issues that design teams may face are making sense of fragmented data collected, sharing insight among the design team, and presenting the data in ways that support the situated design work. This paper introduces *layered scenario mapping*, a technique aimed at meeting such issues when designing a ship's bridge. The technique builds on and expands traditional techniques for representing user data in design and results in a map describing a typical scenario along several dimensions and at different levels of abstraction. It highlights the spatial and temporal aspects of the situation, and emphasises the use of visual presentations. This paper describes why and how the layered scenario mapping technique was created, it critically assesses the technique and discusses experiences with using it. The technique proved to be valuable in making sense of fragmented data, and supported the design team's collaborative work when designing a ship's bridge. It is expected that the technique can also prove valuable when designing for other contexts where the spatial and/or temporal dimensions are of importance.

Keywords: layered scenario mapping; field research; collaborative design; complex environments; ships' bridges

1 Introduction

Having a deep understanding of the situation one designs for is vital in design and many researchers have stressed the importance of field research and ethnographic approaches (e.g., Suchman 2007; Beyer and Holtzblatt 1998; Button 2000; Blomberg, Burrell, and Guest 2003; Lurås and Nordby 2014). It can be challenging, however, to make sense of the fragmented data obtained from field research. Complex projects requiring collaborative design work introduce additional challenges, such as sharing insight among the team and developing a common understanding (Feast 2012; Kleinsmann, Valkenburg, and Buijs 2007). This paper addresses such issues and introduces *layered scenario mapping*, a technique aimed at 1) providing design teams with a frame of reference to use when making sense of data field research, 2) helping design teams share insights, and 3) presenting the situation to design for at the level of granularity necessary to be able to develop credible and relevant detailed designs. As the name suggests, the technique is used to map out a scenario on several layers—that is, along several dimensions and at different levels of abstraction. I will start the paper by discussing selected literature on representing insight in design, before sharing why and

how layered scenario mapping was created. Finally, I will critically discuss the technique.

2 Representing Insight

Data from field research need to be interpreted and consciously designed for their specific purpose in a design project (Beyer and Holtzblatt 1998; Diggins and Tolmie 2003; Mattelmäki, Brandt, and Vaajakallio 2011). How to design such representations, however, is ‘a relatively unexplored topic’ (Diggins and Tolmie 2003, 154). Diggins and Tolmie suggest certain features that make such representations ‘adequate’. They state that the form should be *economical*—that is, it should use as little space as possible and should ‘stand as an interface through which the data can be articulated’ (ibid., 156)—and have an *appropriate format*—that is, have a structure ‘which will be intelligible at a glance’ (ibid. 156). The features of *ordering and logic of practice* address how the representation aids presentation to make what it represents visible, while *indexicality* means that the representation works ‘as a stage (situated device) for various kinds of situated collaborative work’ and has ‘internal features that can be pointed out, pointed to, gestured over and explicated in a variety of ways’ (ibid., 157): Thus, the representation takes on the role of a *boundary object* (Star and Griesemer 1989)—objects that establish a shared context within and among communities of practice, while also inviting different interpretations. Star and Griesemer suggest that there are different types of boundary objects: 1) *repositories* are collections of objects; 2) *ideal types* are abstract objects that provide a ‘good enough’ description of something; 3) *coincident boundaries* ‘are common objects which have the same boundaries but different internal contents’ (ibid., 410); and 4) *standardised forms* are ‘methods of common communication across dispersed work groups’ (ibid., 411). Mattelmäki, Brandt, and Vaajakallio (2011) also discuss the role of representations, describing that they can either be open-ended, inviting several interpretations (such as boundary objects), or closed, which offer fewer interpretations.

Diggins and Tolmie (2003) further stress that a successful representation should hold the feature of *mnemonicity*—a resource for recalling fieldwork—and the feature of *iconicity*, which is a physical representation of the ethnographic findings as a whole. Furthermore, the features of *sequentiality* and *organisational accountability* imply that the representation demonstrates the work that has been carried out, while *integration* implies that the representation serves as a common resource across a project or an organisation.

Different ways of representing outputs of field research have been referred to in the literature. Beyer and Holtzblatt (1998) suggest that the outcomes of field research (*contextual inquiry*) are reworked and presented using five types of *work models*: the *flow model*, the *sequence model*, the *artefact model*, the *cultural model*, and the *physical model*.

Scenarios, typically used to depict a desired future situation, can also be used to communicate findings from field research (Carroll 1995; Bødker 2000; Blomberg, Burrell, and Guest 2003). In design, a scenario ‘projects a concrete description of activity that the user engages in when performing a specific task, a description sufficiently detailed so that design implications can be inferred and reasoned about’ (Carroll 1995, 4). Scenarios are often textual descriptions, but they can also be presented using other means, such as by video or by visual storytelling (Buxton 2007). It is also possible to describe scenarios by presenting events in time, such as in *Sequential Timed Events Plotting* (‘STEP’) (Hendrick and Benner 1987). Nielsen (2002) criticises the scenario technique for providing unengaging character descriptions and focussing merely on user actions rather than on the user as a person.

Task analysis covers a range of techniques used to study what an operator (user) or team of operators need to do to achieve a system goal (Kirwan and Ainsworth 1992). Different data sources can feed into task analysis, including field research. Examples of task analysis techniques are *hierarchical task analysis*, which presents tasks and sub-tasks that need to be carried out to achieve a goal; *timeline analysis*, which presents operator tasks in time; and *link analysis*, which identifies the links between an individual and some part of the system.

While task analysis techniques are valuable in presenting detailed information on user tasks, they do not describe the context of use. *Contextmapping* (Sleeswijk Visser et al. 2005), on the other hand, is a technique specifically aimed at addressing the context and gaining an understanding of peoples’ visions for the future. Although the strength of this approach is that it invites exploration and creativity, it may not provide the level of granularity needed during detailed design.

Many of the techniques for representing the situation to design for have strict boundaries and involve simplification. *Giga-mapping* is a systemic design technique used to ‘embrace complexity’ (Sevaldson 2013). It involves designing vast system maps where relationships between parts of the system are made visible to elicit potential areas for innovation. While one advantage of the technique is its flexibility, this flexibility also means that no starting point is provided, and the technique can be difficult to apply.

In the remainder of the paper I will discuss *layered scenario mapping*, which builds on, expands, and combines many of these methods and techniques.

3 The Ulstein Bridge Concept (UBC) Design Research Project

The *layered scenario mapping* technique originated from design work carried out within the Ulstein Bridge Concept (UBC) design research project conducted at the Oslo School of Architecture and Design. The purposes of UBC were: 1) to design a completely new ship’s bridge for offshore service vessels (i.e. ships serving the oil industry), taking into account the users’ needs and the complex operations these ships engage in, and exploiting possibilities given by new technologies; and 2) to develop design-centred knowledge and processes tailored for innovation activities in the ship industry. The ship’s bridge is the place from whence the captain and the deck officers control a ship.

The project was carried out in close collaboration with Ulstein, a company that designs and builds ships.

The scope of UBC included the whole bridge, including the room layout, furniture, and workstations, as well as the design of interactions, graphical user interfaces, and the audio environment. The bridge design developed by the project is shown in Figure 1.

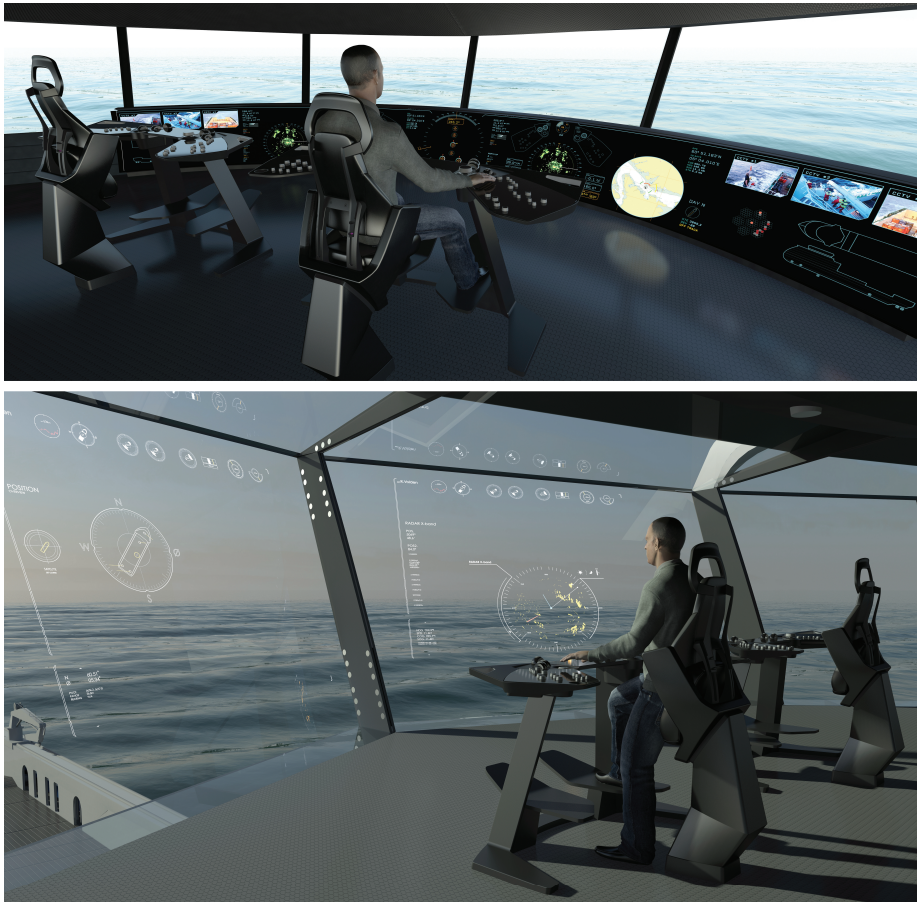


Figure 1: *Ulstein Bridge Vision™*, the conceptual bridge designed by UBC.

3.1 *Research Approach*

UBC applied a *research by design* approach, where design practice is at the core of research and the researcher is also a practitioner, thus conducting research from a ‘first-person perspective’ (Sevaldson 2010). Throughout the process of developing and using layered scenario mapping, the author’s reflections were documented in a research diary, while reflections from other members of the project were collected informally through

project work; formally through short, semi-structured interviews, which were recorded, transcribed, and analysed; and in a workshop devoted to discussing the technique, which was video-recorded and later reviewed. A representative from Ulstein was also interviewed to obtain insights on the company's experiences with layered scenario mapping.

3.2 Motivation for Developing Layered Scenario Mapping

From January 2010 to April 2014, eighteen people were involved in UBC: some throughout the whole project's duration, and others for shorter periods of time. The team consisted of researchers and designers from the fields of industrial, interaction, sound, and graphic design, as well as experts in human factors and engineering. The core team consisted of nine people, one of whom was the author of this article, who held the role of interaction designer and designer-researcher. The work was at times carried out collaboratively across disciplines, while at other times the industrial and interaction designers formed mini-teams to address specific issues. The software developer, sound designer, and graphic designer alternated between individual work, and work at natural crossing points with the other disciplines. Most of our work took place in our lab at the Oslo School of Architecture and Design. Our lab was our 'virtual world' (Schön 1983), where we experimented with different designs and built models and demos.

We conducted a significant amount of field research to learn about what I refer to in this paper as 'the situation we designed for'—that is, the users and their tasks, the operations they carry out, and the context of use. A total of seven field studies lasting from two to eight days were conducted within the project. As reported by Lurås and Nordby (2014), we tested a number of techniques for sharing the data we collected and the insights gained from the field studies within the team. Team members provided formal and informal spoken reports after each field study. Written reports proved to be valuable in communicating focussed topics, but did not convey the richness of the insights we had gained. Images were used to help new members of the team become familiar with the physical environment and the equipment used on-board. We found it difficult, however, to convey the holistic, dynamic, and interactive aspects of the use situation through still images alone. We used video for two purposes: to share detailed information about what happened during a specific offshore operation, and to convey the broader use patterns over a longer time span. We developed personas (Cooper 2004), which proved valuable because they made us realise that we had met the same types of people while at sea. The resulting personas, however, did not play an important role in our work. In addition to conducting field research, we learned about the situation we designed for through two workshops with users; by going through training materials, accident reports, and other written documentation; by attending industry fairs and conferences; and through following mariner work-blogs and online forums (as described in Lurås and Mainsah 2013). Through our substantial efforts in gaining insight, we developed a great deal of knowledge on the situation to design for. The

knowledge was fragmented, however, and was not systemised in a way that made it easy to decipher and share.

We developed our ship's bridge design in several iterations throughout the project period (Lurås and Nordby 2013). In August of 2012, our conceptual bridge (shown in Figure 1) was presented to the public for the first time through a film (see Ulstein 2012), and in June of 2013 an interactive installation of the concept was exhibited at an industry fair. Following these activities, we started to develop a refined version of our concept with the aim of coming closer to realisation. To do this, we needed more detailed information on the situation we designed for. For example, the industrial designers needed to know the users' movements on the bridge and the frequency of use of different pieces of equipment to detail the workstations, while the interaction designers and software developer needed to know exactly what information the users require in order to decide what to present in which display area.

None of the methods and techniques described in Section 2 met all of our needs. Some of the techniques provided the detail, but lacked the context, while others provided contextual insights, but lacked the necessary level of detail. We developed the layered scenario mapping technique presented in this paper with the following objectives:

- (1) To offer a framework to use when interpreting information about the situation we designed for. This framework would help us understand the context and the individual parts of the situation, and how the parts relate to the whole, as well as to other parts.
- (2) To facilitate the sharing of data collected, and insights gained among the team.
- (3) To present the situation we designed for at the level of granularity necessary to gain an in-depth level of understanding. This was to be a description of the current situation, which would enable us to develop credible, relevant, and detailed designs for a desired future situation.

4 Developing and Using Layered Scenario Mapping

Layered scenario mapping was developed by the author with support from three members of the core team of UBC. In the following section, I will describe our process of developing and using the technique, and will introduce the guide that is included in the appendix.

4.1 Selecting the Scenario

A design team can never predict every possible situation in which the products they design will be used. Thus, selecting a scenario that is representative and that covers the most important aspects of the situation we designed for was important. The initial field studies and input from users informed our choice of scenario. We chose 'positioning the vessel alongside the rig and doing loading and offloading operations' for the following reasons:

- *Frequency*: It represents the most common scenario that offshore service vessels engage in in the North Sea.
- *Criticality*: The scenario includes tasks that users deem to be high-risk. In the first field studies, users were asked about what they feared most could happen in the course of their work. The users instantly replied ‘losing position while on DP’, referring to dynamic positioning, a computer-controlled system that automatically maintains a vessel’s position and heading. This system plays an important role in keeping the vessel at a safe distance from the rig in the chosen scenario.

4.2 Gathering Information and Gaining Insights

We found that the best strategy for gaining insights on the situation we designed for was to conduct field studies at sea. We mapped out the main steps of the scenario in the first field study of the project in January 2010, although not with the purpose of developing a scenario. In three field studies conducted in 2012 we gathered information that was specifically aimed at mapping out in detail how the scenario played out.

Through our work, we developed an approach to conducting field studies that are referred to as *design-driven field research* (Lurås and Nordby 2014). In this we stress three focus areas: 1) data mapping, 2) experiencing life at sea, and 3) on-site design reflection. *Data mapping* involves collecting specific data, such as data on user tasks and equipment. *Experiencing life at sea* suggests an ethnography-inspired approach similar to ‘empathic design’ (Leonard and Rayport 1997; Koskinen, Battarbee, and Mattelmäki 2003; Mattelmäki, Vaajakallio, and Koskinen 2014) and focuses on social and cultural aspects. It also involves understanding the environmental, temporal, and bodily aspects of life at sea. *Design reflection* involves interpreting what one observes through a ‘designer’s lens’, and reflecting on design opportunities while in the field.

Most important in informing the layered scenario mapping was data mapping. We used a range of methods to map the data we needed. Observations and interviews in context were most important. The formal methods we used included *Comms Usage Diagram* (Stanton et al. 2005, 374-379), used to document the communication that was taking place, and *Applied Cognitive Task Analysis* (‘ACTA’) (Militello and Hutton 1998), which we used to analyse the expertise needed and to identify critical points in the scenario. The secondary sources we used included training materials, procedures and checklists, and reports of incidents that had happened during these types of operations in the past.

4.3 The Design of the Map

Designing the map involved deciding on what data to include, and how to present it. The content that the team included in the map was decided as a result of a collaborative process. Those who were working with the map made an initial list of potential content

types to include based on experience from former design projects, as well as on the needs that were found during the first iterations of our bridge design. This list was presented to the rest of the team, which then made comments and suggestions. A new version was developed and once again discussed with other members of the team, until the final list was defined.

We initially wanted to make both a paper-based and an interactive map. We were unable to find an ‘out of the box’ interactive solution, however, and due to limited time and project resources, we decided at that stage only to make a non-interactive version. We created the map in Adobe InDesign and plotted it on paper. The resulting map was a 0.9 m x 4.3 m poster (see Figure 2).



Figure 2: The resulting map hanging on the wall of our lab.

We experimented with different layouts of the map. Our aims were to present the information both at the overview level and in detail, and to make visible how the information was related. In the resulting layout (Figure 3) the overview information was presented to the left and detailed information to the right.

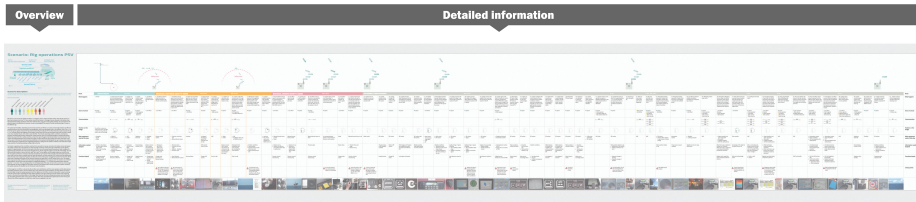


Figure 3: The layout and logic of the map: Overview information to the left and the detailed information (timeline matrix) to the right.

The overview is meant to give the reader a frame of reference to use when deciphering the detailed information. It includes a descriptive title, a visual presentation of the ship's technical specifications, a description of the scene and introduction to the scenario, a presentation of the actors involved in the scenario, a written scenario story, and document information.

The detailed information section comprises the main part of the map, and is presented using a 'timeline matrix', with a step-by-step description of what goes on. The timeline is not linear in a mathematical sense, meaning that there is no fixed scale; one step does not represent a set time period. We decided on this layout because we had a need for detailed information of very short time periods, and a mathematically linear timeline would result in an impractically long map.

Each row in the timeline represents a step in the scenario and provides:

- a visual presentation of the vessel's position in relation to other objects, such as the port and the rig;
- the mode of operation, indicating what kinds of rules apply, and what technical mode the vessel is in;
- a short description of what happens;
- the actors involved, and who communicates with whom and by what means;
- a visual presentation of the users' positions on the bridge, shown in a bird's-eye view;
- what equipment is used;
- the information and functionality the users need to be able to carry out each task; and
- illustrative photos to provide contextual information.

We used ACTA (Militello and Hutton 1998) to identify the steps that were particularly important to ensure safety, which we highlighted as critical points. The process of designing the map resulted in both our specific map and in a template, which can be used by other design teams as a starting point for making similar mappings.

Figure 4 shows details of the map. Descriptions of each content element are provided in the guide in the appendix.

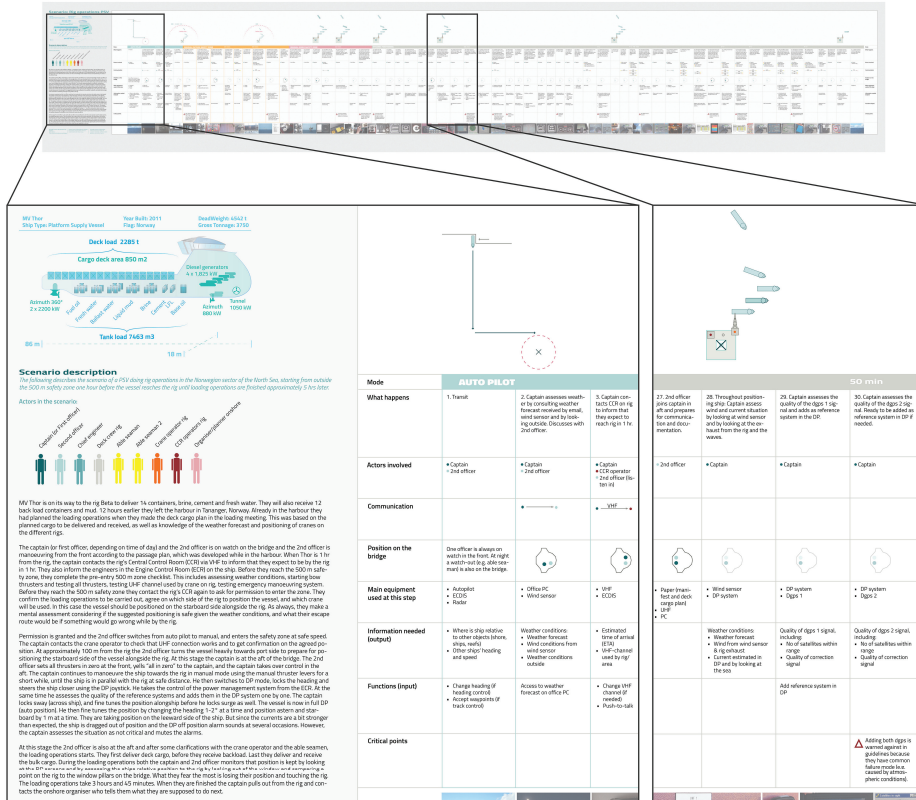


Figure 4: Details of the map.

4.4 Use of Layered Scenario Mapping

We used the map both to gain insights into the situation to design for and in detailing our bridge design. It provided an organising principle to sort and make sense of the data on the situation to design for and helped us transfer knowledge from those project members who had taken part in the field studies to those who had not. Referring to Star and Griesemer's (1989) types of boundary objects, it was a 'repository' of data from field studies (although limited to the format), which could be accessed and used by all. It served as an 'ideal type' of the situation we designed for, in that it showed a generalised presentation of a typical way the scenario could play out. The timeline

served as a ‘coincident boundary’ that could encompass a considerable amount of the data gathered during the field studies. Although it was not used as a ‘standardised form’, the layered scenario mapping provides a method for common communication of such scenarios in the future.

In UBC, individual team members used the map to generate and test ideas. The map served as a stage for a ‘conversation with the design situation’ (Schön 1983) and guided us in the process of detailing our design. We also used the map in collaborative sessions to discuss the appropriateness of ideas. The map further played an important role in a workshop we conducted with users. We used the map to prepare for the workshop, and in the workshop we used the scenario as an outline for an enactment of our proposed new design in a full-scale prototype. We also used the scenario as a basis for asking ‘what if’ questions, such as ‘What if the scenario played out at a different time of year, or with a different type of ship?’ This gave us insights into the diversity involved in the situation we designed for.

The first version of the map was thoroughly reviewed by two deck officers at Aalesund University College (one of the partners of the project), and we made minor corrections and updates based on their input. We found that the format of the map was well-fitted for presenting our understanding of the situation to design for, and thus could also serve as a boundary object for engaging users and other stakeholders in the design process.

4.5 Guide

We developed a guide to using layered scenario mapping (see the appendix). The guide can be applied directly in design projects to sort and map out data that have already been collected, or it may be used to identify information that needs to be mapped out, and to prepare for data collection activities, such as field studies. The guide is not intended as a definitive recipe; design teams using the guide must still identify a relevant scenario, decide what information they need to map out, gather and interpret the information needed, and design their final map. The content categories included, and the layout of the map, can serve as a useful starting point, however.

5 Discussion

In the following section I will assess how layered scenario mapping meets the objectives presented in Section 3.2, and will consider the ‘adequacy’ of the technique in relation to Diggins and Tolmie’s (2003) features of the successful design of outputs from field research. I will also discuss transferability and further development of the technique.

5.1 Coherence with Objectives

Framework to Use when Interpreting Information

When designing the map, we found that the defined content and layout made it easier to

sort and interpret data from different sources. The final map proved to be successful in helping us gain a holistic understanding of the situation we designed for, while at the same time providing the necessary details. This was especially true for those who had not taken part in the field studies.

Not all parts of the map were used to the same extent. The description of what happens in the timeline matrix was the most-used part of the map, and the design team stressed the visual elements as being important in gaining a broader understanding of the scenario. The written story did not play the role we expected in creating a frame of reference. This may be because the team members were already familiar with the scenario, and thus had a frame that enabled them to make sense of the details. The story did prove valuable in developing the map, though.

One shortcoming with the map that we observed was that we had not made visible connections between steps at different times that influenced each other; for example, the officers check the weather forecast in port to decide how to place the containers on the cargo deck, which informs how the vessel should be positioned in relation to the rig hours (or even days) later.

Facilitate Sharing of Data Collected and Insights Gained

The responses from the team when they were presented with the map stood out when compared with other means of sharing data and insight from the field studies. The way the data had been filtered, sorted, and put into a framework—particularly the timeline matrix—seems to have made the data more accessible. The map invited readers to delve into the material in a manner that we had not seen before. Some team members who had not taken part in the field studies stressed how spending a couple of hours going through the scenario helped them to get the situation we designed for ‘under their skin’. As Beyer and Holtzblatt (1998) observed with their work models, our map became a substitute for doing field research. A few of the team members found that it was challenging to go through the map because of its extensiveness, although they acknowledged that the chosen scenario was inherently complex and thus not easy to grasp. The map made this complexity visible. The users validating the scenario made a similar observation; they were surprised by how complex this scenario, normally considered to be relatively simple, actually was when mapped out in detail.

As noted by Feast (2012), collaboration is more than merely distributing information. It is also about building new knowledge. We found that the map invited comments, corrections, and clarifying questions, and thus facilitated mutual knowledge development. This resulted in a shared understanding of the situation we had designed for. The map’s level of detail may have contributed to this understanding. Had a more high-level description been used, the readers of the map would have been required to add more information mentally, and different readers could have developed different mental models of the scenario.

Presenting the Situation at the Necessary Level of Granularity

The initial idea was that the current scenario would form a basis, from whence we could zoom out and identify functions that could be fulfilled in new ways in future scenarios. ‘Functions’ here refer to high-level goals. By asking ‘why’ something is carried out in the current scenario, the function at a higher level of abstraction can be identified, and by asking ‘how’, one invites ideas for new ways of fulfilling the functions. Such an approach acknowledges that designing implies inventing new ways to work (Beyer and Holtzblatt 1998). The description of the current scenario would also help us to establish the framework conditions and to identify the details we needed in defining our designs.

In many ways, the map was successful in doing these things. It also invited many new ideas. As one of the project members said, ‘I get hundreds of little ideas for how we can support the users from this’. One example is that the map demonstrated ‘unnecessary’ tasks carried out by the users, such as documenting actions in checklists, which could have been automatically registered. Another example is that the map made the parameters that the users check repeatedly during the scenario explicit, such as the vessel’s position in relation to the set position, and the amount of bulk cargo transferred during offloading. Through the map, we identified the potential for presenting such information in better ways, using continuous visual and audio indicators.

We found, however, that it could occasionally be difficult to zoom out, and to consider the situation we had designed for at a higher level of abstraction. On some occasions, we redesigned the interaction that was defined in the current scenario directly, rather than considering whether or not the user action itself needed to be redesigned. This is an example of constraints of future thinking (Diggins and Tolmie 2003, 152) and invites the question: is layered scenario mapping open enough? We had already used a range of open-ended techniques early in the design process, and we did not find that the map threatened the concept that had already been developed. Still, this may be a limitation to be aware of in future usage of the technique.

Referring to our *model for design-driven field research* (Lurås and Nordby 2014), layered scenario mapping relies mostly on what we refer to as ‘data mapping’. This was intentional, as we had a need for specific data. The limited focus on ‘experiencing life at sea’ and ‘design reflection’, however, may invite the critique that the technique focusses too much on user actions, and does not evoke the designers’ empathy for the users (similar to Nielsen’s [2002] critique of scenarios). Many have stressed that empathy is vital in design and creative thinking (e.g., Leonard and Rayport 1997; Koskinen, Battarbee, and Mattelmäki 2003; Kouprie and Sleeswijk Visser 2009; Mattelmäki, Vaajakallio, and Koskinen 2014). Layered scenario mapping builds on field research, which is a good way to develop empathy with the users. However, the design and content of the map influences to what degree the map itself evokes empathy. Our detailed descriptions of the users’ tasks make it possible to envision what being in ‘the users’ shoes’ would feel like, and thus support empathy. We suspect, however, that our final scenario could have benefitted from additional visual material, e.g. images from the users’ point of view at each step of the timeline matrix. Others who intend to

use the technique should consider how to evoke empathy through their maps and possibly find inspiration in techniques that emphasise empathy to a greater extent, such as contextmapping (Sleeswijk Visser et al. 2005).

5.2 The ‘Adequacy’ of Layered Scenario Mapping

Although Diggins and Tolmie (2003) focus on the transference of insight from ethnographers to designers, their features of ‘adequate’ design of outputs from field research also seem relevant when designers conduct field research and make representations for themselves and fellow team members. I therefore use Diggins and Tolmie’s features in an assessment of the layered scenario mapping technique.

Economy

Our map was inspired by Giga-mapping (Sevaldson 2013) in its extensiveness, and took the form of a 0.9 m x 4.3 m poster. This size poster may seem ‘uneconomic’. It is not easy to handle, and requires a large amount of wall space. Still, we found it appropriate in many ways. Too much emphasis on the economy of such representations may lead to simplifications, which can make the representation less useful. We found that the large format enabled us to present a substantial amount of information that could be accessed in parallel, and helped to create a holistic understanding of the situation. The presentation of information at different levels of detail made it easier to see how the parts related to each other, and to the whole. Having a paper-based representation did, however, introduce challenges when collaborating with team members located elsewhere. Although the map was shared as a PDF file, the PDF did, for example, not contain the annotations made on the poster hanging on the wall of our lab.

Appropriate Format and Ordering and Logic of Practice

The individual parts of the map were partly influenced by techniques we had former experience with, and were partly developed from scratch. The story in the overview information was similar to a textual scenario (Carroll 1995; Bødker 2000). The timeline matrix was influenced by hierarchical task analysis (Kirwan and Ainsworth 1992), timeline analysis (ibid.), and STEP diagrams (Hendrick and Benner 1987). The visual presentation of the communication between actors was inspired by Comms Usage Diagrams (Stanton et al. 2005, 374–379), and the actors’ position on the bridge resembled a link analysis (Kirwan and Ainsworth 1992) or physical work model (Beyer and Holtzblatt 1998). While the critical points were identified through ACTA interviews (Militello and Hutton 1998), ACTA does not represent the critical points in a timeline. The remaining content categories were included and designed based on our needs. We found that the layout of the map, and particularly the visual elements, played an important role in creating a holistic understanding of the context for user actions. A short introduction was valuable to help people read the map. Still, many readers of the map quickly understood its logic (described in Section 4.3) and started making sense of

the content right away, presumably because conventional logic such as a timeline was used.

Indexicality

Our map hung on the wall of our lab and, as described, became a boundary object that was used in collaborative design sessions and was referred to repeatedly, and thus, held the feature of indexicality.

Iconicity, Sequentiality, and Organisational Accountability

We were surprised to see what an effect the map had outside of the core team of UBC. It became an icon of the substantial fieldwork we had conducted, and it resulted in a greater focus on field research within Ulstein. Another interesting observation was that the users validating the map started referring to it as an entity that conveyed the complexity of an operation. They stated that if we were to map out the more complex operation of ‘anchor handling’, the map would have been twice as long.

Integration

We observed that people who were both internal and external to the project quickly obtained a sense of having a stake in the scenario. The map has been used as a resource in other projects within Ulstein, and the company now considers the map to be a business-critical resource. One reason for this may be that emphasising user needs and conducting field research in design for these industries is rare (Lützhöft 2004), and therefore few descriptions of the users’ situation exist.

5.3 Transferability to Other Contexts

Layered scenario mapping was developed specifically to support the design of a ship’s bridge. The technique is most relevant when designing for situations that include spatial and/or temporal dimensions. It may be used with little alteration when designing for moving environments in other transportation modes. When designing for other control environments—such as process plant control, involving control room operators and field operators—an adapted version of the technique may give new insights into the control situation. It may also be useful in other professional settings, such as hospitals where healthcare professionals collaborate on treating patients over time in different locations. Layered scenario mapping could also be used when designing for less complex scenarios in which the temporal and spatial dimensions are important, such as design related to mobile phones.

5.4 Further Development

While we have shown that layered scenario mapping as described here can be used ‘as is’, the technique may be developed further, in many directions. For one, the content of

the map could be elaborated upon. We mapped out the scenario from one perspective only: that of the deck officers on the bridge. We could have obtained broader insight if we had also mapped out the scenario from the other actors' perspectives—that is, the able seamen on the cargo deck, the engineers in the ship's engine control room, the crew on the rig, or even the on-shore personnel. Further, the layered scenario mapping technique could encourage more structured interpretations of what the current scenario would mean for a future scenario, and thus more actively invite 'design reflection'. One idea would be to include a layer that explicitly addresses 'what could be'.

New ways of presenting the map and its data could be considered in future versions. We found a range of benefits with our paper-based map: it made it easy to access information in parallel, and it supported the development of a holistic view of the situation; it invited annotations; it was easy to refer to in collaborative design work; and the physical map became an icon of the work conducted. It would still be interesting to investigate the benefits of *digital* layered scenario mapping, which, as originally intended, could serve as a digital 'repository' (Star and Griesemer 1989). Wodehouse and Ion (2010) have described the advantages of digitising information. Such information can easily be accessed, revised, edited, and communicated across distances.

A digitised version could ease sharing and exploring the digital material collected during field studies (such as images, video, and audio recordings) and enable sorting and filtering of the data. Making raw data on users available to the whole team can result in increased empathy for the users (Kouprie and Sleswijk Visser 2009). In our experiences with different ways of reporting from field research, however, we found that it can be difficult to make sense of raw data. The logic of the scenario could therefore be used as an entrance into the data and presumably make it easier to make sense of the data. A digital map should also include the interpretations of those collecting the data.

Considerable work is needed to make a digital version. To attain the suggested functionality, all data would need to be described using a strict syntax. Another challenge is 'to find effective approaches to presenting and using digital information' (Wodehouse and Ion 2010, 4), and the map should be appropriately redesigned for screen-based use. Furthermore, one must consider how to maintain the advantages of the paper-based version in a digital version.

6 Conclusion

My colleagues and I experienced challenges with making use of the data from field research when designing a ship's bridge and developed the technique of *layered scenario mapping* as a response. Layered scenario mapping builds on existing techniques addressing the situation we are designing for, and combines these techniques in a unique way. The technique helped us make sense of fragmented data, and resulted in a map that supported our collaborative work. The map also became an icon of the substantial fieldwork we had conducted.

While layered scenario mapping was developed specifically to meet the needs faced when designing a ship's bridge, we expect that the technique can also prove valuable when designing for other contexts where the spatial and/or temporal dimensions are of importance.

Acknowledgements

This work was supported by the Research Council of Norway under the MAROFF programme; and the Ulstein Group. I would like to thank the crew who shared their insights and thoughts during our field studies, the shipping companies who allowed us onboard, the Ulstein Group, and the deck officers at Aalesund University College who validated the scenario. Thanks also to the project members of the Ulstein Bridge Concept design research project, who helped develop the layered scenario mapping and shared their experiences with using it. Special thanks to Svein Inge Bjørkhaug, who helped to make the illustrations used in the map, and to Kjetil Nordby, Birger Sevaldson, Henry Mainsah, and Marianne Støren Berg for valuable feedback on this paper.

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8 Appendix: Guide: Layered Scenario Mapping

Layered scenario mapping

Layered scenario mapping is a technique used to gain insight into the 'situation one designs for'. It is a systemic technique and emphasises presenting information in different layers going from an overview to very detailed information. The technique proposes a structured approach to collecting and presenting data and provides a template for sorting and presenting the data in a layered manner hierarchically, spatially, and temporally.

The layered scenario mapping process Preparation

A) Identify the scenario to map out. The scenario should be representative and cover the most important aspects of the 'situation one designs for'. The selection can be informed by the objectives of the design project, and criteria for selecting the scenario can be based on frequency (how often something happens) and/or criticality/importance (related to the potential consequences if something goes wrong). Some insight on the situation one is designing for is required to select an appropriate scenario. Involvement of users and subject matter experts is encouraged. Identify the main steps and make draft of the outline.

B) Define type of data to be collected. This depends on both the needs of the design project and how the data will be presented (see Designing the scenario). The template provided on the next page can be used as a starting point. Adapt according to your needs.

C) Identify data sources. The users, subject matter experts, and the field site may be primary sources of information. Other sources may include user training

materials, user manuals, regulations and procedures, incident reports relevant to the scenario, and online materials shared by users.

D) Plan how data collection should be carried out and decide on methods and techniques to be used.

Observational studies, interviews with users and subject matter experts, and other techniques involving users are valuable approaches. The guide *Design-driven field research at sea*¹ may prove valuable if you plan to do field studies.

The template on the next page can be used as the basis of an observation form. Communication analysis tools such as *Comms Usage Diagrams*² can be used to identify who communicates with whom in the scenario and by which means, *link analysis*³ can be used to identify how actors physically move, and *Applied cognitive task analysis (ACTA)*⁴ can prove valuable in determining expertise needed and identifying critical points.

Consider what kinds of video/audio recordings to make and what images to take and the equipment needed to do so. Making a list can be useful.

E) Make practical arrangements. Agree with companies and users on field trips, interviews, etc. Note: This can be time consuming. Start early and set aside sufficient time for this activity.

Data collection

Collect data as planned. Note: You may need to carry out data collection activities several times as deficiencies are identified and new needs emerge during designing of the scenario.

Designing the scenario

Decide on the format and layout of a scenario map that supports the presentation of both overview information and detailed data. Designing the map goes beyond listing the data collected. It involves developing new knowledge by interpreting the collected data, collating the data, and designing the data. Use visual presentation whenever appropriate. Spatial and temporal data are particularly appropriate for visual presentation.

The map can be presented analogously or digitally. The template presented on the next page can be used for paper-based versions. Note: The template is suggested as a starting point, and the layout of the map should be adjusted to the needs of the specific design project.

Validation of scenario

Ensuring that the information included in the map is correct is important. Invite users and other subject matter experts to examine and validate the scenario.

¹ See Stanton et. al (2005). *Human factors methods: a practical guide for engineering and design*. Aldershot: Ashgate.

² See Stanton et. al (2005). *Human factors methods: a practical guide for engineering and design*. Aldershot: Ashgate.

³ See Stanton et. al (2005). *Human factors methods: a practical guide for engineering and design*. Aldershot: Ashgate. or Kirwan & Ainsworth (1992). *A Guide to task analysis*. London: Taylor & Francis.

⁴ Mittlelo & Hutton (1998). Applied cognitive task analysis (ACTA): a practitioner's toolkit for understanding cognitive task demands. *Ergonomics*, 41(11), 1618–1641.

Layered scenario mapping template

The template on the previous page suggests how information can be presented with overview information to the left and detailed information to the right. The overview gives the reader a frame of reference to use when making sense of the detailed information. The detailed view consists of a timeline matrix with step-by-step descriptions. The number of steps depends on the length of the scenario and the needed level of granularity. The following content elements are included:

- 1) **Descriptive title**
- 2) **Visual presentation of ship's technical specifications.** Presents what the users physically control and the technical systems to design for controlling.
- 3) **Description of the scene and introduction to scenario.** Lets the readers of the map know the setting of the scenario.
- 4) **Presentation of actors involved in scenario.** Lets the readers know who is involved. Colour coding of the actors can be useful.
- 5) **Written scenario story.** Presents the scenario from start to finish. Provides the readers with an initial frame of reference to use when interpreting the detailed information. Also useful in developing the outline of the timeline matrix.
- 6) **Document info.** States which data sources the map builds on. Includes version of the document and date. Adds to the trustworthiness of the map.
- 7) **Timeline.** Not necessarily linear in a mathematical sense (it must not have a fixed scale where one step represent a set time period).

8) **Visual presentation of vessel position.** The vessel is shown in relation to other objects, such as the port and the rig.

9) **Mode.** The mode of operation indicates what kinds of rules apply and the technical mode of the vessel.

10) **What happens.** Gives a short description of what happens at each step.

11) **Actors involved.** Presents the main actors involved at each step. Colour coding from item 4 is used.

12) **Communication.** Shows who communicates with whom and by what means for each step. Colour coding from item 4 is used.

13) **Position.** Visual presentation of the users' position at each step in a bird's-eye view (here, position on the ship's bridge). Colour coding from item 4 is used.

14) **Equipment used.** Shows what kind of equipment is used at each step.

15) **Information needed.** Describes information the users need to be able to carry out the actions at each step. Includes information from technical systems and the natural environment. Needed to judge what information to present when, where, and how.

16) **Functionality needed.** Describes the functions the users need to be able to carry out their tasks at each step. Needed when designing controllers and other interactive elements.

17) **Critical points.** If the step is particularly important to ensure safety, it is highlighted, and the critical factors are pinpointed. The critical points can, for example, be identified through ACTA or risk analysis.

18) **Illustrative photos.** Provide contextual information and can, for example, show the physical environment or the equipment used. Could also include pictures of the actors in the scenario.

Advantages to the technique

- Easy to understand and requires little training.
- Offers a framework for sorting and making sense of large amounts of data from a range of sources.
- The map can support collaborative work and be used to share insight among a design team.
- Different disciplines of a development team can use the map for different purposes.
- The map can be used to document work done on the project, such as field research.

Limitations of the technique

- Can be time-consuming and relies on substantial data collection.
- May lead to fixation on the current situation and requires conscious interpretation of what the scenario means for the design of future situations.

Things to consider

- The example used in this guide is a ship's bridge but can be adapted to other complex environments.
- To overcome the limitations of the technique, consider combining it with more open-ended and future-oriented techniques.
- Information with a lower level of detail gives a more open-ended map that invite interpretations useful at the start of the design process, while more detailed information may result in a less-open map useful later in the design process.

PUBLICATION 6

Lurås, Sigrun. Forthcoming. "Systems Intertwined: A Systemic View on the Design Situation". *Design Issues*.

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Excluded from the digital version of the thesis for copyright reasons. The published article will appear in the Summer 2016 (32:3) issue of Design Issues.

ERRATA LIST

Side/line/ footnote/ figure	Original text	Corrected text
v/37	This is thesis by publication, which consists of an exegesis (included	This is a thesis by publication, which consists of an exegesis (included
vii/32	I owe special thanks to the other Ph.D. fellows at AHO. Nina Lysbakken,	I owe thanks to the other Ph.D. fellows at AHO. Special thanks to Nina Lysbakken;
viii/3	I am grateful to my employer, DNV GL, who gave me leave	I am grateful to DNV GL for giving me leave
vii/8	to my current leader, Anne Wahlstrøm , for supporting me in the finishing stages.	to Anne Wahlstrøm, for supporting me in the finishing stages.
ix/16	ensuring a satisfying working environment for those working in such settings.	ensuring a satisfying working environment for those working in such settings.
2/1	Examples include the concepts of <i>integrated bridge systems</i> , ² which implies interconnecting systems on a ship's bridge in a way that allows for	Examples include the concepts of <i>integrated bridge systems</i> , which implies interconnecting systems on a ship's bridge ² in a way that allows for
5/2	UBC project, and knowledge <i>for</i> design would be developed based on the	UBC project, and knowledge <i>for</i> design would be developed on the
10/36	the model of design-driven field research introduced in Publication 3, and	the model for design-driven field research introduced in Publication 3, and
11/11	Citation: Lurås, Sigrun. Forthcoming 2015. "Layered Scenario Mapping: A Multidimensional Mapping Technique for Collaborative Design". <i>CoDesign</i> , 11(2). doi:10.1080/15710882.2015.1072221.	Citation: Lurås, Sigrun. 2015. "Layered Scenario Mapping: A Multidimensional Mapping Technique for Collaborative Design". <i>CoDesign</i> . doi:10.1080/15710882.2015.1072221.
13/5	I introduce the Ulstein Bridge Concept design research project, in which	I introduce the Ulstein Bridge Concept (UBC) design research project, in which

Figure 7		[changed the positions of innovation and designer's intention to correspond with the text]
38/17	have been developed by Ryan (2014) and Jones (2014a). Jones suggests	have been developed by Ryan (2014) and Peter Jones (2014a). Jones suggests
41/29	but something defined by intelligence' (Beer 1994, 242). This implies that	but something defined by intelligence' (Beer 1994/1966, 242). This implies
47/15	relation to what purpose they serve. Peter Jones (2014) draws on different	relation to what purpose they serve. Peter Jones (2014a) draws on different
Text in Figure 11	A weakness with the scenarios is	A weakness with the scenario is
71/13	onshore was difficult. We thus tried to make the most of the field studies,	onshore is difficult. We thus tried to make the most of the field studies,
80/ footnote 8	'Head-up' technologies, discussed at more length in Section 5.3.1 and seen in Figure 32 , refer to presentation of information without requiring users to look away from their viewpoints.	'Head-up' technologies, discussed at more length in Section 5.3.1 and seen in Figure 33 , refer to presentation of information without requiring users to look away from their viewpoints.
83/33	that I was free to share openly. I should mentioned that Ulstein has been accommodating and has allowed us to share a substantial amount of information,	that I was free to share openly. I should mention that Ulstein has been accommodating and has allowed me to share a substantial amount of information,
103/32	responsibilities within the project. The system we design is similar to	responsibilities within the project. The system we design within is similar to
103/39	part of thinking about systems .	part of thinking systemically .
104/7	scholars (e.g. Schön [1983]) through the notion of seeing-moving-seeing .	scholars (e.g. Schön [1983]) through the notion of seeing-moving-seeing).
104/22	The systemic sensemaking model for design introduced in Publication 6	The systemic model of the design situation introduced in Publication 6

104/30	The systemic sensemaking model for design invites considering the	The systemic model of the design situation invites considering the
104/39	appreciative system (Vickers 1965). Through the model, I argue that we,	appreciative systems (Vickers 1965). Through the model, I argue that we,
105/1	through designing, change the world a little, and consequently our design	by designing, change the world a little, and consequently our design
105/8	The systemic sensemaking model for design is generic, and thus does not	The systemic model of the design situation is generic, and thus does not
107/18	the inclusion of expert users is recommended (Roesler and Woods 2008)	the inclusion of expert users is recommended when designing for professional use (Roesler and Woods 2008).
113/14	system we designed, we explored the use of mariner workblogs and online	system we designed for , we explored the use of mariner workblogs and
116/8	the ship, and visual representation of the thrusters map their placement on the	the ship, and visual representations of the thrusters map their placement on the
120/6	DNV's class rules further define what should be part of the conning	DNV's class rules define what should be part of the conning
125/35	Although I do not specifically discuss the transferability of these results to	Although we do not specifically discuss the transferability of these results to
130/18	<i>mapping</i> , presented in Publication 5.	<i>mapping</i> (presented in Publication 5).
144/29	IMO (International Marine Organization). 1996. "RESOLUTION MSC.64(67)	IMO (International Maritime Organization). 1996. "RESOLUTION MSC.64(67)
144/40	IMO (International Maritime Organization) , 2009. <i>SOLAS: Consolidated Text of</i>	———. 2009. <i>SOLAS: Consolidated Text of</i>
157/9	designhøgskolen i Oslo). The research institution where the research	designhøgskolen i Oslo). The research institution where the research

160/10	UBV: Ulstein Bridge Visions. The pilot study taking place 2010 which	UBV: Ulstein Bridge Visions. The pilot study taking place in 2010 which
161/3	The following is an overview of publications written and presentations	The following is an overview of publications written and presentations
164/5	Think of a dream project for maritime or offshore industry: If you had all	Think of a dream project for the maritime or offshore industry: If you had all
164/22	(Sum up the main things that has been said in the interview.) Have I	(Sum up the main things that have been said in the interview.) Have I
Title page Publication 5	Lurås, Sigrun. Forthcoming. "Layered Scenario Mapping: A Multidimensional Mapping Technique for Collaborative Design". <i>CoDesign</i> , 11(2). doi:10.1080/15710882.2015.1072221.	Lurås, Sigrun. 2015. "Layered Scenario Mapping: A Multidimensional Mapping Technique for Collaborative Design". <i>CoDesign</i> . doi:10.1080/15710882.2015.1072221.
Title page Publication 5	© 2015 Taylor & Francis. Reprinted with permission	Preprint version. Printed with permission from Taylor & Francis.
Title page Publication 6	Preprint version.	Preprint version. Printed with permission from the MIT Press.
Publication 6 p. 5/ footnote 32	Sigrun Lurås, Margareta Lützhöft, and Birger Sevaldson, "In Unfamiliar Fields: Industrial and Interaction Designers in the Norwegian Offshore Industries," <i>International Journal of Design</i> (forthcoming).	Sigrun Lurås, Margareta Lützhöft, and Birger Sevaldson, "Meeting the Complex and Unfamiliar: Lessons from Design in the Offshore Industry," <i>International Journal of Design</i> 9, no. 2 (2015): 141–54. http://www.ijdesign.org/ojs/index.php/IJDesign/article/view/1845
Publication 6 p. 6/ footnote 34; p. 9/ footnote 43; p.10/ footnote 44	Lurås, Lützhöft, and Sevaldson, "In Unfamiliar Fields: Industrial and Interaction Designers in the Norwegian Offshore Industries."	Lurås, Lützhöft, and Sevaldson, "Meeting the Complex and Unfamiliar: Lessons from Design in the Offshore Industry."