From Field to Simulator: Visualising Ethnographic Outcomes to Support Systems Developers

Yushan Pan

Doctoral Dissertation

Submitted for the Partial Fulfilment of the degree of

Philosophiae Doctor

Faculty of Mathematics and Natural Sciences
Department of Informatics
University of Oslo

2018

UiO : University of Oslo

Project sponsorship

This doctoral study was mainly conducted at **University of Oslo (UiO)**.

Financial support for the doctoral study provided by ***SFI MOVE – Centre for Marine Operations, Department of Ocean Operations and Civil Engineering, Faculty of Engineering, NTNU***

UiO : Institutt for informatikk
Det matematisk-naturvitenskapelige fakultet

NTNU
Faculty of Engineering
Department of Ocean Operations and Civil Engineering

MOVE
SFI Marine Operations

År

Tittel

Forfatter

http://www.duo.uio.no/

Trykk: Reprosentralen, Universitetet i Oslo

Summary

A maritime simulator is a training and research platform for marine operations. Such simulators are frequently used to prepare marine operators for maritime industries in western Norway. Although maritime simulators were not developed with a focus on the cooperative work practices of marine operators, marine operators are in practice trained in cooperative groups. Hence, there is a distance between simulated training and actual work, which could lead to high risks in the workplace. Thus, this interpretative-based ethnographic study was conducted to investigate how marine operators work cooperatively with specific systems, such as dynamic positioning (DP) systems and automatic integration systems (AIS). The study also investigates how artefacts in the workspace on a ship's bridge at sea could be used to help systems developers redesign maritime simulators. The study uses actor-network theory (ANT) and concepts from computer-supported cooperative work (CSCW) such as awareness and computational artefacts to analyse the ways in which cooperative work is conducted. Three workshops were conducted on land with maritime systems developers to explore visualisation techniques so as to represent the ethnographic outcomes that are used to inform the design process. Thus, this study contributes insights from the CSCW field to the maritime domain by considering social aspects of cooperative work in engineering.

This manuscript also contributes to design research by exploring the cooperative work of marine operators. Researchers may use the outcomes of this study as a resource as they work with system developers who are outside the informatics field. This work shows how academic contributions can be used in work practices by configuring relations between ethnographic outcomes and design to convince other professionals such as systems developers in the maritime domain. This study shows how to use insights from ANT and CSCW in a visualisation approach, thereby to include the cooperative work of marine operators in the design process. By allowing two different work practices – those of marine operators and systems developers – to meet together, this study contributes a supportive tool by adding a new mechanism for making sense of ethnographic outcomes beyond artificial simulations and experimental results.

To implement the findings of this study, maritime project managers should consider that ethnographic outcomes provide good resources for designing simulators that

resemble, as closely as possible, the systems that are used in reality. The development of such simulators requires the collaboration of ethnographers and systems developers, and such collaboration is badly needed in the current maritime industry. Only through such collaboration will it be possible to configure the relations between work practices and maritime simulators in the design process and thereby envision how the latter could better support work practices in the future.

Abbreviation

NTNU – Norwegian University of Science and Technology

UiO – University of Oslo

CSCW- Computer-supported Cooperative Work

DP – Dynamic Positioning

AIS – Automatic Integration Systems

ANT – Actor network theory

ICT – Information and Communication Technology

UML – User Modelling Language

IS – Information Systems

GCE – Global Centres of Expertise

NSD – Norsk senter for forskningsdata [Norwegian Centre for Research Data]

CS – Computer Science

DESIGN – The Research Group: Design of Information Systems

ACM- Association for Computing Machinery

IEEE – Institute of Electrical and Electronics Engineers

VTS – Vessel Traffic Service

FRAM – Functional-resonance Analysis Method

AIS – Association for Information Systems

EUSSET – European Society for Socially Embedded Technologies

LGBTQ – Lesbian**,** Gay, Bisexual, Transgender, and Queer

PD – Participatory Design

Preface

This study is submitted in partial fulfilment of the degree of philosophy doctor at University of Oslo (UiO), the Faculty of Mathematics and Natural Sciences, Department of Informatics. The work done for this study has mainly been performed and as parts of the research activities at the Department of Informatics, University of Oslo and Norwegian University of Science and Technology (NTNU) at the Faculty of Engineering, Department of Ocean Operations and Civil Engineering.

致我的爸爸潘炳刚，妈妈方闵玉和妻子武辰。

Acknowledgments

Frist and foremost, I want to thank Sisse Finken (ITU), Hans Petter Hildre (NTNU), and Tone Bratteteig (UiO). It has been an honour to be their Ph.D. student. I appreciate all their contributions of time and ideas to make my Ph.D. experience productive and stimulating. Special thanks to Sisse, she has taught me both consciously and unconsciously, how to be a good research scholar and how good academic writing is done. Thank you for numerous discussions, lots of proofreading, continuous guidance and making time for meetings and answering my emails even during the busiest times. I also want to give a special thank you to Hans Petter; I appreciate all the financial supports for my study. He offered me many chances to make my Ph.D. possible. Thank you very much for letting me join your research and helping me throughout the toughest moments when I was not sure, I could make it through. I also want to thank Tone. I appreciate all our discussion during my stay in Oslo. Also, I appreciate her invaluable suggestions on the manuscript of this study.

I particularly thank Christina Mörtberg (Linneuniversitetet) for constructive comments on my manuscript of this study. I also want to thank Alma Leora Culén (UiO) for offering comments to strengthen my arguments in some chapters of this study. I would also like to thank Steinar Nistad. Thank you for offering me a chance to stay in Ålesund when I was finalizing this study.

I would also like to thank Siri Schulerud, Gunn Helen Hellevik, Magnhild Kopperstad Wolff, Unni Sletten, Arnfinn Oksavik, Arnt Håken Barmen, Marte Fanneløb Giskeødegård, Tron Resnes, Terje Fiskerstrand, Tore Relling, and the staff of the Department of Ocean Operations and Civil Engineering at NTNU. Thank you for your support and interesting discussion. My apologies to all of you who have not been mentioned, I cannot mention you all, but no one has been forgotten.

Thank you to Jo Herstad, Maja van Der Velden and Gisle Hannemyr and the other members of the Design of Information Systems group, UiO. The members of the DESIGN group have contributed immensely to my personal and professional time at UiO. The group has been a source of friendships and good advice and collaboration. I would also like to acknowledge the participants of the Ph.D. days at IFI. I very much appreciated your enthusiasm, intensity, willingness to share your insights on Ph.D. studies. Also, thank you very much to Fritz Albregtsen and Mozhdeh Sheibani Harat at the Department of Informatics at UiO for the administrative supports on behalf of the Ph.D. board at the university throughout the toughest moments.

I would like to acknowledge Ade Mabogunje at Stanford University. Though you only guided me in a short period of time, you inspired my interest in the visualisation of CSCW insights for maritime design and sharpened my thinking in so many ways. Thank you so much.

To my friends Sichao Song, Suhas Govind Joshi, Rune Rosseland, Guri Verne, Margaret Machniak Sommervold, Andrea Alessandro Gasparini, Eunji Lee, Anita Woll, Cong Liu, Guoyuan Li, Yue Li, Sumit Pandey, Swati Srivastava, Yingguang Chu, Jifeng Xu, Naoe Tatara, Yanbin Wu, Marlen Chawani, Jifeng Xu, Eirik Homlong, Lillian Vederhus, Hanne Cecilie Geirbo, Made Agus Setiawan, Rami Zghyer, Yonathan Redda, and Zheng Wang, you were always there listening to me and creating greater social life in Ålesund, Oslo, Tokyo, Kawasaki, Kobe, Pittsburgh, and San Jose and Xi'an. Thank you for the wonderful times. Thanks also to Richard for his expert language editing.

我非常感谢我的岳父母。感谢他们一直以来的理解和耐心。我还要感谢我的妻子武辰，感谢你无尽的爱，耐心和积极的生活态度。没有你的陪伴，这篇论文可能无法按时完成。

我生在一个了不起的家庭。感谢父亲的大度豁达，母亲的温良贤惠勤劳持家。感谢我的父母赐给我健康的体魄，聪慧的头脑。更要感谢他们的教导方式，多为言传身教。感谢他们的开明，让我学会为自己的选择负责，他们只建议不做主。感谢他们对我的爱，让我获得了巨大的精神支柱和经济支持。在我少年时，我们曾经经历过一段艰难的岁月。我的父母用行动告诉我遇到困难不可怕，积极面对且坚韧不拔总能克服一切困难。谢谢你们。

Ålesund, 2018
Yushan Pan

Contents

Figures

Tables

1 Introduction

This chapter introduces the topic of this study and provides an overview of it. First, Section 1.1 presents the research background and Section 1.2 describes the motivation and research position of the study, including the research questions. Section 1.3 introduces the research approach. Section 1.4 discusses the audience and the scope of the study. Section 1.5 considers the contributions of the study, and Section 1.6 presents the structure of this study.

1.1 Research background

Currently, at least 30% of unsafe marine operations are caused by the failure of marine operators' cooperative work (Baker and McCafferty 2005). The reasons for this high rate of unsafe operations are as follows. First, in the maritime industry, maritime simulators are used to train marine operators to work together. The purpose is to prepare marine operators to perform real work at sea, though there is no record that existing simulators are effective in this training (maritime simulator meeting notes, March 3, 2013). Second, though marine operators are trained in maritime simulators (Sellberg 2017), the simulators are not designed and developed to support their cooperative work (Hepsø and Botnevik 2002; maritime simulator meeting notes, March 3, 2013). For these two reasons, industries in western Norway and the Department of Ocean Operations and Civil Engineering at the Norwegian University of Science and Technology have set the short-term goal of designing maritime simulators that can better support the cooperative work of marine operators (maritime simulator meeting notes, March 3, 2013). They have also established the long-term goal of producing maritime simulators that are as similar as possible to the workspaces[1] on vessels, thereby to reduce the number of accidents that occur in cooperative work (Hildre 2010).

However, it is not known whether training in existing simulators is sufficient to provide suggestions for designing maritime simulators that meet the short-term goal

[1] In this study, the workspace (Pomeroy and Jones 2002) is an operational area that consists of offshore operating systems, hardware, and other physical tools on an offshore vessel. This workspace focuses exclusively on the marine operations involved in offshore oil and gas activities.

(maritime simulator meeting notes, March 3, 2013). In addition, if training provided in the simulators is inadequate, the assessment of the training of marine operations in simulators will not provide information enough to improve their technical performance (maritime simulator meeting notes, March 3, 2013). Therefore, though I considered the evaluation of marine operators' performance to be a core element at the beginning of my study, I began to focus on the design of maritime simulators as I gained knowledge about this area. Thus, this text is entitled *From Field to Simulator: Visualising Ethnographic Outcomes to Support Systems Developers*. This study thus considers the cooperative work of marine operators at sea to provide information to systems developers who design land-based maritime simulators.

1.2 Motivation and research position

The above two issues, which were identified in the meeting attracted my attention because I hold a master's degree in software engineering[2] (I was educated as a systems developer) and a bachelor's degree in applied mathematics, and I worked as a software consultant for a few years. I thought that simulated software and hardware systems could help marine operators adapt existing technical structures and artefacts to accomplish the tasks expected by developers. At that time, I wondered why the advanced technology used in the maritime domain could not duplicate the success encountered in the software-engineering field—such as we see in backup solutions, algorithms, multiple datasets, and various hardware protections of human errors—to simulate the cooperative work that takes place in practice at sea (Dunn 2003). Thus, I was seeking a software-engineering approach that could help us understand cooperative work in the maritime domain. Perhaps I could contribute to designing simulators by enhancing both software and hardware systems? However, over time, and with my experience in design-oriented research at the University of Oslo, I revised my thoughts.

[2] Software engineering is the application of engineering to the development of software in a systematic method. Software engineers apply the rules and regulations of software engineering to the design, development, maintenance, testing, and evaluation of the software and systems that allow the operation of computers or anything containing software (IEEE 2011).

At that time, I sought to determine the users in my study. The term *users* is used to define human-computer interactions in the software-engineering field: If I were a systems developer who could deliver the requirements for systems design, which could I then incorporate line-by-line into a software code for maritime simulators? However, though I see myself as a systems developer[3], I found that the backgrounds of most designers of maritime simulators are not like my own. There are some overlapping courses—such as those which go over the requirements of engineering and systems development[4] (personal communication with systems developers in the maritime domain, April 4, 2013)—but not all the courses are same. In the field of systems development, systems developers are professional mechanical engineers who focus on automation controls (mechanical engineers in the maritime design field, meeting notes, April 4, 2013).

I asked myself the following question: If I positioned myself between marine operators and maritime systems developers, could I work on designing a maritime simulator? I realized that I could not. Instead, I could focus on how marine operators work together at sea. Following Bannon et al., (2011), I noted that these users are professionals in their work context. I decided to include their work practices in the design processes, as their work practices have been overlooked in the design of maritime simulators (mechanical engineers in the maritime design field, meeting notes, April 4, 2013). Previous studies (Lurås and Mainsah 2013) have found that it is difficult for external visitors, including researchers, to access the marine operations on a vessel. I thought that, if I were to gain access to these operations, I could contribute to the knowledge of systems developers by investigating and identifying the cooperative work practices involved in them.

I began to look for an approach that could open up insights regarding cooperative work. Practice-based, computer-supported cooperative-work (CSCW) research[5]

[3] With my background in Software Engineering.
[4] Systems development refers to the engineering systems development in this study. The rules of systems developments apply to a range of hardware and software configurations in the maritime domain.
[5] Grudin and Poltrock (1997) have distinguished differences among CSCW research in North America, Europe and Asian. The difference can also be found in Heaton's article (Heaton 1999). Bjørn et al (2016) call the European tradition on CSCW

(Bjørn et al., 2016; Schmidt 2018; Wulf et al., 2015) attracted my attention during my coursework for the DESIGN group at the University of Oslo. At that time, the lecturer, my classmates and I explored the concepts and theories used in CSCW research, aiming to understand how it could contribute to the design of computer systems to support end users' cooperative work in the general field of informatics (Schmidt 2011). My interest in the CSCW field grew from there as I acquired the knowledge necessary to investigate my concerns about my project. I had hoped that, when I had finished the course and obtained inspirations from group discussions, I would have enough knowledge to understand ethnographic studies and work with systems developers who design maritime simulators. In addition, I thought that I could also offer requirement specifications (Randall et al., 2007) on cooperative work with which to inform systems developers[6], as other researchers do in their design of cooperative systems.

However, previous researchers (Baxter and Sommervile 2011) have argued that, though CSCW is a design-oriented field, it informs design by offering requirement specifications and other analytical lenses (Randall et al., 2007) rather than by providing hands-on design guidance that system developers can use in the general design of cooperative systems (Dourish 2006; Christensen 2013). If no hands-on guidance was the challenge in systems design—as it was—then it could be that maritime systems developers with less knowledge of CSCW may be challenged to implement the analytical outcomes. Though it was challenging, it seemed to be an interesting topic for a doctoral dissertation. Thus, I located the study within the CSCW field but aimed to offer suggestions for the maritime domain.

1.2.1 Research question

Therefore, I formulated the following general research question:

research as practice-based CSCW research. Or, in general some researchers name it as practice-based computing (Wulf et al., 2015, Schmidt 2018).

[6] In the maritime domain, systems developers are different from software designer or engineers in the computer science field. Their background is mechanical engineering, mechanics, automation, and systems engineering.

Regarding the cooperative work of marine operators, how could outcomes of ethnographic studies facilitate the design of maritime simulators?

This research question is, of course, quite broad; it could cover a wide range of issues and perspectives within CSCW. Because I had limited experience regarding maritime operations, I was interested to learn how maritime operators work cooperatively and how they interact with technologies that ensure safety. Thus, the first research question is as follows:

RQ 1: What resources are used in safe cooperation on a ship's bridge at sea?

Although CSCW does concern safety issues, *safe cooperative work* has various meanings. However, because the maritime domain is mainly an engineering field, it is believed that safety can be ensured by evaluating the mechanical attributes of a technology (Hjorth 2015; Sadeghi et al., 2016). My research position drives me to seek a social-technical approach to designing a technology to support safe cooperation. Though researchers have argued that ethnographic studies could help systems developers build a social-technical approach to designing systems (Sharp et al., 2016), there is a distance between ethnographic outcomes and synthesis solutions in the software-engineering field (Baxter and Sommerville 2011; Button et al., 2015; Randall et al., 2007). Thus, the second research question is as follows:

RQ 2: In what way can the safe cooperative work of marine operators help to inform the design of maritime simulators?

Therefore, I believe that a social-technical approach (Hanseth and Monteiro 2015) can be used to inform systems developers about 'what', 'where' and 'why' a component of a maritime simulator could be designed for supporting safe cooperative work.

1.3 Research approach

The present study partly addresses the short-term goal for informing the design of maritime simulators. The maritime sector in western Norway and the Research Council of Norway sponsored this study. Collaborating institutions are the Department of Ocean Operations and Civil Engineering (NTNU), the Department of Informatics at the University of Oslo and other industrial partners.

To better understand cooperative work, I used an ethnographic approach, as I was interested in how natural cooperative work is accomplished on a ship's bridge. The study was started in the autumn of 2013, and it was completed in the spring of 2017. The study took place in two settings. For the ethnographic study at sea, I studied the marine operators on an offshore vessel at sea from spring of 2015 to summer of 2015. On land, I conducted workshops and interviews with systems developers from autumn of 2015 to autumn of 2016.

In conducting this research, I gained inspiration from the DESIGN group at the Department of Informatics, University of Oslo. In this group, researchers include users' preferences in the design process. With this background, as mentioned above, I aimed to bring the cooperative work of marine operators into the design process. I also aimed to apply ethnographic outcomes to inspire systems developers in the design process. Thus, I considered CSCW both because it provides insights into analysing cooperative work practices and because it informs design.

The study is based on two core concepts: 'awareness' (Schmidt 2002; Tenenberg et al., 2016) and 'computational artefact' (Christensen and Harper 2016; Schmidt and Bansler 2016). The study focuses on using ethnographic outcomes as a visualised, practical means of informing systems developers in the maritime domain. To convince these developers that simulators can support the cooperative work of marine operators, the present work combines ANT and CSCW to visualise actor networks through the language that is familiar to systems developers in their design process. Thus, this study aims to shorten the distance between ethnographic outcomes and practical work in the design of maritime simulators.

1.4 The audiences and scope of the study

The intended audience of this study consists of academics in the design field with the purpose of bridging the distance between academic work and industrial needs. Similar to other studies (Blomberg et al., 1993; D'Mello and Eriksen 2010; Randall et al., 2007; Simonsen and Kensing 1998; Sylvest 2017), this study is based on the argument that academic results should be functional in their application to industrial contexts. Moreover, unlike the mainstream navigation studies in the maritime literature, the present study focuses on how offshore activities are carried out on offshore vessels. Thus, the manipulation of a vessel at sea from one area to another is beyond the scope of this study.

1.5 Overall contributions

Most technical solutions in the maritime domain focus on the training and evaluation of marine operators' cooperative work in simulators (Barnett et al., 2003; Karlsson 2011; Sendi 2015; Lewin 2015). However, this study focuses on how ethnographic studies can help us understand the cooperative practices of marine operators at sea. Hence, through the outcomes of the ethnographic study, this study contributes to bringing cooperative work back into the maritime design process.

Compared to other projects—such as providing a context for designers (Blomberg et al., 1993), making prototypes with designers (Randall et al., 2007) and designing new curricula (Simonsen and Kensing, 1998)—this study seeks to provide a way to represent CSCW insights by using the common-sense language of the engineering field (Khovanskaya et al., 2017, Forsythe 1999; Simonsen and Kensing, 1998). This study assumes that the safe cooperative work of marine operators can be represented as a visualised diagram. Ethnographers do not merely report how safe cooperative work is done; they also 'talk back' to improve the design. Thus, this contribution could help solve the dilemma of using academic knowledge to convince systems developers in the maritime industries. Because visualised representations of ethnographic outcomes constitute a new way of making sense of ethnographic outcomes beyond analytical results, mock-ups and new curricula, this work will provide insights to systems developers in their working language and provide understanding of the social aspects of designing simulators to support safe cooperative work. As discussed by Randall et al. (2007), ethnographic studies can help in the design of a useful system. Therefore, this study contributes by providing an approach to designing maritime simulators.

To implement the future design of maritime products, the following two points should be followed. Primarily, systems developers should realise that their design processes must consider the cooperative work of marine operators. The professional skills of marine operators in the field are fruitful resources for updating all simulators on land. Second, the managers of maritime-simulator design projects should understand that making room for an ethnographic study could help return those fruitful resources to the design process. Ethnographers are professionals who study cultures and people in their work contexts by interpreting the phenomena in work settings. They provide powerful insights that help in the design of technologies. Thus, project managers need to bear in mind that collaboration with ethnographers and systems developers in the design process could serve to improve design.

1.5.1 Papers included in this study

Below, I have listed five articles that jointly answer the main research question. I have also marked out which papers can refer to research questions (RQ) 1 and 2.

- **Paper 1:** Pan, Y., Kom, S., and Finken, S. (2015). Complex Systems, Cooperative Work, and Usability. *Journal of Usability Studies, pp.100-112.* (RQ1)
- **Paper 2:** Pan, Y. (2016). Design of Digital Environments for Operations on Vessels. In *COOP 2016: Proceedings of the 12th International Conference on the Design of Cooperative Systems, pp.123-138.* (RQ1)
- **Paper 3:** Pan. Y., Finken, S. (2016). Visualizing Actor Network for Cooperative Systems in Marine Technology. In *IFIP International Conference on Human Choice and Computers, pp.178-190.* (RQ2)
- **Paper 4:** Pan, Y., Hildre, H. P. (2016). Using Actor Network to Enhance Maritime System Design[7]. In *Proceedings of the International Conference on Learning and Collaboration Technologies. Lecture Notes in Computer Science, pp.616-627* (RQ2)
- **Paper 5:** Pan, Y., Finken, S. (2018). From Offshore Operation to Onshore Simulator: Using Visualized Ethnographic Outcomes to Work with Systems Developers. *Journal of Informatics, 5(10)* (RQ2)

Other articles (see below) are not listed in this study, as they address topics which are outside the scope of this study. Though they are not included, the findings also

[7] Systems design is the process of defining the modules, architecture, interfaces, and data for a software or system to satisfy specified requirements. In this study, systems design refers to studies on systems analysis in the CSCW field.

partially contribute to this study by providing some support to the discussion and arguments of the included articles.

- **Paper 6:** Pan, Y. (2016) Improving Maritime Technology: A Cooperative Technology Perspective on Cooperative Artefacts. In *Proceedings of the OCEANS' 16 MTS/IEEE.* pp.1-6.
- **Paper 7:** Pan, Y. (2015). Suggestions on Communications Systems for Offshore Vessels. *Dilemmas 2015 Papers from the 18th Annual International Conference on Dilemmas for Human Services: Organizing, Designing and Managing. Linnaeus University Press.* pp. 1-12.
- **Paper 8:** Pan, Y. (2016). Cooperative Systems for Marine Operations Using Actor Network Design. In IEEE *SMC Proceedings of 20th International Conference on Computer Supported Cooperative Work in Design.* pp.607-612.
- **Paper 9**: Pan, Y., Finken, S., and Kom, S. (2015). Are Current Usability Methods Viable for Marine Operation Systems? In 8th International Conference on Advances in Computer-Human Interaction. pp.161-167.
- **Paper 10**: Pan, Y., Kom, S., Finken, S., and Hildre, H. P. (2014). An Analytical Review of Usability Evaluation for Ship Bridge Multiscreen Complex Systems. In *Human Factors in Ship Design and Operation.* pp.1-12.
- **Paper 11**: Vederhus, L., Pan, Y. (2016). Surface-to-seabed Safety: Advantages of Simulator Practice for Subsea Installation. *International Journal of Safety and Security Engineering*. 6 (2): 301-309.
- **Paper 12:** Pan, Y., Hildre, H. P. (2018) Holistic Human Safety in the Design of Marine Operations Safety. *Special Issues on Maritime Safety and Operations, Journal of Ocean Engineering. Elsevier. 151: 379-389.*

1.6 Structure of this study

This study is organised as follows:

Chapter 2: Literature Review. The literature review positions the present study in relation to similar and related studies. I provide an overview of CSCW research on designing systems to support cooperative work in a variety of domains. Relevant studies on safety and CSCW research are also presented. Moreover, I discuss safety and human-centred design in the maritime domain. Based on the literature review, various methods of visualising empirical data are introduced, including artefacts, notes and photos.

Chapter 3: Analytical Framework. Actor-network theory and CSCW are introduced to analyse and translate the material gathered from a workspace on an offshore vessel. The concepts of awareness and ‘computational artefacts’ are presented in the ethnographic studies to work with systems developers for visualising the ethnographic outcomes.

Chapter 4: Empirical Settings. The study setting at sea is introduced, including the humans and non-humans in the workspace on a ship's bridge and their cooperative work in marine operations. The empirical setting for collaboration with systems developers in workshops at NTNU is also introduced.

Chapter 5: Methodology. This chapter describes ethnographic research: the methods used (i.e., interviews, participating observation, notes and photos), data analysis and ethical considerations.

Chapter 6: Findings. This chapter summarises the findings of the study, which are presented in the papers that form part of this study.

Chapter 7: The research endeavour. This chapter discusses my role in the present study and the generalisability of my work.

Chapter 8: Discussion. The findings are discussed, and the research questions are answered. The limitations of the study and reasons for them are also discussed.

Chapter 8: The contributions of the study are summarised, and areas for future research are recommended.

2 Literature review

This chapter provides an overview of previous research. Section 2.1 provides an overview of current CSCW studies, focusing on how cooperative work informs design. Section 2.2 reviews safety studies in CSCW research, as they have yielded diverse understandings of safety in cooperative systems. Section 2.3 presents an overview of current studies in the maritime sector, including consideration of the latest research concerning ships' bridges and human-centred vessel designs. Section 2.4 considers a large number of studies regarding the visualisation of empirical data. The chapter ends by summarising the contributions of this study and linking it to previous research.

The literature was searched by using keywords such as *CSCW*, *cooperative systems*, *cooperative work*, *visualisation*, *maritime*, *vessel*, *ship's bridge*, *simulator*, *safety*, *safe* and combinations thereof in digital libraries including ACM, IEEE Xplore, AIS, Springer Link, Elsevier and EUSSET.

2.1 CSCW research

The CSCW research focuses on cooperative work (Schmidt, 2011) among individuals and groups. It emphasises how tasks are coordinated and how artefacts and systems are organised to support cooperative work (Carstensen and Sørensen 1996). Other CSCW studies have been conducted in a range of research domains to inform design. The following studies have been reviewed to yield information regarding the core theme of 'collaborative design': organisational studies, studies of collaboration in different workplaces, studies of collaboration with systems-development teams, studies of collaboration among participants and workspace studies and design.

2.1.1 Organizational studies in CSCW

The first theme concerns organisational studies because users are not unrelated individuals but are organised into groups. Organizational studies inspired my work by reminding me that it is vital to acknowledge users in systems design. In particular, it is important to understand the relationships among people, technology and work settings.

For example, one well-known study, that of Bowers et al. (1995), focuses on the printing systems in an organisation. The authors examine how employees arrange their printing tasks by using computer systems in contrast to the traditional approach of the mechanical printing press. The authors describe how employees attempt to accommodate their orders with the system's orders, and they suggest that workflow systems can be seen as a technology for ordering and holding both the employees and the system accountable. Moreover, in a study of routine work in an integrated computing environment, Gasser (1986) reports that the key factor in such systems is the difference between the work routines used in computing and the users' primary work. Several studies have focused on analysing and articulating the use of computer systems and the relations between users and technology (Cohen et al., 2000; Hachani et al., 2013; Schmidt and Bannon 1992; Star and Strauss 1999; Strauss 1988).

A common feature of these studies is that they all analyse 'work practices'. These studies describe how a technology or system is used by investigating the relations between people and organisations. These studies argue that systems development should address the problems users have faced and the work contingencies they have adapted to shape the organisational relationships among users, developers and the main actors. In other words, systems development should address how a system is developed around these concerns (Bannon 1992). It is important to understand how marine operators work in reality rather than imagine how they are trained individually to work as a group. To my knowledge, no previous study has investigated practice-based CSCW in the maritime domain.

2.1.2 Collaboration with systems-development teams

Some studies focus on systems development. In the current maritime domain, cooperative actors are the development teams that design maritime simulators rather than the marine operators. However, marine operators are also cooperative actors, as are the operating systems and artefacts which are included in their workspaces on vessels. Thus, it is fruitful to engage with marine operators to better understand their everyday work.

For example, empirical software and agile systems development (Beyene et al., 2009; Grinter 2003; Procter et al., 2011) focuses on the re-composition of software fragments by different development teams. These studies discuss the importance of collaborative relationships and organisational policies applied to collaborative work in systems-development teams. However, they focus on the different functions of the parts of a system and on assembling the parts designed by development teams in different locations. These studies all examine the collaborative approach of development teams to a wide range of factors: development requirements, project budgets, schedules and distributed locations.

Researchers have also attempted to develop collaborative systems through collaborative-systems architecture: e.g., by tailoring cooperative, multi-user displays in air-traffic control in the UK (Bentley et al., 1992) or by developing an artefact-based collaboration system to support individual work and distributed groups (Jeffay et al., 1992). The goal of both studies is to describe the process of collaboration among the ethnographers, cognitive psychologists, anthropologists, and computer scientists who conducted these studies in collaborative groups. However, these scholars focused on individuals to understand distributed computing for generating requirement specifications. The above-mentioned studies contribute to our understanding CSCW technologies as software platforms which can be used to support cooperative work.

I learned from my study that maritime safety and operations require the collaboration of people who have different competencies in marine operations, such as marine operators. Thus, the cooperation of different marine operators in a shared technological platform might be fruitful in creating a better maritime simulator. In my understanding, these contributions may help to reform simulator design in the maritime domain. However, such collaboration is a key challenge for research in the CSCW field, as is indicated by Carstensen and Schmidt (2003, p. 618):

> As indicated research and systems design work within CSCW are confronted with a number of hard challenges. First of all, a much better and well-conceptualised understanding of cooperative work and its complexity is required. Collaboration actors monitor and cope with immense complex structures in their field of work. However, to be able to provide systems for communicating, motioning, articulating activities, etc. with respect to the field of work we have to understand how fieldwork is conceptualised and how the typifications applied evolve over time and during work.

According to Carstensen and Schmidt (2003), the design of a better cooperative system must take cooperative actors into account. Thus, collaboration with systems-development teams might help reform the design process for systems developers in the maritime domain by providing a better understanding of cooperative actors (i.e., marine operators). It is therefore important to investigate the operators' cooperative work in a way which considers the design of maritime simulators.

2.1.3 Collaboration in different workplaces

Cooperative work in marine operations occurs in different places on a vessel. Thus, it is important to know how to support collaboration in different work spaces. I want to identify cooperative work and the reasons for its performance (Sharp et al., 2016). These identifications are important if we are to strengthen our investigations of the social and human aspects of designing maritime simulators.

Some previous studies have focused on ways in which the cooperative work of users in workplaces has informed design (Bansler et al., 2013): e.g., in controlling the London underground (Heath and Luff, 1991), in supporting collaborative work with ConversationBuilder[8] (Kaplan et al., 1992) and in developing health-care-information systems (Heath et al., 2002). These studies pay particular attention to how users work cooperatively with artefacts and computer systems. The findings show that individuals create awareness regarding the work practices of others to achieve successful collaboration (Kaplan et al., 1992). Moreover, Teneberg et al. (2016) argue that the tightly coupled work of two individuals in a group can also create awareness of other groups during the cooperation. Thus, it is important to consider how awareness in a group informs the design of computational systems so as to better support cooperative work.

These studies inspired my decision to use the awareness concept, as it is important to know how marine operators work together. Based on this choice, I focused on how operators create awareness and cooperate successfully in the workspace at sea. Through the concept of awareness, I began to consider CSCW as a flat organisation

[8] ConversationBuilder is a web-based protocol that can actively support individual users' trade-offs during their collaboration.

(Sørgaard 1987; Michael 2017) rather than as a process of predefining a function that could support cooperative work.

2.1.4 Collaboration of the participants

In an overview of the relations among people, technology, and work settings and between collaborative development teams and collaborative users in different places, it is vital to know how users cooperate so as to make sense of design suggestions.

Previous studies have focused on the collaboration of participants. For example, researchers conducted a study to determine how health work is achieved collaboratively and practically (Bjørn and Østerlund 2014; Bjørn and Rødje 2008; Fitzpatrick and Ellingsen 2013). These researchers analysed social interactions, organisational work and the procedures used by nurses and doctors—including their collective tasks, artefacts and activities. They used an ethnographic approach (Randall et al., 2007) to focus on the cooperation of researchers and users and to analyse systems use so as to inform systems development in a grounded-design approach (Betz and Wulf 2018; Stevens et al., 2018). Researchers who are mainly interested in end-user development through participatory design (Betz and Wulf 2018; Stevens et al., 2018) and systems developers are expected to understand these analytical outcomes in the design process. Another example is provided by Hughes et al. (1992), who explore the issues involved in applying the findings of ethnographic studies of work in the context of systems development. They argue that ethnographers can form a bridge between users and designers. In another article (Twidale et al., 1993), computer scientists examined the internal collaboration of computer scientists. These computer scientists showed that designers' notepads are used to support cooperative designs in a software-design project (Twidale et al., 1993).

Although CSCW research has shown that an ethnographic approach can bridge users and designers, systems developers (Baxter and Sommerville 2011; Lenberg et al., 2015; Twidale et al., 1993) follow IEEE international standards and focus on the formal and non-formal functionalities of systems during the design process (IEEE 2011). Cooperative work is not considered to be a non-functional requirement for systems development; nor is it supported by functionalities in developed systems (Cabitza et al., 2016). However, some researchers (Sharp et al., 2016) in the software-engineering field argue that an ethnographic approach can provide an opportunity to identify sustainable improvement in software practices by analysing what is done and why it is done a particular way. Hence, ethnographic study can help designers achieve useful and useable systems (Sharp et al., 2016). Thus, I conducted field work to consider cooperative work of marine operators into account to analyse and to use the ethnographic outcomes for working with systems developers (Khovanskaya et al., 2017). Examples include considering how awareness is established among maritime operators in cooperative work and how the analysis of awareness can be reflected in a design.

2.1.5 Workspace studies and design

Sharp et al. (2016) argue that ethnographic study can improve systems design by enabling systems developers to obtain the same view of the workspace as ethnographers (Christensen 2013). In their discussion of how ethnographic studies could be used in software engineering, Sharp et al. (2016, p. 787) encourage software engineers to consider being ethnographers:

> Ethnography provides an analytical focus that allows the capture of not only what is done in practice, but also why things are done the way they are. This provide a valuable opportunity in the context of empirical software engineering, because capturing both the "what" and the "why" of practice provides a solid foundation of identifying sustainable improvements.

Hence, ethnographic studies could inform and improve the design process. However, the implementation of a system for CSCW presents a challenge (Raval and Dourish 2016). This is because qualitative studies might not convince people in the maritime field. The descriptive-oriented simulator making of ethnographers and designers might not satisfy systems developers in their technical work (maritime simulator systems developers meeting notes, April 15, 2014).

Because Sharp et al.'s recommendation is new to the engineering field, no detailed information about how engineers could use ethnography to design systems has been documented. In workplace studies, researchers phrase their insights to enable others to obtain a view of the workplace (Dourish 2006; Christensen 2013). For example, Rooksby (2013) and Goulden et al. (2017) claim that researchers who provide social insights into the use of technology should phrase their conclusions in the native language of those who will use them in their work contexts.

This finding is interesting. I believe it is crucial to bridging the distance between marine operators and maritime systems developers. If we see marine operators' work as a social activity and simulator design as a technical action, it is important to design a maritime simulator without distinguishing the two approaches. Instead, to bridge the distance, it is vital to explore a way to combine them in a social-technical approach by including the cooperative work of marine operators in the design processes. However, such work is difficult in the maritime domain, where it is believed that the social aspects of designing maritime simulators could be improved outside the technical actions through evaluation.

2.2 Safety in CSCW research

There are various understandings of *safety* in the field of informatics.[9] As Wittgenstein (2009, p. 159[e*]) states, 'Concepts lead us to make investigations. They are the expression of our interest and direct our interest'. Some researchers in the informatics field engage in CSCW research with different interests, as they are investigating safety differently, such as studies of safety as an ethical or political issue or other kind of issue (e.g., privacy, violence, integrity, etc.; see Section 2.2.1) – and train reliable organisations (e.g., human organisations; see Section 2.2.2) to achieve attributes of safety. In addition, safety is considered in software applications and models for CSCW applications (see Section 2.2.3).

2.2.1 Safety as an ethical, political and miscellaneous issue in CSCW studies

First, I introduce safety as an ethical issue, as it is considered in the literature on CSCW research. In most cases, CSCW researchers consider safety to result from interactions between users and technology based on ethical issues. For example,

[9] The informatics field focuses on theory and design oriented study of information technology use, and concentrates artificial science with the intertwined complex of people and information technology as its subject matter (Dahlbom 1996).
*e means the page in the book is an English translation. Hence, the page number is marked as p.159[e].

researchers who publish in ACM CSCW proceedings report that, due to safety concerns caused by online privacy policies, users must face struggles between the secular value of social media and their own Islamic culture (Abokhodair and Vieweg 2016). In addition, due to incomplete privacy policies, teenagers may easily discover violent, sexual and obscene content online (Yarosh et al., 2016). Moreover, in the business world, LinkedIn's users have to be concerned with safety, as they never know who is viewing their profile or for what purpose (Hoyle et al., 2017).

People in LGBTQ groups have unwillingly become visible in some local communities and have accordingly become concerned for their safety (Hardy and Lindtner 2017) and uncomfortable with the possibility being recognised in public. Researchers also report dangerous online dating among LGBTQ people on Craigslist[10] and Grindr[11] (Zytko et al., 2015). Users can also encounter intimidation and online harassment when they use an application or system; this is especially true for women (Vitak et al., 2017) and children (Ghosh et al., 2018).

Thus, to create a 'safe' virtual world, some researchers, such as Ringland et al. (2015), suggest demonstrating the online spaces virtually. Thus, Traunmueller et al. (2016) report that online space can be used as a virtual world in which to investigate how people perceive safety when encountering other people on the streets and buildings in unfamiliar urban areas.

Moreover, researchers study safety concerns caused by the loss of anonymity that occurs when editing *Wikipedia* (Forte et al., 2017). According to Wong and Neustaedter (2017), CSCW researchers may also have to focus on how to investigate technology to support on-board flight attendants and to promote safety and a high level of customer service. Researchers state that the immaterial factors of labour, political economy (Raval and Dourish 2016) and general ethical considerations (Zytko et al., 2015) might also matter for CSCW researchers.

For mobile apps, researchers also investigate the fact that mobile applications can cause safety concerns due to a lack of collaboration between users and application

[10] Graigslist is an American classified advertisements webpage with multiple features such as jobs, housing, for sale, items wanted, services, community, gigs, and discussion forums (Wikipedia 2018a).
[11] Grindr is a geosocial networking mobile app for helping gay and bisexual men meet other men in their area (Wikipedia 2018b).

developers, as the developers may dismiss the problems which cause safety concerns in technology use. For example, communication between canines and police officers can be weakened by noisy locations, long distances and crowed spaces. For these reasons, the connection between canines and officers must face low speed and ineffective communication in explosive detection searches (Alcaidinho et al., 2017). In a family communication study, Wisniewski et al. (2017a, b) suggest that, to solve the problem of poor communication between parents and their children, family systems should be considered when children are unwilling to share their safety concerns when using online browsing.

In the healthcare domain, Pine and Mazmanian (2014) draw on the theoretical lens of new institutionalism to outline how institutional understanding can increase safety and accountability and thereby shape doctors' experiences of electronic medical-records systems (EMRs). They argue that safety concerns in EMRs are negative—particularly when work is coordinated inaccurately among doctors and nurses (Pine and Mazmanian 2014). Bossen and Jensen (2014) report similar results, indicating that, to facilitate patient safety, it is fruitful for doctors to achieve an overview of patient cases. In this manner, paper-based records can be used to inform EMR design. In addition, Ozcan et al. (2017) studied fast responses to nearby cardiac arrests. They explain how to build targeted-responder models to explore barriers to the commitment and performance of a responder.

It is important to note that the above-mentioned studies are concerned with safety as with ethical, political and other miscellaneous issues. Thus, researchers are keen to inform developers how to improve systems to avoid safety issues. I am also concerned with safety issues. However, I consider that safety is coupled with cooperative work among marine operators over the duration of their cooperation. Previous research indicates that my work may deviate from safety studies in CSCW and add to the literature which considers safety concerns that arise in the process of cooperative work. However, in addition the above-mentioned safety studies in CSCW research, there is another kind of study that is close to my study: the study of highly reliable organisations. Though the present study also deviates from it, I still present such studies in the next section to distinguish them.

2.2.2 Safety in highly reliable organisations

Some studies consider how to deal with organisational complexity and culture in highly reliable organisations (Perrow 1985; Weick 1987; Harper et al., 1991; LaPorte and Consolini 1991) so as to achieve safe work environments with respect to *high-risk technologies*. These researchers are interested in investigating how a highly reliable human organisation can overcome problematic issues in a work organisation, such as those which are encountered in air-traffic control (Bentley et al., 1995; Harper et al., 1991; Hughes et al., 1992). In aircraft-carrier-operations studies (Rochlin et al., 1987; LaPorte and Consolini 1991), researchers claim that the U.S. navy is a highly reliable organisation in terms of safety-critical technology and safety concerns caused by the complexity of its organisational structure. The intention of these studies is to argue that the division of labour can *reduce* safety concerns for humans who are concerned with their work safety and efficiency. Such considerations aim to turn the concern for safety into a focus on social-network analysis as an aid to overcoming technology failures.

As Weick (1987, p. 112) argues, 'accidents occur because the humans who operate and manage complex systems are themselves not sufficiently complex to sense and anticipate the problems generated by those systems. Thus, it is normal that a safety-critical technology itself may have errors, such as design problems (Perrow 1985). However, to work in high-risk technologies with fewer safety issues, researchers suggest that we need to train humans who work with high-risk technologies to work as highly reliable teams (Perrow 1985; Rochlin et al., 1987; Weick 1987; LaPorte and Consolini 1991). The key argument here, which is like the argument proposed by Harper et al. (1991, p. 230) in their study on air traffic control, is as follows:

> The intersection of the division of labour around sector suites is focussed on the flight strips. By noting down on the strips any relevant details, all members of the team are able to see 'at a glance' the state of the sector, and what their responsibilities are or are likely to be … Our point, though, is that this [the capacity to decode 'at a glance'] is not just a matter of perception, cognition and ergonomics, but concerns the servicing of the relations between participants in a working division of labour.

The division of labour is used to minimise distractions for the participants so they can work safely. Weick (1987) believes that the technology is introduced. He argues that if people do not perform tasks in the way technology tells them, then safety problems can arise along with changes in the dynamic of human organisation (Weick 1987).

Thus, the argument is that safety concerns should be avoided through trial-and-error processes at work via various organisational behaviours such as team organisation, operations scheduling and mission planning (LaPorte and Consolini 1991). However, Bannon (1992) adds that, though people may be given a technology that they are not familiar with, they nevertheless act as professionals in their work settings. They are also designers of the technology, as they have the ability to suggest improvements until the technology becomes truly useful. Thus, consistent with Bannon (1992), I disagree with Weick about training only highly reliable human organisation to handle high-risk technologies. Most importantly, I advocate taking the work practices of users into account so as to shed light on the design of technology.

2.2.3 Software applications and models as safety attributes for CSCW applications

There are also a few studies which address the development of safety attributes in software applications and models. For example, some researchers use a mathematical lens to represent requirements for designing CSCW applications (Foley and Jacob 1995; Lu et al., 2010). Others make goal-oriented models to represent safety requirements (Teruel et al., 2013) or to identify distinct requirements regarding availability, integrity, confidentiality and access leakage for CSCW applications (Ahmed and Tripathi 2010). All such studies rely more heavily on technical approaches than on social aspects, and none of them considers social activities in systems design. Though I do not seek technical solutions in the design of cooperative systems, it is interesting to note that representing requirement specifications to developers may help me to engage with maritime systems developers in my work on design simulators. Now it is necessary to review safety and human-centred design in consideration of the difference between my efforts and other studies in the maritime domain.

2.3 Safety and Human-centred Design in Maritime Studies

Although *safety* is understood in various ways in both CSCW and the maritime domain, its meaning is very straightforward in most maritime studies, as it concerns safety issues which are caused by the technical failures of systems (Johnson 2004;

Pan and Hildre 2018; Park et al., 2004). Safety issues arise from the application of engineering and management principles, criteria and techniques so as to optimise risks within the constraints of operational effectiveness, time and cost throughout all phases of a system's life cycle (Akeel and Bell 2013). The safety of the system is addressed by testing computer applications to improve them (Sadeghi et al., 2015) and by determining how systems can be used without risk (Rausand and Utne 2009). The safety of users is affected by the safety of the system (Akeel and Bell 2013), and it is related to the safety of human engagement with technology. Thus, in this section, it is necessary to describe how design deals with safety in the maritime domain. I accordingly discuss ways in which a social-technical approach might contribute new insights which can inform the design of a maritime simulator.

According to the Marine Technology Programme with Specialisation in Marine-system Design offered at NTNU (2016), systems design for marine operations is concerned mainly with the development of technical systems which are comprised of multiple elements that meet the requirements of end users (NTNU 2016). Researchers focus on using mathematical and physical methods to enhance the safety and reliability of ships in marine operations (Backalov et al., 2016) and to estimate fuel consumption and operating costs (Carlton 2007; Molland 2011). Researchers also discuss hydrostatics to predict the stability of a ship by computing its characteristics (Biran and Pulido 2013). In the maritime domain, systems developers apply information and communication technologies (ICT) to computer-aided design (CAD), technical analyses, simulation and risk-and-safety analysis (NTNU 2016). Maritime simulators are developed by using this technical approach (Olaiya 2002; *Inspectie Leefomgeving en Transport* 2015; Kongsberg 2017).

2.3.1 Studies on ship's bridge

Given the overall idea of designing simulators in the maritime domain, I pay special attention to the operations on a ship's bridge. I want to learn how studies are conducted on a ship's bridge. However, only a few studies in the maritime domain have focused on the design of offshore operating systems and the actual physical work settings on a ship's bridge. These studies have focused on how scenario-based evaluations can be used to improve the design of a ship's bridge. For example, consider an experimental assessment of a ship's bridge which is focused on a usability evaluation to study the crew's interaction with physical control tools (Papachristos et al., 2012) by investigating human-machine interactions (Lützhöft 2004; Olsson and Jansson 2006). Though these studies were strongly linked to the investigation of human-factors issues, researchers have found that safety may also be evaluated in a group operation (Harvey and Stanton 2014). Only one study reports that fieldwork can be utilised to improve the physical layout of a ship's bridge (Lurås, 2016). Though fieldwork is useful for improving the design of a ship's bridge, dealing with the relations between usability and design may promote the safe cooperation of the marine operators on a ship's bridge.

As discussed in the previous sections of this chapter, safe cooperation goes beyond technical issues in computer systems. It is not fruitful to evaluate individual work practices, as the nature of cooperation is complex than individual collections (Pan et al., 2015; Pan et al., 2014). Evaluations can guarantee only that an operator can finish a given task; they cannot determine how he or she will perform in a practical situation (Pan et al., 2015) or at an organisational level (Vederhus and Pan 2016). Randall et al. (2007) argue that not all work is task-oriented. Therefore, it is important that we determine whether technologies which are 'deemed to be useful may depend on a set of moral and symbolic perspectives' (Randall et al., 2007, p. 268). Hence, evaluation is used as a means to improve the design of maritime technologies, but evaluations are less convincing, as this method concentrates on the tasks performed in a context and the time taken to complete them. Hence, it is useful to add a new approach to design using the social-technical approach by focusing on how the safe cooperation of marine operators is accomplished. This approach allows researchers to show systems developers the importance of work practices in real situations.

2.3.2 Human-centred Studies on marine design

There are also some studies in the maritime domain which, in recent years, have introduced human-centred design to the design process[12]. For example, Lundh and Rydstedt (2016) determine how engine-room staff members perceive the major technical and organizational changes in the shipping industry and how their

[12] Researchers at Chalmers University of Technology particularly contribute to this field.

perceptions affect job demands and skill resources. Through individual and focus-group interviews with engine crews, the researchers conclude that engine crews feel that their work situations are resources for elaborating the psychosocial work environment. The major changes in the working conditions on board can be achieved through interview analysis. Lundh and Rydstedt claim that, due to changes in work content, the organisation of the crew and the workplace cause unsafe feelings. Though it is a human-factor study with a focus on the physical layout of the engine room, I would argue that it is a good example to hear the voices of the crew when design-relevant research is conducted.

In addition, Mallam et al. (2017a, 2017b) state that, to design a safe ship, the physical layout of a ship's on-board work environment must be in focus. The improper design of such a layout may introduce unsafe work procedures and work practices. Thus, the authors designed an 'ergonomic ship-evaluation tool' for introducing participatory design (PD) as a way to design a ship. This tool can create an environment that will help naval architects, crews and ergonomists work together to develop human-centred design solutions for physical work environments. Depending on the design approach, the crews will have an impact on the design process. The authors are interested in an environment for designing ships which can be used to gain insight into what crews demand rather than what their work practices are in reality. The work practices of crews in reality are less important to the naval designer and ergonomist in creating a digital platform. The authors focus mainly on the crew's opinion of the lab-based design scenario. Furthermore, regarding interface design, de Vries et al. (2017) propose that human-centred design can be successfully achieved within the context of ship design by using case studies. They create a conceptual model for two offshore wind-turbine installation vessels and use design as a mediating tool between ship designers, users and human-factor specialists to utilize the model for integrating a dynamic positioning system. The authors conclude that their new design is good for both the ship and the people who own the ship in their daily operations. Costa et al. (2017) use activity theory as a theoretical lens through which to investigate how human-centred design theory can be practiced in a ship-design firm. The work practices of users (marine navigators) are not included, as the authors focus only on how designers, human-factor specialists, ergonomists and consultants can design a useful interface for navigators to use.

There are also studies in the maritime domain which focus mainly on the development of end-users. Praetorius et al. (2015) argue that, to make design changes for safety support in vessel-traffic service (VTS), it is important to properly analyse and understand the everyday operations of VTS operators. Using a functional-resonance-analysis method (FRAM), the authors claim that—by determining how the VTS system maintains control, and by knowing how resilience-engineering abilities are used—it is possible to identify and discuss system functions so as to request solutions from human-factors specialists. We can even estimate how alternations to technology and organisation will affect overall VTS performance. Moreover, Petersen et al. (2015) argue that maritime technology is a multidisciplinary field. They suggest that an ontological, epistemological and methodological grounding of systems design could benefit both fields in systems design and human factors. With a focus on the work practices of systems developers, the authors call for more effort to explore and improve our understanding of systems design towards achieving the fruitful interaction of human-factors specialists and systems developers in the maritime domain. A similar study in the maritime domain can also be found in the usability literature—as in Man et al. (2017), who investigate the distance between users and designers. The authors aim to address human-factors concerns for future IT design and development in the maritime domain.

The above-mentioned studies in the maritime domain are merits, as they position humans in the centre when designing ships. However, it is necessary to go on to engage the work practices of marine operators in the design process of shaping the non-physical workspace, as in operational systems. Thus, the present study adds to the literature which shows how operational systems are shaped and reshaped in the design process, using the safe, cooperative work of marine operators as resources. To my knowledge, this method is new to the maritime domain.

2.4 The ways of visualizing empirical data

2.4.1 Studies on visualization

Some researchers communicate their insights through papers, photos and drawings for the purpose of helping engineers broaden their designs (Bucciarelli 1988; Hine 2008; Vinck 2003; Henderson 1999). These studies are relevant to the present study, which employs visualisation to communicate the findings of ethnographic studies conducted at sea to systems developers. For example, Bucciarelli (1988) argues that, though ethnographers use storytelling, they can also employ the visual diagrams and sketches design engineers use in the production of automobiles, kitchen appliances and computers. Moreover, ethnographers who understand engineering as a social process can utilise visual representation to visualise what they observe (Suchman 2001), thus inspiring professionals to think more broadly about their work (Vinck 2003; Hine 2008). Moreover, Henderson (1999) describes how engineers integrate pencil and paper with automatic approaches. She notes that extensive on-site studies have helped overcome the limitations of traditional, computer-aided design (CAD) and have emphasized the many ways in which visual cognition can be expressed. This study finds that engineers who dislike CAD have developed the concept of 'meta-indexicality'. A visual representation can be used interactively to combine many diverse levels of knowledge, thereby serving as a meeting ground (and sometimes as a battleground) for many types of workers. This explains why visual tools such as pencils, papers and drawings are so powerful (Henderson 1999; Petroski 1996; Petroski 1992).

Similarly, Ewenstein and Whyte (2007) observe that researchers use artefacts such as language or symbols to develop a platform on which to exchange ideas with architectural researchers and traffic engineers. They argue that visual representations of fieldwork by researchers can help illuminate system design in the real world. For example, Checkland and Poulter (2010) argue that the real world is complex and messy primarily because human beings inhabit it. To deal with such complexity, they propose a method called soft-system methodology. By depicting human activity in rich pictures, they show the logical process which needs to be followed to achieve a look of systems. However, these studies aim at analysing cooperative work in the organisational context rather than in the use of technology (Randall et al., 2007). Importantly, though researchers have shown the possibility of expressing insights into systems design, systems developers are concerned with the synthesis of technical solutions to discuss social and human activity in the design process, and they require specific information about technology (Randall et al., 2007).

Therefore, though storytelling, visualising social vision and modelling human activity are powerful tools, the challenge in this study is to shorten the distance between the outcomes of ethnographers and the solutions of systems developers. It is urgent that I find a way to articulate my expertise to someone who is not an expert in my field. Because this study is interdisciplinary (CSCW and marine engineering), I must solve the issue of creating a common platform (Forsythe 1999) on which systems developers and ethnographers can synthesise social and technical solutions. Previous studies show that, through ethnographic fieldwork, there is a chance for ethnographers to communicate the phenomenon in that context to others (Moeran 2009).

However, in previous studies of visualisation, it is noticeable that researchers have focused on the roles and activities of humans rather than on illustrating how humans and non-humans are connected to accomplish tasks. In addition, if we take unified modelling language (UML) (Matha 2008) as an example in systems design, UML focuses mainly on how communications and information are exchanged technically. It is less about how humans are involved in the activities of information exchange (Guiochet et al., 2003). For example, UML indicates how information and communication flows between technical devices (Reichwein 2011); less interesting is how cooperative work is accomplished through the cooperative systems and how humans are involved in this process. Thus, I believe that a combination of UML and ANT will help demonstrate how communication and information exchanges occur in a specific work situation and who is involved and how this event is achieved. Therefore, ANT as a means of visualisation is necessary because ANT treats humans and objects as equivalent actors in the construction of systems (Alexander and Silvis 2014). Hence, in this study, the ethnographic studies are conducted first to study the prior work done in designing maritime workspaces on ships' bridges, then to translate the outcomes of the study to shed light on the changing of maritime simulators. Thus, my focus on visualisation provides a practical way for including ethnographic outcomes in synthesised solutions that focus on both human activities and technology.

2.4.2 Theoretical methods in a visualisation toolkit for ANT studies

In this section, I introduce studies of ANT[13] in the informatics field to make empirical findings visible in design (Banks 2007; Storni 2012, 2015; Payne 2017). This prior research is remarkably useful for my study because it allows me to understand how marine operators work together. It also helps me understand how marine operators and maritime technologies are connected in workspaces for different tasks. This understanding could help to determine the relations of different technologies in the workspace and how they are linked by other technologies outside the workspace during marine operations. For example, scholars use ANT to analyse how a new technology (e.g., the camera) participates in the process and to introduce changes into pre-established work practices (Aanestad 2003). Thus, technology, tools and work practice can be viewed as an actor network (Berg 1997), the configuration of which changes continuously (Callon 1986a; Aanestad 2003). An example was presented in a study of water-pumping devices in Zimbabwe wherein researchers transformed what it means to be an actor (de Laet and Mol 2000). Similar studies have shown that designing a system should be based upon a better understanding of different actors and their relations in different actor networks (Alexander and Silvis 2014; Payne 2017).

Furthermore, in understanding the actor network, it is also necessary to consider how ANT can help us understand work practices by translating different actors' interests in an artefact. For example, Kimnbull (2009) shows that, to find meaning in how people use artefacts, it is necessary to translate[14] how artefacts are used and how users regulate their interest during the work. Similar work was conducted in two projects for online communities on DotPotis and the Smart ID card (Heimeier 2013). These studies focus on how an object can be translated against the balanced interests of different people. The researchers argue that the translation can help model online communities so that systems designers[15] can understand the medium in which their users approach these systems (artefacts). However, according to Randall et al. (2007, pp. 224–225),

[13] ANT and its concepts will be introduced in Chapter 3.
[14] The concept of translation will be introduced in Chapter 3.
[15] The systems designers in this study are IS professionals. They are not designers in the maritime domain. Systems developers design engineering projects in the maritime domain.

> A focus on the spatial arrangement of things, on their ecological patterning has the merit, or at least the distinctive quality, of recognising that different artefacts can have different qualities dependent upon the way other artefacts are used in that place. This approach leads one way from the over-simple assumption that the medium of an artefact has universal properties that apply in all places and all times, rather than having properties whose salience is melded by the affordances of other artefacts and the process(es) of which the artefacts in question are a part. It is all too easy to slip into that manner of thinking that holds that there might be an observable and simple essence (or a model) underneath it all.

Spatial patterning can be understood as consisting of text and rich diagrams (Salavati 2016). However, ANT-analysis diagrams (AADs) (Payne 2017) are aimed at visualising activity to interpret narratives, which helps researchers clarify their thinking through the use of visual support diagrams. These previous studies are non-design-oriented ethnographies. Of course, researchers can point out artefacts that are important to them. However, such artefacts can easily be overlooked in cooperative tasks across the division of labour because of the lack of expertise (Randall et al., 2007, p. 225). Therefore, the researcher must create a 'mechanism of interaction' (Schmidt et al., 1993) with which to facilitate a certain degree of flexibility to display the actors in an ANT for the members of the cooperation team.

Indeed, previous research shows that ANT has been used for visualising activities such as AADs (Payne 2017) and for finding meaning in artefacts (Kimnbull 2009, Heimeier 2013). This has been an inspiration for the present study. However, the use of ANT for highlighting actors in a visualised diagram to help systems developers respond to the same information as the researcher so as to describe and carry out a design is, to my knowledge, not found in the literature. Thus, in my work, I use ANT to 'dialogue' (Randall, 2018) with systems developers to better design simulators.

2.5 **Summary**

The literature review presented in this chapter introduces CSCW studies, safety studies in the CSCW field and the design of maritime technologies with a safety focus. Though ethnography is used to investigate cooperative work, people and work settings in most CSCW studies, the use of ethnographic outcomes to investigate safe cooperation and inform the design of cooperative systems is overlooked. Moreover, though safety is considered in the CSCW field, they are failed to address safety in cooperation. Furthermore, though safety is a core element in the maritime domain, current evaluations of technology do not indicate how to improve the cooperative work of marine operators from a systems-design perspective. The review revealed a distance in the literature regarding how ethnographic outcomes and analyses can be visualised so that systems developers can use such resources in designing maritime simulators that consider the safe cooperation of marine operators.

Hence, my study aims to help systems design bridge the distance in the extant literature. By accessing the field and conducting ethnographic studies, new methodologies for conveying how maritime simulators can be designed are developed with regard to the safe cooperation of groups at sea. Thus, the next chapter describes how ANT and the concepts of CSCW are used to facilitate the analysis of my ethnographic studies. I also discuss how the analytical results of ethnographic studies can be represented visually so as to help systems developers design maritime simulators.

3 Analytical concepts

Section 3.1 introduces ANT and then defines the concepts of ‘translation’, ‘actor’, and ‘actor network’. Section 3.2 introduces the concepts of awareness and ‘computational artefact’ which underpin the analysis. Section 3.3 discusses the use of CSCW and ANT in the present study. Section 3.4 concludes by stating that these analytical concepts are useful in forming an approach that can be used to determine how a safe cooperative work is completed by actors who do not have expertise in ethnography.

3.1 Actor-network theory

I briefly introduce ANT and the concepts that are related to my study. The marine operators in the workspace on a ship’s bridge do not work alone. The computer technologies within the workspace are included in the cooperation with other marine operators and technologies outside the ship’s bridge. Actor-network theory thus provides a method for describing how, where, and to what extent technology influences human behaviour (Monteiro 2000). Moreover, ANT helps to examine relations between the marine operators and the computer technologies within the workspaces on the ship’s bridge and in other places on the ship during marine operations.

Law (2009, p. 141) defined ANT as follows:

> Actor network theory is a disparate family of material-semiotic tools, sensibilities and methods of analysis that treat everything in the social and natural worlds as a continuously generated effect of the webs of relations within which they are located. It assumes that nothing has reality or form outside the enactment of those relations. Its studies explore and characterise the webs and the practices that carry them. Like other material-semiotic approaches, the actor-network approach thus describes the enactment of materially and discursively heterogeneous relations that produce and reshuffle all kinds of actors including objects, subjects, human beings, machines, animals, ‘nature’, ideas, organisations, inequalities, scale and sizes, and geographical arrangements.

Thus, ANT provides a framework and a systematic means for considering factors in social and natural worlds (Latour 2005b). Actor-network theory does not explain why the network exists; it is instead concerned with the organisation of actor networks, how they form and how they can fall apart (Smith et al., 2017). Actor-network theory is not a unified conceptual system, and its trade-offs are extensive (Aanestad 2003). The following paragraphs provide a brief overview of the aspects of ANT that are related to my study.

Actor-network theory uses the so-called generalised-symmetry principle, according to which human and non-human things should be incorporated into the same conceptual network and allocated the same amount of agency (Callon 1986a). An actor is that which accomplishes or undergoes an act. When we act, we always interact with others. As Law (1992) has stated, ‘Interaction is all that there is’. During interactions, we change the other actors. At the same time, however, the other actors are changing us (Dankert 2017). I also follow this principle and deal with the cooperation between humans and non-humans because this is essential to a successful marine operation. That is, a successful marine operation has to do both with how humans work together and, most importantly, with how humans, machines, systems and other types of artefacts work together. Consistent with this, the actor concept is important to the present study. In addition, ANT considers that both human beings and non-human entities constantly influence us. Hence, the specific mechanisms at work can be described in detail while allowing the actor to be treated fairly (Latour 2005a).

Regarding the actor network, Callon describes how actor-worlds (speaking metaphorically) function and how relations between the different actors are organised and structured (Callon 1986a). Callon (1986a, p. 28) explains as follows:

> It is clear that an actor-world may be more, or less, extended, heterogeneous and complex. How shall we describe this range of possibilities and the translations that occur between them? To answer this question, we introduce the notion of actor-network. This concept allows us to describe the dynamics and internal structure of actor worlds.

Given this explanation, we can understand that an actor network is a heterogeneous network of human and non-human actors. The relationships between them are important (Callon 1986a, 1991). Thus, in an actor network, no priority is given to either humans or non-humans. Hence, the unit of analysis in ANT is not an individual human or a non-human actor; instead, it is the relations between them (Aanestad 2003). Moreover, to understand the actor network and how it is established, Law (1999, p. 5) states that ANT is ‘intentionally oxymoronic, a tension which lies between the ‘centred’ actor and the ‘de-centred’ network. There is tension because the actors have their own interests, which may create chaos, and because the translation of the stability of this chaos has played a vital role. Thus, to understand an actor network involves describing how actors’ interests are translated in an actor network. Translation helps an actor interpret the ideas of others and match them with his or her own ideas. Interests, stability and social order are continually negotiated ‘as a social process of aligning interests’ (Hanseth and Monteiro 2015). As defined by Callon (1999, p. 223), translation is a process that requires actors to remember the following:

> To translate is to displace… and to express in one’s own language what others say and want, why they act in the way they do and how they associate with each other: it is to establish oneself as a spokesman.

The process of translation consists of four moments. Here, I briefly introduce them. I do not use these moments in my study, but I introduce them here nonetheless because they are important to the understanding of translation: *problematisation*, *interessement*, *enrolment* and *mobilisation* (Callon 1986a). In *problematisation*, the most important actors define their interests so the other actors can associate their own interests with those of the most important actors. In *interessement*, actors who have the same interests in the same actor network are bonded. *Enrolment* is the outcome of *problematisation* and *interessement*, in which more actors are attached whose interests must be defined and synchronised. In *mobilisation*, the most important actors assume the role of spokesperson for the passive network actors and seek to mobilise them to act. Hence, according to ANT, when an actor network is established as the result of a social process, a certain degree of alignment of interests[16] is achieved (Callon 1991). The solution is constituted by an aligned actor network that includes humans and non-humans. An actor network is heterogeneous (Labour 1996), which means that there is an open-ended array of actors that need to define a problem and a set of relevant actors who define the problem and a programme for dealing with it. In addition, the primary actors recruit other actors to assume roles in the network. The roles are defined, and the actors formally accept and take on these roles to seek action.

[16] Symmetry in early ANT was criticized as ‘technological determinism’ (Star 1988). However, ANT proponents positioned it between social determinism and technological determinism (Jones 1998). This study does not include this debate about ANT.

Thus, there is no strict, top-down control over such a collection of actors. In contrast, ANT leans toward a bottom-up impression (Cordella and Shaikh 2003). Consistent with above discussion, actor network is also an important concept in the present study. An actor network can accordingly help us understand how, who, when and why an actor plays a role in a network. Significantly, this tells me that, when addressing cooperative work, the relationships between actors in the network are vital. In this manner, I could investigate cooperation to focus on several actors and their relationships in marine operations rather than on a sole contributor to a marine operation. Importantly, the cooperation between actors in marine operations is also dynamic. Therefore, when an actor network becomes dynamic, ANT has the power to explain such dynamics. Law (1992) proposes that the act of lovemaking is the only possible purely social relation, though other factors also play a role in it.

The ANT assumes that there are no purely human or non-human networks. Each network contain elements of both and is heterogeneous and social-technical (Latour 1999; Hanseth et al., 2004). To ease the confusion surrounding the unit of analysis, Latour (1990) advises us to think about nodes—which have as many dimensions as they have connections—instead of thinking about surfaces and the dimensions of these surfaces. For instance, the foundational ANT studies focus on the breakdowns in which networks become visible. Thus, ANT is concerned with the links that hold and the links that do not hold (Murdoch 1998) in network dynamics. The study of network dynamics assumes that actors have different and often incompatible interests. The social order or the stability of a network depends on its alignment (Aanestad 2003).

I also discuss actors and the actor network. However, I use these concepts in relation to the bottom-up idea because ANT rejects the idea that there is a purely social actor or a purely social relation (Latour 2004). I also search for ways in which aspects of social studies can inform design. Moreover, I concentrate on how the social relations of actors are strongly linked with technology and how actors are displayed in an actor network that is logical for conceptualization by systems developers. This focus is different from that of other ANT studies which focus on the theoretical analysis of the 'hows' of a social network (Law 2009). However, my use of ANT is important, as it could help systems developers clarify when, how and what to use to support cooperative work in an actor network without following the principle of 'translation'.

However, it is important to point out that ANT has nothing to do with any particular form of graphical modelling; rather, the nature of the relationships in the network that bring together actors seems to require some graphical representation (Payne 2017). It is vital distinguish my use of *translation* from that of other ANT writers. My use is similar to that of some researchers (Blomberg et al., 1993; Khovanskaya et al., 2017; Randall et al., 2007; Simonsen and Kensing 1998) in the design field.

Consistent with this, it is possible to identify the actors in the actor network of skills, artefacts, practices, tests and agreements to establish a social order (including technology) as the material (Callon 1991; Monteiro and Hanseth 1996) for the purpose of illustration. Hence, the bottom-up idea is powerful in expressing that the nature of the cooperation between humans and non-humans reshapes the concept of technology as a honeycomb because both technology and social relations are coupled in a flat organisation (Sørgaard 1987; Michael 2017).

In my understanding, Latour (1990, p. 4) has argued that the actor network cannot be described without recognising it as fibrous or thread-like:

> A[N]T makes use of some of the simples properties of nets and then add to it an actor that does some work; the addition of such an ontological ingredient deeply modifies it.

The actors and the network constantly and dynamically redefine each other. According to Callon (1987, p. 93),

> An actor network is simultaneously an actor whose activity is networking heterogeneous elements and a network that is able to redefine and transform what it is made of.

Consequently, as Law has explained, ANT assumes that ‘social structure’ is a verb rather than a noun, as the structure is not freestanding but is an effect in a constant state of reproduction (Law 1992). Hence, illustrating actor networks and how they change constantly prioritises the cooperative work of marine operators in systems design before systems develop (Butler et al., 1996; Maier and Rechtin 2000). Thus, the dynamics of the actor network on the ship’s bridge are represented visibly to inspire systems developers in their daily work. Thus, in the following section, I describe my use of ANT as a visualisation tool.

3.1.1 ANT as visualisation

In my study, work on the ship's bridge is not conceived as a simple interaction between humans and non-humans or as humans simply doing their work. Instead, it involves a large social-technical environment that is integrated with systems, workspaces and artefacts – and their combinations – in a cooperative process. To deal with such relationships, the actor network is visualised to illustrate how actors and artefacts are connected. Thus, the visualisation shows how an actor network is established to support a specific task. It helps to establish the analytical field of the social-technical environment, which is used to investigate the design of cooperative systems.

Hence, the visualisation of an actor network suggests (Yaneva 2009) a comprehensive view of the cooperation of different actors, revealing their many material dimensions (without limiting them in advance to pure material properties or social symbols) (Yaneva 2009). For example, Yaneva (2009) states that ANT could help outline an understanding of social work concerning objects and incorporated actions so as to rearticulate new social ties. Without this, it is impossible to understand the *designerliness* of design objects, networks and artefacts, providing only an explanation of design (Yaneva 2009). Again, ANT is not associated with any particular form of diagram or model but is rather understood as a visual metaphor (Payne 2017). For example, Callon (1986a) shows employment in simple schematics, and Latour et al. (2012) visualise interconnections between authors, keywords and references in articles which aim at identifying stabilities and clusters of issues and other relationships. Silvis and Alexander (2014) show diagrams—which they call ANT Graphical Syntax (ANT-gs)—to translate the actor network. They also provide a notation that represents changes and cross influences (Silvis and Alexander 2014). Another example: Ponti (2012) combines ANT with event-structure analysis, focusing on how events become causal during network development. Supported by specialist software, the author claims that events can be analysed through the diagrams by concentrating on sequences and relationships. However, Payne (2017) argues that, with little attention paid to the actors and their networks, it is a challenge to show objects in a network. Thus, it is difficult to allow ANT analysts to focus on an objects' character or its nature and relationships.

Although ANT as visualisation, in previous studies, focuses either on the development of actor networks or on objects' relationships, the visualisation of the actor network can be used to explore interactions and effects in situations involving any humans and non-humans. The above-mentioned literature inspires me with the realization that, through visualisation of actor networks, ANT could provide systems developers with a better understanding of the nature of cooperative work. However, in the current literature, ANT does not privilege the power to outline dynamic changes of information exchanges in design process for those who are in the software-engineering field. Thus, the present study may add to the literature regarding how systems developers can design technical elements in a system and try to contextualise them in drawings and representations of both non-human and human activities. Such contextualisation allows qualitative researchers to explain the design to those outside their own fields. Following ANT in visual representations, they could interpret the context as moving, evolving and changing along with various design elements to satisfy the dimensions of materials that impinge on every stage in the design of a technology.

Thus, the present study combines the analytical lenses of ANT and CSCW. Before I briefly explain the concept from CSCW, I consider the way in which it is used in my work. At sea, the aim was to understand how marine operators work in groups with the enabling technologies of offshore operating systems and artefacts (e.g., paper forms, calculators and alarm clocks). In my work, ANT serves as an analytical lens for outlining the actor network, and CSCW works to unpack the 'whats' and 'hows' in designing the interactive relations between humans and non-humans in that actor network.

3.2 **Analytical concepts from CSCW**

According to Wilson (1991, p. 6), *CSCW* is,

> A generic term which combines the understanding of the way people work in groups with enabling technologies of computer networking and associated hardware, software, services and techniques.

The CSCW concerns computer technologies, hardware, software, and data services as applications which are used to support the work of a group of humans. Thus, the

CSCW lens can provide insights into how to redesign computer technologies to consider the social aspect. By using CSCW, I am able to identify ways in which supported offshore operating systems and artefacts could be designed. For example, as theoretical underpinnings, CSCW insights could reveal the computer technologies that should be designed to support cooperative work. Hence, cooperation in the network of marine operators, computer systems, artefacts and their combinations in performing tasks is considered in maritime design. To obtain a clear picture of cooperation in maritime tasks. I also consider how marine operators adjust their activities, such as by utilising artefacts to support computer systems during marine operations. Thus, I have selected the concepts of 'awareness' (Schmidt 2002; Tenenberg et al., 2016) and 'computational artefacts' (Christensen and Harper 2016; Bødker and Klokmose 2012; Schmidt and Bansler 2016). I describe the concepts in detail and explain the reasons for choosing them in the following sections.

3.2.1 Awareness

In CSCW, awareness is different from the concept of awareness that is used in the engineering community (Schmidt, 2002). In the engineering field, Endsley defines awareness as situational awareness (Endsley 1988, 1995, 2015). Awareness is understood as a mental model for acquiring information (i.e., pre-attentive processing, attention, perception and working memory) from surrounding environments and for analysing stress, workload and complexity in relation to systems design, interface design and automation.

However, in the CSCW field, awareness is understood to consist of ongoing activities in collaboration with others in an immediate environment (Heath et al., 2002). According to Heath et al., (2002, p. 318):

> In particular we wish to suggest that awareness is not simply a 'state of mind' or a 'cognitive ability,' but rather a feature of practical action which is systematically accomplished within developing course of everyday activities.

Furthermore,

> With regard to awareness, an activity can be configured so as to engender a series of actions from a colleague; a colleague who, until that moment, might well be engaged in a distinct and unrelated activity. (p. 324)

I am also concerned about the awareness of humans and non-humans regarding the output of work practices and their adjustment to other actors' activities. Thus, my use of *awareness* aligns with its definition in the CSCW field. However, Schmidt (2002, p. 295) advocates considering the following questions about 'awareness':

> How does the actor determine what is relevant to their own efforts? How does the actor manage to sort out and pick up what is relevant? How does actor modulate their activities so as to make relevant aspects accessible to colleagues, and determine what is relevant for others?

It is clear that awareness concerns the social context of work through which an individual actor cooperates with other actors, engages in individual activities, deals with tasks and adjusts activities accordingly (Gutwin and Greenberg 2002). In this context, *awareness* does not refer to the category of a mental state which exists independently of action but to a person who is becoming aware of *something*: 'Awareness is an integrated aspect of practice and must be investigated as such' (Schmidt 2002, p. 288). Hence, using the concept of awareness helps to illustrate individual activities rather than mental models. Such illustrations provide a way to show the relations between individuals through their cooperative work activities. This concept is central to the present study.

Tenenberg et al. (2016) expand the understanding of awareness in a group of individuals as group activities in a social context. Importantly, we need to note how the members of a group cooperate to deal with tasks and adjust their activities. Of course, the awareness in a group of individuals can help in showing the interactive relations between individuals. The main concern of awareness in a group is how to deal with awareness in cooperation. As Schmidt (2002, p. 289) explains, awareness in cooperation can be interpreted as how articulation work enables cooperative work:

> Awareness is thus conceived of as awareness of the social context and is seen as something that engenders 'informal interactions' and 'a shared culture' or even the formation of collaborative alliances. There are, of course, domains in which awareness of the general social context is an important aspect of articulation work, especially in domains such as politics and management where the formation of coalitions is of paramount importance, or domains such as teaching where socialisation is crucial; but in the wide and multifarious world of cooperative work such settings and situations are exceptional.

Thus, understanding awareness in a group should take the articulation work that is ascribed by single actors into account to focus on the collective action of the network. The members articulate the why, where, when, what and how of the task to function within the network or stay enrolled in it (Heath et al., 2002). The collective action of the network is the meshing together of people, artefacts and information (Blomberg and Karasti 2013) regarding who, what, where, when and how the cooperative work is arranged (Crabtree and Mortier 2015; Schmidt and Bannon 1992; Star and Strauss 1999). According to Aanestad (2003), awareness in cooperation is about action and its associated entities, which means that it is not a property of humans but rather of an association of actors. Through the ANT lens, she further argues that organisations are consequently described as networks of heterogeneous actors which are brought together into more or less stable associations. Hence, awareness becomes about knowing who is 'around', what activities are occurring, and who is talking with whom. Awareness provides a view of others in the work setting.

Thus, to summarise the importance of awareness in the present study, I focus on how actors are arranged in an actor network through their surrounding activities to reveal interactive relationships between them. Awareness shows how such interactive relationships among actors are established in a marine operation and with social meanings. Thus, awareness in cooperation in the present study is about identifying how the actor network is built and how actors establish interactive relationships among them in marine operations. The advantage of using the concept of awareness is that the principle of the actor network allows us to consider the work done by non-humans. By allowing researchers to include technologies as actors in the design process, researchers may be able to create a richer picture of the actor network in specific contexts. Thus, awareness can assist in determining who participates in actor networks and what type of support is needed (Latour 1999). Another advantage of using awareness is that it can show how interactive relations in the marine operations are established when working with systems developers.

Finally, it is important to notice that awareness is hardly a unique concept in the CSCW field (Schmidt 2002). Computer-supported cooperative-work researchers have contributed to defining the notion of awareness by offering several understandings of *awareness* to CSCW research. For example, *awareness* is understood as an integrated aspect of practice (Bly et al., 1993). In this situation, it is about the social context of work rather than about the ongoing activities and artefacts of a joint cooperative work (Schmidt 2002). In addition, ‘awareness is also understood as actors tacitly and seamlessly aligning and integrating their distributed practices and yet independent activities’ (Gutwin and Greenberg 2002). Moreover, awareness is about taking a phenomenon that actors align and integrating their activities with the activities of other co-actors without interrupting the current line of action (Dourish 1997; Heath et al 2002). However, my understanding of awareness is consistent with Schmidt’s (2002, p. 293) argument:

> In order to understand the phenomenon of awareness in cooperative work we have to address the fact that the world in which cooperating workers act and interact is given to them as a meaning world.

In this vein, again, awareness has nothing to do with cognitivism but must be investigated as an integrated aspect of practices (Schmidt 2002). In the present study, this concept fruitfully supports the analysis of how marine operations are aligned and integrated in distributed places. It is useful in the software-engineering field for showing systems developers that a specific task is accomplished through certain operational systems and marine operators in a particular situation.

3.2.2 Artefacts in CSCW and computational artefacts

I described awareness in the previous section. In this section, I introduce another concept which is important to this study: the artefact. What is the role of an artefact in an actor network, and how should the notion of artefact be understood so as to inspire systems developers in their design work? As defined by the *Oxford Dictionary*, an artefact is ‘an object made by human beings, typically one of cultural or historical interest’ (Oxford University Press 2017). In the CSCW field, artefacts are considered to be tools used to coordinate work and to analyse the problem of ‘distributed coordination’ (Randall et al., 2007), which has to do with the particular arrangement of artefacts and how they are used to realise cooperative work.

In the present study, this concept is important in focusing on how maritime technical artefacts support the social aspect of cooperative work. Randall et al. (2007, p. 222) offer the following explanation:

> Yates, an organisational historian, described how in the late Victorian era memos, files, standard forms, and the like evolved to solve problems of 'distributed coordination', as organisations became larger and the problems of management and control correspondingly increased. According to her, these kinds of bureaucratic artefacts specifically evolved so as to function in distributed organisations. Only with them could coordination of a certain, document-centred type, occur. A particular step change in distributed organisation was enabled by the vertical filing cabinet, she argues, because it allowed easy storage and ready access to much more information than had been possible before.
>
> Whatever one thinks of Yates' work, the point is that artefact, things, have had a role in distributed systems since long before that term was used to label computer-based systems.

The design of artefacts should be close to the 'ecological arrangement of things for work' (Randall et al., 2007). The artefact plays an important role in coordinating work practices (Kuutti 2013). The artefact is not only technical. The use of artefacts in work has drawn attention in the CSCW field (Christensen 2006; Ackerman et al., 2013; Kuutti 2013).

Some researchers understand artefacts are just bounded objects via human activities in terms of illustrating cooperative work practices (Bjørn and Østerlund 2014). According to Bjørn and Østerlund (2014), such investigations could facilitate the search for interactions among materials, materials and their locations and materials and the human mobility patterns associated with different bounding (Bjørn and Østerlund 2014). Researchers assume that materiality is important, and they aim to explore the effects of materiality on cooperative work. For example, they want to study how various subsets of objects and spaces act as mechanisms that mediate the work that needs to be done in a work place (Randall et al., 2007).

In contrast to above understanding of artefacts, Suchman (2007, 1997, p. 1) defines the 'computational artefact' and argues that it follows the dynamics of work practices rather than being merely a tool in the workplace. This definition highlights the importance of the social context of artefact use and the work practices that make cooperative work possible:

> The dynamics of computational artefacts extend beyond the interface narrowly defined, to relations of people with each other and to the place of computing in their ongoing activities. System

> design, it follows, must include not only the design of innovative technologies, but their artful integration with the rest of the social and material world.

According to this definition, I understand that artefacts consist of more than a physical shape in the present study. Artefacts also help users function in their daily work practices (Schmidt and Bansler 2016). Moreover, artefacts are designed to act according to the activities in which they are used, to be incorporated into sophisticated semiotic practices and to respond to and integrate unfolding events that go beyond function to address social meaning (Schmidt and Bansler 2016). Hence, artefacts become computational artefacts and are not only things but are also integral parts of the work practice (Christensen 2014). Therefore, the computational aspects of artefacts, in my understanding, are events occasioned by people that are given the meaning of ‘automation capabilities’ through cooperative work. Such computational aspects are interlocked in artefacts that may not have been designed by systems developers but are nonetheless performed as actions through cooperative work in and across actors and actor networks. This means that much performativity may exist in artefacts. This performativity needs computational support if it is to support cooperative work.

According to Schmidt and Bansler (2016, p. 24),

> An artefact such as a calculating machine may be able to perform ‘automatically’, i.e., proceed causally (for a period of time and under certain operational conditions) and without human intervention, but it does not make sense to say that it ‘calculates’ in and of itself.
>
> The point is that to calculate is a normatively constituted activity; it is an activity governed by rules of what amounts to correct procedure and correct result: it is a practice.

Thus, it should be clear that artefacts support not only cooperative work. Moreover, social contexts and social work practices facilitate collaborative work (Christensen and Harper 2016). Furthermore, and most importantly, such efforts offer an important idea with which to think of the combination of the material and non-material in relation to work practice. It is fruitful to tell the whole story of the relations of artefacts as the non-material components of human practices (Ackerman et al., 2013; Christensen 2006; Schmidt and Wagner 2004). Thus, Schmidt and Bansler (2016, p. 24) suggest the following about the computational artefact:

> That is, it is we who, by manual control of tools and instruments or by the use of more or less automatic machines, do the work. Sure, the use of automatic machinery as part of our practices may have implications for these practices (educational, organisational, etc.), but they are nevertheless just that: technical compliments of our practices. It only makes sense to talk about this mechanical (or causal) regularity from the point of view and in the context of the normative regularity of our practices in which these artefacts are integral technical complements. In other words, it is we who engage in normatively constituted practices, by using rulers, compasses, and by using machines, computational artefacts included.

Schmidt and Bansler (2016) report that computational artefacts are unidentifiable concerning the time and situations in which they are employed by users. Consistent with this, computational artefacts become dynamic, and the factors around them—such as social meaning and work practices—are vital too. This is an important issue for me to think about in the context of thinking about how I can inspire systems developers to have a broad view of artefacts.

The present study focuses on the work practices of marine operators rather than on the identification of artefacts. I focus on marine operators in marine operations, the systems in which they work and the situations that form actor networks. In her doctoral dissertation on Xerox Star, Suchman (1985, p. 3) observes the following:

> We now have a new technology which has brought with it the idea that rather than just using machines, we interact with them. In particular, the notion of "human-machine interaction" pervades technical and popular discussion of computers, their design and use. Amidst ongoing debate over specific problems in the design and use of interactive machines, however, no question is raised regarding the bases for the idea of human-machine interaction itself.

Thus, to investigate it further, I understand the basis of computational artefacts as the process of shaping interactive relationships regarding the tasks of each operator and the connections among the various tasks – that is, the interactive relations. This understanding contributes to shifting the focus from the internal opacity (Schmidt and Bansler 2016) of an artefact to its relations to human practices in a cooperative social context. According to Schmidt and Bansler (2016, p. 30),

> We do not need to understand the internal mechanism of an artefact in order to make rational use of it; nor do we in fact normally do that. One does not need, say, to understand the specifics of the

> lattice structure of steel alloys causing the operational properties of one's damascenes kitchen knife: its hardness, its tensile strength, its elasticity. What one needs to understand is its 'functionality'. And in the case of machinery, what one needs to know is the dependable regularity of its behaviour. That's all.

Thus, according to Schmidt and Bansler, the 'functionality' could provide me with the opportunity to use the computational artefact to enhance the translation of ethnographic outcomes so that the project audience could shift its focus from the internal mechanism of an artefact to understanding an artifact as a computational artefact and its relations in human practices in the maritime domain.

3.3 **ANT and CSCW**

I am particularly interested in collaborating with systems developers so as to inspire them to design simulators that support interactive relations among operators, artefacts and maritime technologies to improve cooperation in such actor networks. Thus, it is worth discussing the relations between ANT and CSCW before concluding this chapter.

Arguably, some researchers focus on recognising various materials that have different qualities depending upon how they are used in specific places. In this case, no matter how the material is bounded through time and space in cooperative work, it is completely static, irrespective of the execution of the coordination it prescribes (Schmidt 1997). However, Schmidt argues that material not only stipulates articulation work (e.g., a standard operating procedure in a social order) (Schmidt 1997) but is inscribed as a result of the delegation of social roles to non-humans (Schmidt and Wagner 2004). This argument responds to the ambiguous notion of the 'social construction of technology' and the socially deterministic view of material (Law 2009). Actor-network-theory scholars have bypassed the question of how social relations are mediated by materials to study the fundamental question of why materials proliferate in human societies (Shiga 2007). This focus differs from the CSCW point of view of the role of materials in cooperative work. The interactive relations of the materials used by human actors may not be critical to researchers. However, in the context of the present study, it is important to consider how such interactive relations shape and reshape in marine operations if I am to show how to design maritime simulators. This focus, I believe, is much closer to the role of systems developers, as it could show them how technology can be connected to support specific work practices.

In fact, combining CSCW and ANT is not new to the CSCW field. According to Schmidt (2000),

> When engaged in a cooperative effect, actors are objectively and materially interdependent. Their interdependence inescapably has causal aspects, and their actions and interactions are both intentional and material. Again, this is not sensational news. Some may refer to this duplicity as the ‘double character of work process’ (Karl 1867) or by conceiving of it as a socio-technical systems (Emery and Trist 1965; Woodward 1965) or ‘distributed cognition’ (Hutchins 1994), or as a network of actors and artefacts (Law and Hassard 1999) or whatever. These are merely different ways of stating the problem. The challenge is to develop the conceptual implications of this insight and understand the intricate interplay of the causal and the intentional, of the material and the culture.

Thus, a combination of CSCW and ANT is essential to supporting interactive relations between actors. In cooperative work, the relations between human and non-human should be considered in the design of maritime simulators. They should be considered to be social-technical associations between humans and non-humans. If this is the case, it reinforces my argument that interactive relations among actors and an emphasis on the design of maritime simulators are at the centre of the present study. Such combinations also help in viewing relationships among marine operators, operational systems, alarm clocks, calculators and other artefacts in marine operations as a whole. All are objectively and materially interdependent. They are shaping and can reshape their relationships in and across different actor networks. Each actor network can correspond to how an operation is achieved. This means the relationship between humans and non-humans in marine operations is associated through interests, regardless of what they are and no matter the historical phenomenon. In this manner, we need only to understand how actors find their positions to accomplish marine operations as a subject. This kind of subject-object relationship (Marx 1845) has developed in the course of actor evaluation in the actor network. This is probably consistent with Marx’s (1845) understanding of the concept of work – and it helps in identifying interactive relationships and in tracking relationships when they become complex. Thus, I find combining ANT and CSCW an appropriate way to analyse marine operations due to their complex, diverse, and instantaneously changing characteristics.

3.4 Summary

This chapter has emphasised the use of ANT as an analytical lens which can be used to shape our understanding of cooperative work and the computer systems that support it. This understanding is important for researchers who are considering the marine tasks involved in cooperative work. In addition, this chapter has introduced and clarified the definition of *awareness* for the present study. The notion of a *computational artefact* has also been introduced. Furthermore, this chapter presents my understanding of the relationship between ANT and CSCW. In the next chapter, I introduce the empirical setting of the cooperative work: the workspace on a ship's bridge and the workshops in Ålesund.

4 Empirical setting

This chapter begins by presenting an overview of the selection of empirical settings. Section 4.1 describes the background of the study. Section 4.2 describes accessing a ship's bridge on a vessel at sea. Section 4.3 presents the research activities which were conducted in the field. Before offering detailed information about empirical settings, a brief introduction to the participants is provided in Section 4.4. The setting of the workspace on a ship's bridge is introduced in Section 4.5. The workshop setting is described in Section 4.6. The chapter is summarised in Section 4.7.

4.1 Background of the study

In this section, I summarise the different opinions which were available in the maritime domain before I went to the field. I was interested in determining the safety concerns in cooperative work in the marine workspace, as marine operations are presently regarded as the only work of a marine operator (notes from meeting with maritime professionals at NTNU, May 14, 2014). In addition, I was invited to hold a seminar with mechanical engineers at NTNU to discuss new technology that may be implemented in cooperative workspaces to improve maritime safety and operations (notes from seminar in mechanics lab at NTNU, July 2, 2013). During the seminar, the mechanical engineers discussed the challenges of supporting marine operators' cooperative work; they suggested that connecting the different facilities of operating systems might provide a way to solve the problem. Their proposal is an example of mechanical engineers' tendency to focus on technological factors rather than human values (personal communication with mechanical engineers). They also expressed the belief that the evaluation of connected facilities could improve maritime safety and operations. I was told that if the evaluation of the simulators could help identify safety issues, there would be fewer differences in the work of marine operators in a workspace on a ship's bridge.

After the seminar with the mechanical engineers at NTNU, in a workshop at the University of Oslo (notes from workshop, September 4, 2013), I was told about an incident that occurred in 2007, in which some people were killed and others were injured because of a lack of support for marine operators' cooperative work. These different experiences and meetings inspired me to examine maritime workspaces to learn what it is like to work in them. I visited the centre for maritime simulators at NTNU to obtain an overview before I went into the field at sea.

The first meeting in the different maritime simulator rooms was at NTNU (notes, August 22, 2014). Systems developers attended the meeting. They showed that maritime simulators are similar to the workspaces encountered on the offshore supply vessels that I would visit a few months later at sea. The key difference was the following. I was told that working conditions were hard to predict and that it is particularly difficult to replicate how marine operators react during their work to different situations at sea. Though the systems developers said that they strived to create plausible scenarios of tough tasks in the simulators, the marine operators' performances did not accord with the expected results (notes from meeting with marine professionals, August 14, 2014). Since I already knew that simulators are not designed to support cooperative work, I was not interested in examining the operators' performance with the simulators. Instead, I decided to investigate the ways in which cooperative work is done in the field.

4.2 Boarding a vessel

Before boarding a vessel, I also visited a simulation company in Ålesund on several occasions. I was told that the simulators designed by the company are similar to operations at sea but that there are some differences (meeting with maritime professionals on August 14, 2014). I was told that the simulation company could not access the field. The most challenging problem is that the design of the simulators considers only individual operations, such as DP and automatic integrated operations. I was told that the simulators were developed based on the requirements of shipping companies regarding their needs at sea. This limitation could be a common issue, as some researchers and designers report that specific safety certificates are required to access such environments (Lurås and Mainsah 2013).

Fortunately, in response to my request, a shipping company gave me permission to board a vessel. In 2015, the company had regular monthly routes in the North Sea and the Norwegian Sea because of several internal agreements with industries and the university. In my request, I mentioned the purpose of my study, which is to learn about the work practices of marine operators. The company approved my request and assigned me to an offshore supply vessel and a contact person. I was allowed to board this vessel as many times as I could in Norwegian waters. Hence, if the vessel went into international waters or across the borders between Norway and other nations, I was not allowed to be on board. The contact person guided me through the ship and provided a basic overview of the workspace, which facilitated my understanding of the workspace and provided detailed knowledge about when and how the marine operators worked with offshore operating systems, other artefacts such as physical tools and paper forms. In my case, my research in the workspace on the ship's bridge was not restricted, but I was advised by the contact person not to access other areas.

4.2.1 Meeting with marine operators

The first meeting with the marine operators in their workspace was on an offshore supply vessel in the winter of 2015 a few hours before it sailed (notes, January 29, 2015). The chief officer explained to me that their work was conducted mainly on the ship's bridge. The captain of the ship guided me to the bridge and showed how they used the offshore operating systems and other artefacts in the workspace. I learned that the vessel appointed was an offshore supply vessel and that this type of vessel chiefly provided services to different platforms at sea. Their work, repeated many times during a workday, included positioning the vessel and providing actual services to a platform. Positioning and service work are the fundamental functions of several types of offshore vessels, as they involve the dynamic-positioning (DP) system and automatic-integration system (AIS) (notes, January 29, 2015) that are required in providing services to oil platforms. Thus, I chose DP and AIS operations as the subjects of my study, and I was granted permission to participate in all operations in the workspace on the ship's bridge during my fieldwork.

4.3 Research activity

Figure 1 shows my activities (marked areas) in the field, which took place in both the North Sea and the Norwegian Sea. My study in this workspace was performed from January of 2015 to of June 2015. I usually stayed on board for 6 to 12 days, depending on the schedules of the marine operators. After the field work at sea, the research activities on land in Ålesund were carried out (located with a dot) by bringing in the cooperative work of marine operators at sea to inform professionals who design and develop marine operating systems, equipment and other facilities in marine operations in the maritime domain.

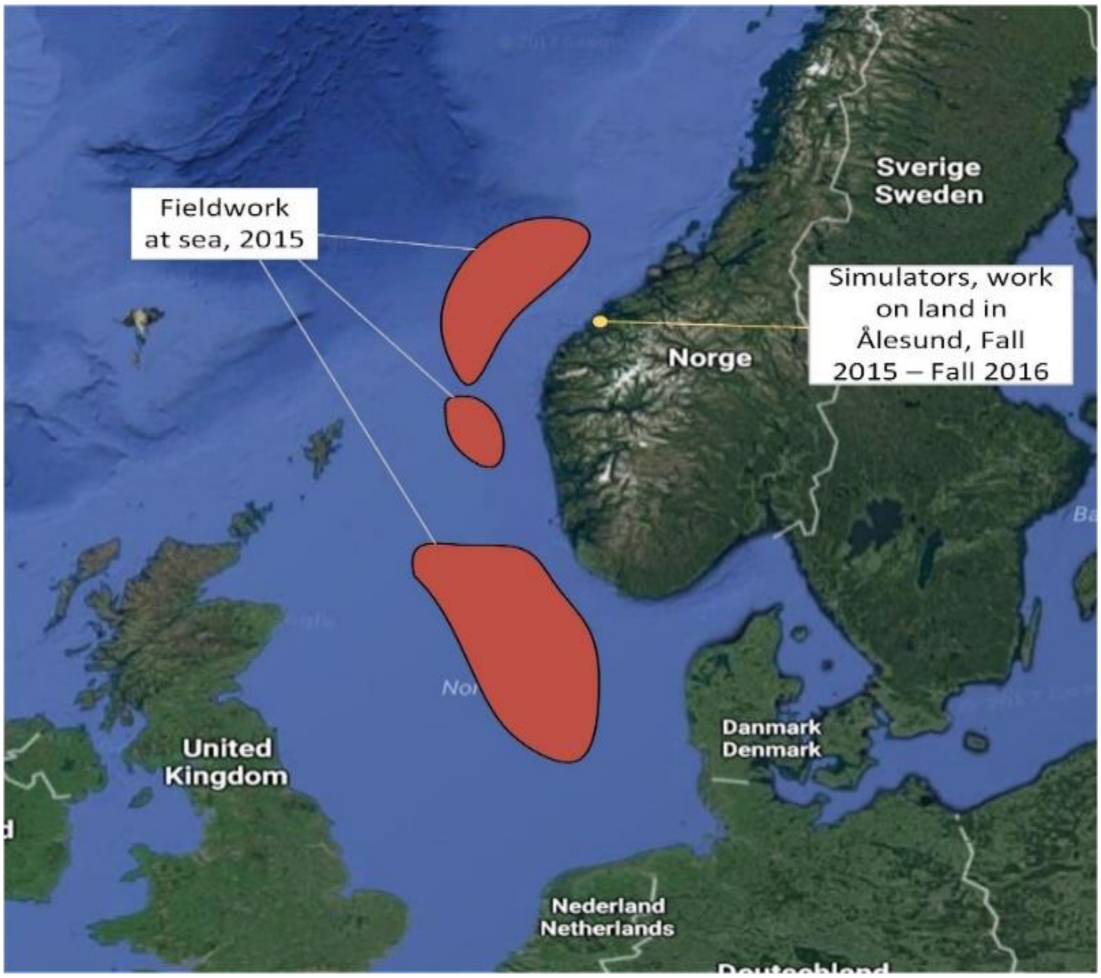

Figure 1: The study locations from 2015 to 2016

Figure 2 provides a timeline which shows when, where and with whom I worked. The purpose of this figure is to provide an overview of the research concerns according to different timescales. The figure also shows the project's starting and closing dates. The figure does not include all my activities but mainly shows the core events of the project.

4.4 A brief introduction of participants

In the following sections, I introduce the workspace of the offshore vessel at sea, which was the ship's bridge. I compare the operators' work on the vessel with the training in the simulator. The following provides a brief introduction.

- *Marine operators* is a general term used for the professionals who work on offshore vessels at sea. The work of conducting marine operations takes place on the ship's bridge or in other places on the vessel. They are occasionally trained in simulators according the oil and shipping company's policy.
- A chief or first officer is a marine operator who works on a ship's bridge. The chief or first officer works on a ship's bridge only during marine operations. This study focuses on the operation of the DP and AIS systems.
- The captain is the head of the marine operators who work on a ship's bridge.
- Systems developers are professionals who are educated as mechanical and automation experts and who work on the design and development of maritime simulators.
- The manager of the shipping company is the person who manages day-to-day business affairs and advises concerning professional matters, long-term plans and other relevant work. A manager coordinated my fieldwork on the offshore vessel at sea.

	2013	**2014**	**2015**	**2016**
Project Planning	Meetings and Seminar	Mechanical Engineers and Systems Developers		
Fieldwork at Sea			Marine Operators and I	
Workshop on Land				Systems Developers and I
Company Visiting				Systems Developers and I

Time	**Place**	**Activity**	**People**
03.03.2013	NTNU	Meeting at Simulator Room	Maritime Professionals and I
04.04.2013	NTNU	Personal Meeting	Maritime Professionals and I
04.04.2013	NTNU	Mechanical lab Meeting	Maritime Professionals and I
02.07.2013	NTNU	Mechanical lab Meeting	Maritime Professionals and I
13.08.2013	UiO	PhD started	I

04.09.2013	UiO	PhD Seminar	PhD students
08/2013-06/2014	UiO	Coursework	I
14.08.2014	NTNU	Meeting	Maritime Professionals and I
22.08.2014	NTNU	Meeting at Simulator Room	Maritime Professionals and I
01/2015-06/2015	At Sea	Fieldwork	Marine operators and I
08/2015-08/2016	NTNU	Workshop	Systems Developers and I
09.10.2016	Company	Visiting and Meeting	Systems Developers and I
31.12.2016	UiO and NTNU	Project Finished	I

Figure 2: Timeline showing main activities, places and people[17]

4.5 Workspace on the ship's bridge

In this section, I describe the workspace on the vessel, which was the bridge. The physical layout of the bridge consisted of offshore operating systems, multiple screens and the interactions of the marine operators. Two chairs were positioned so that the maritime operators could automatically move back and forth among the 16 screens for DP, AIS, monitoring and radar systems; the notebook for documenting work tasks provided by the onshore shipping company; and communication devices (see Figure 3). As shown in Figure 3, the workspace included DP systems (white circles), AIS systems (white rectangles), communication devices and another part of the workspace.

[17] In Figure 2, maritime professionals are mechanical engineers and systems developers at NTNU. Systems developers in the workshop and I visited in company are external people outside of NTNU.

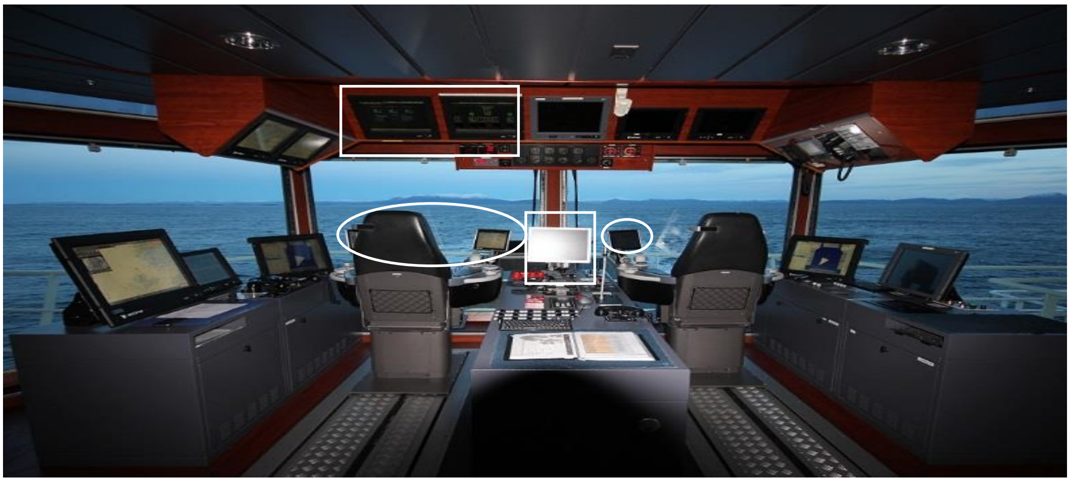

Figure 3: Portion of the marine operations workspace, including DP (white circle), AIS (white rectangle), notebook, chairs and communication devices (Photo: Yushan Pan, 2015)

Another part of the workspace on the ship's bridge held a printer, a checklist for marine operations and a computer for checking weather information and emails (see Figure 4). The marine operators on the bridge worked with DP systems, AIS systems and communication devices in their daily tasks at sea.

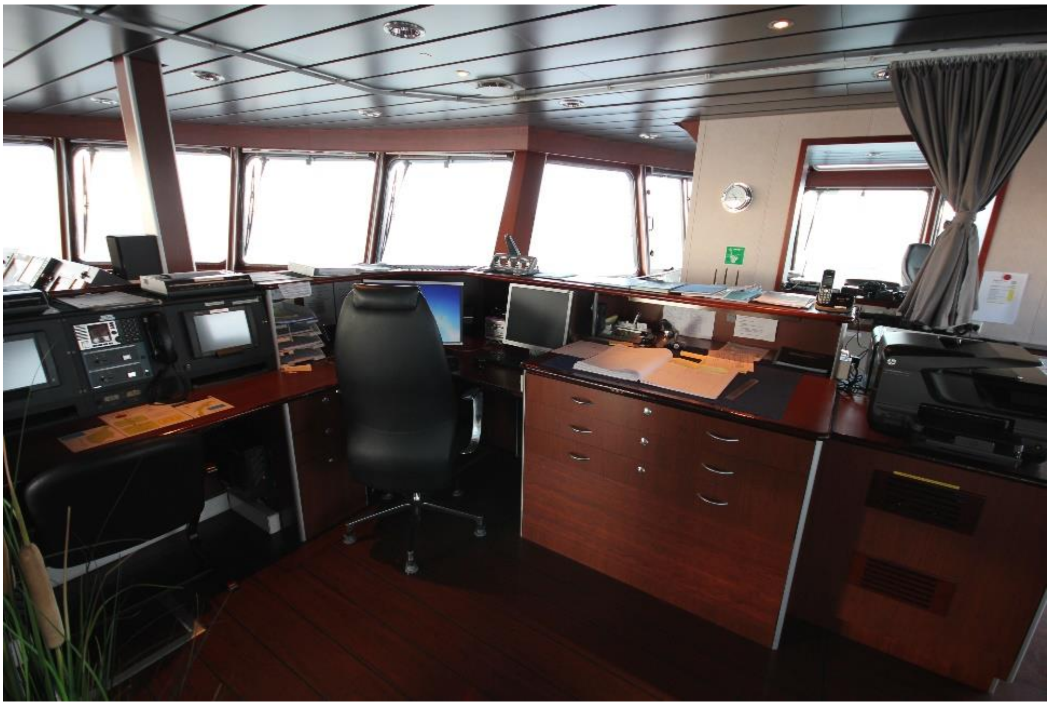

Figure 4: Another part of the workspace on the ship's bridge, including computers, a printer, a checklist book on the table, and radar systems (Photo: Yushan Pan, 2015)

Importantly, marine operations also rely on the assistance of different areas, such as the ship's deck and the crane operating on a platform. However, in the present study, I focused on the operations that took place on the ship's bridge.

4.5.1 Maritime workspace on the bridge of the ship bridge at sea

I now describe the artefacts used on the ship's bridge at sea, including the offshore operating systems, a calculator and alarm clock. The marine operators worked simultaneously with the deck crew, the platform crew members, and the engineers in the engine room (fieldwork notes, January 29, 2015).

Figure 5 shows four screens. The three with black frames are the DP systems. The DP systems are placed at both the left and right chairs. The chairs support the operators who are interacting with the DP systems, the DP displays and the joysticks, though they are not in front of the window. Moreover, the chairs can assist the operators in moving back and forth automatically.

Both operators can use any DP display to position the vessel, but they need to cooperate, as the DP display does not inform them about the distance between the vessel and other objects at sea such as oil platforms (fieldwork notes, January 29, 2015). In addition, the operators in the workspace on a ship's bridge need to work with crewmembers on the deck and the oil platform when the vessel is on site. The operators on the ship's bridge need to guide the crewmembers on the deck in successfully connecting the vessel with the oil platform. This work requires the operators on the ship's bridge to observe the position of the crane and pipe tube on the oil platform. They then need to inform the crewmembers on the deck (fieldwork notes, February 11, 2015). Furthermore, the operators need to work cooperatively through the AIS systems when the vessel and the oil Platform Are connected. One operator needs to work on the DP systems to keep the vessel still while another operator may work with the AIS systems to provide drilling mud or fresh water from/to the oil platform (fieldwork notes, March 22, 2015). Moreover, if needed, the person who works with the AIS systems also needs to cooperate with the crew members on the oil platform to position the containers, which are lifted from or lowered to the oil platform from the vessel. In this case, the operator also needs to cooperate with the crewmembers on the deck to find the correct containers to lift to the oil platform (fieldwork notes, May 29, 2015).

Figure 5: The DP system on both the left and right chairs. In the background are containers of different colours (the colours have no specific meaning). (Photo: Yushan Pan, 2015)

The AIS system consists of a ballast system (see Figure 6), a liquid mud system, a tank-cleaning system and a stripping system. Only two displays are used to display the AIS systems on the left chair. In addition, a display is used between the two chairs to share information with the operator (the bottom right corner, white circles, see Figure 7).

Figure 6: AIS system (Photo: Yushan Pan, 2015)

Figure 7: The AIS displays marked with white circles (Photo: Yushan Pan, 2015)

When the marine operators provide services to a platform, they can thus simultaneously and continuously monitor the information provided by all four systems. For example, the operators manipulate the DP systems to transfer information about the vessel’s position to the AIS systems. When sea waves move the vessel close to the platform, the AIS and DP systems do not send any signal to the operators. The services must be stopped, and the operators must reposition the vessel to reconnect with the platform.

In the following, I present three vignettes to show how the cooperative work of marine operators, operating systems, and the calculator and alarm clock are used to accomplish marine operations. The first two vignettes are examples of the fieldwork at sea. They illustrate only two aspects of the entire operation. The third vignette illustrates a complete marine operation. The aim of this vignette is to illustrate that cooperative systems are useful in supporting safe cooperation in a smooth sequence.

4.5.1.1 Vignette 1: A situation from dynamic positioning operation

This section addresses safety concerns in a workspace in which a group of operators work in their operations with DP, AIS, a calculator and an alarm clock. The DP operations are fundamental in all systems on the ship's bridge, and they are designed to maintain safety through effective positioning. The complexity operators face includes the work conditions imposed by waves and winds and the threat of a collision between the vessel and the oil platform. Moreover, improper operation of the DP systems can cause a problem in maintaining the balance of the vessel.

During the work, one of the operators, Andre (fictitious name), requests his colleague, Emil (fictitious name), to report on the weather conditions. Emil walks to a computer, which is not part of the DP system, turns on the display, and pulls up a weather-report page. The weather report is important because, if the wave and winds are too high, all operations must be postponed. However, the weather report is not part of the DP systems. Hence, Emil must log the information on a checklist, including the current time and place, and then hand it to Andre. When Andre has the information, he picks up one of the communication channels and speaks to the engine room to check the engine status.

At this time, the engine room responds that the power is sufficient for the operation. Andre requests the engine room to report the status of the containers under the deck of the vessel, as they are important for maintaining the balance of vessel. The DP systems show only the pressure of the piping tube on the display, so it is impossible to see the location of the piping tube, which is too far away for Andre to observe (see Figure 8).

Figure 8: Emil checks the location of the rig to help Andre. (Photo: Yushan Pan, 2015)

Thus, when the engine room replies that the pipe pressure is satisfactory, Andre walks back to the DP system and sits in the duty operator's chair. The engine room checks the vessel's balance during the DP operations. If the weight is unbalanced, the vessel could capsize. In addition, the deck crew needs to cooperate with Andre by opening the valve on the container when the pipe is connected to the oil platform. He needs to shift mud from Container 5 (on the left side of the vessel) to Container 6 (on the right side of the vessel). In this operation, he uses two artefacts—an alarm clock and a calculator—because he needs to know the exchanging speed of the mud (see Figure 9). In addition, no functional support is provided by the DP systems. As I learned in the field, all team members on the ship's bridge use the alarm clock and the calculator. They said, 'We care for the safety of such work by ourselves. We need to keep the vessel in a good balance.'

Figure 9 Alarm clock and calculator used by marine operators (Photos: Yushan Pan, 2015)

For example, Andre records all the necessary information on the checklist that Emil gave him, and he begins to use the calculator. He wants to know how much mud he needs to move to Container 6 from Container 5. When he finishes his calculation, he fills out a paper form and delivers it to Emil to sign. Andre then sets a five-hour alarm on the clock before he pipes the mud and water from Container 5 (see Figure 10). He operates the container systems to pipe the mud and water, and he stops when he hears *the alarm. He then asks Emil to check the waves and wind so as to position the vessel appropriately to maintain its balance.*

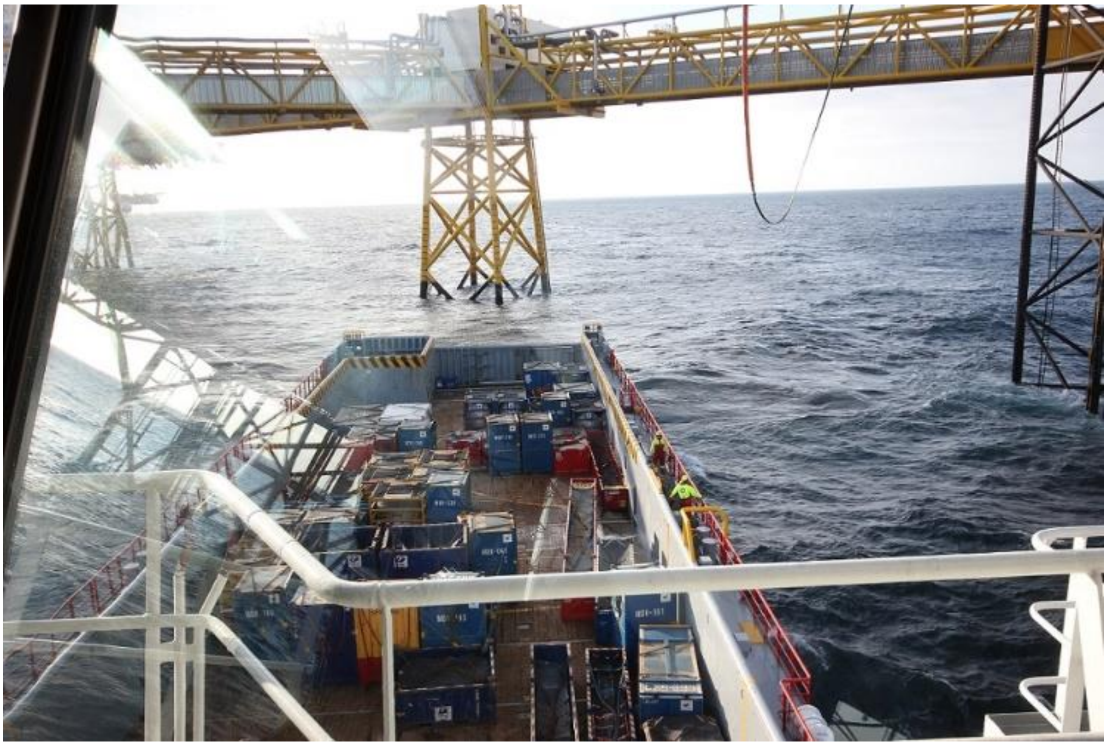

Figure 10: Shifting containers 5 and 6 under the deck while servicing the oil platform. Two deck crews check the pipeline and help to measure the distance between the vessel and the oil platform. (Photo: Yushan Pan, 2015)

Emil walks to the computer again, checks it, writes down the information about the waves and wind and then speaks to Andre. Emil writes down the information and brings it to Andre. Then Andre asks the engine room and the crew to report when the vessel's position is satisfactory. He then requests the oil platform to take back the crane, as he cannot see it and the DP systems cannot detect it. Thus, Andre asks for help from Emil to observe the position of the crane. With Emil's help, Andre adjusts the position of the vessel under the oil platform. During the adjustment of the position, the deck crew reports information to Andre, as it is hard to observe a 100-metre-long vessel if it is too close to a platform.

4.5.1.2 Vignette 2: A sudden service changing request from the oil platform

This vignette illustrates a situation in which the marine operators on a ship's bridge use the DP and AIS systems associated with the physical structures in the workspace.

Unlike the first vignette, this vignette shows cooperative work changes in different situations. All the names in this vignette are fictitious.

Tom is an operator who works on ship's bridge. His main job is to perform DP and control the automatic integrated systems during marine operations—particularly service operations. Ali is the captain. His main job is to make final decisions and assist Tom during tasks—for example, by printing checklists, checking and marking the amount and the weight of the cargo that is loaded from the platforms during operations.

This vignette takes place on a sunny day. Waves and wind are within a reasonable fluctuation range (waves < 3 m, wind < 4 m/s). Tom has already positioned the vessel under the oil platform. In addition, the pipe is already connected between the vessel and the oil platform. Tom asks Ali if he checked and approved the checklists. Ali replies that he did, but he only has an old version of the cargo and mission lists. Then Tom confirms with the engine room that everything is satisfactory. Tom asks Ali to monitor and record the cargo from the oil Platform Because the weight of the cargo could make the vessel lose balance during the service operation of giving and retrieving water and mud from the platform. As described previously, the AIS is an integrated system that controls the containers under a vessel's deck. Tom and Ali are working on different tasks. Tom pays attention to the AIS system. He needs to know how much water or mud he needs to provide the platform from the vessel's containers. Ali needs to work on recording the amount of cargo, as the cargo's weight can help him estimate where to position the cargo on the deck to maintain the balance of the vessel. In all these operations, the decision-making power is not in the hands of the people who work on the ship's bridge. The oil platform decides how much water and mud it needs, including the types of mud. In addition, the oil platform may also make unplanned changes to the cargo (see Figure 11).

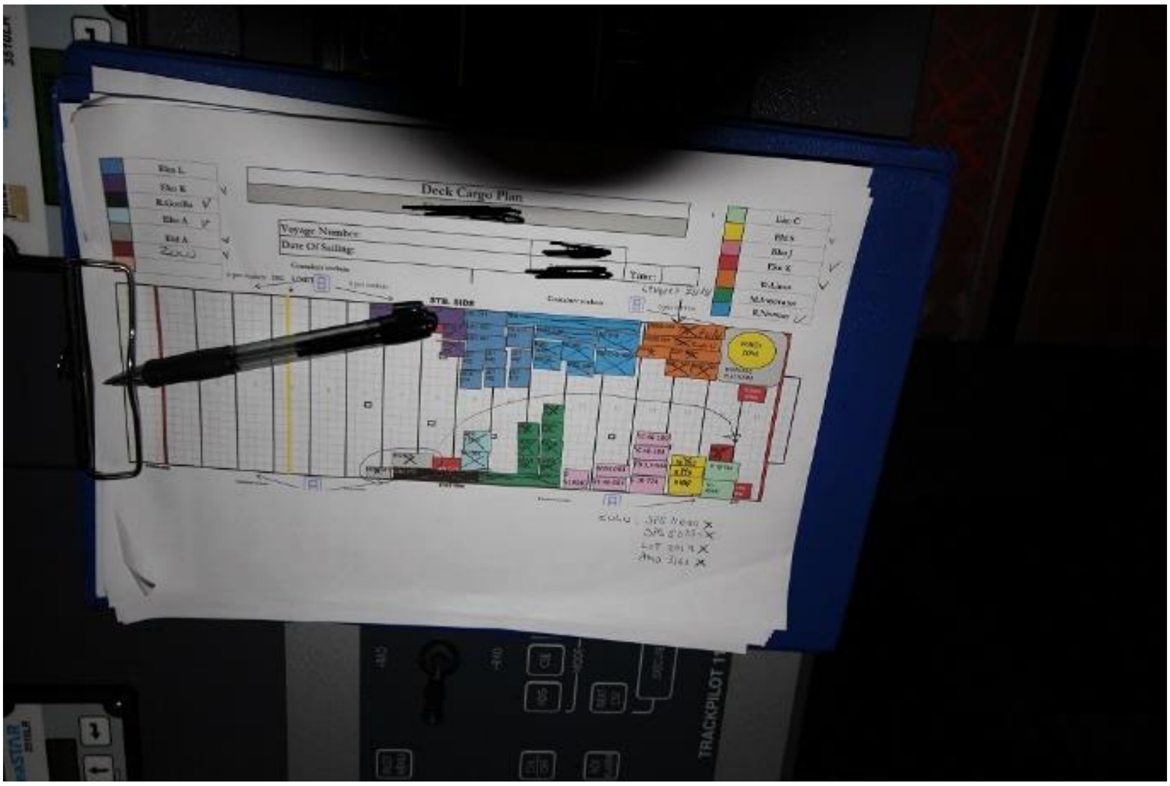

Figure 11: The changed cargo plan (Photo: Yushan Pan, 2015)

The cargo, water and mud are usually handled simultaneously. The crew on the platform decides how much waste water needs to be returned to the vessel. This information is not available to the bridge operators or the shipping company beforehand, as it is immediate and dynamic. Based on the dynamic information about water, mud and cargo, Tom and Ali balance the vessel during their offshore work and keep the vessel in a safe situation by avoiding imbalance. However, they need to adjust their activities during their operations, as the waves can cause an unbalanced vessel to capsize since the weather is dynamic at sea.

After a while, the platform calls on the vessel to change the mud Type II to Type IV. The platform sends an email to ask how much of Type IV mud they need. Tom answers, 'No problem' and asks Ali to check the email. Tom asks Ali to check the email because he is in charge of the DP operations that maintain the vessel in a proper position. At the same time, he is working on receiving the waste water from the platform. Before he is asked to check the email, Ali is recording the cargo loaded from the platform. Tom needs the cargo information associated with the AIS system to ensure that the vessel is in a safe situation regarding the balance and distance to the platform caused by the sea waves. Tom will be put at risk if Ali leaves immediately to *check email in the office (see Figure 13), as he would not then be able to acquire information about the cargo. The cargo service work could not be stopped because it is done quickly due to the economic agreement between the shipping company and the oil company (notes from the meeting with other stakeholders, 2015). Hence, it is a dilemma for both Ali and Tom.*

Unfortunately, there is no good solution, as neither Tom nor Ali can wait until their tasks at hand are finished. They have to respond as quickly as possible. There are many uncertainties during operations regarding wind, waves, changing mud, water, exchanging cargo and so on. If the weather conditions do not permit such operations, they have to wait. However, the amount of work time is limited, and the operators have to get back to the quay on schedule[18]*. Otherwise, the company will incur unnecessary expenses on the booked quay. The waiting time at sea also incurs costs, such as fuel costs. Hence, operators normally react when the work has to change, though there may be some unsafe conditions. Ali runs to the office area immediately as Tom has requested. He runs along a narrow channel on the bridge rather than using the moveable chair. He uses the computer and checks the email from the platform. Then he prints the email and picks up the new checklist (see Figure 12).*

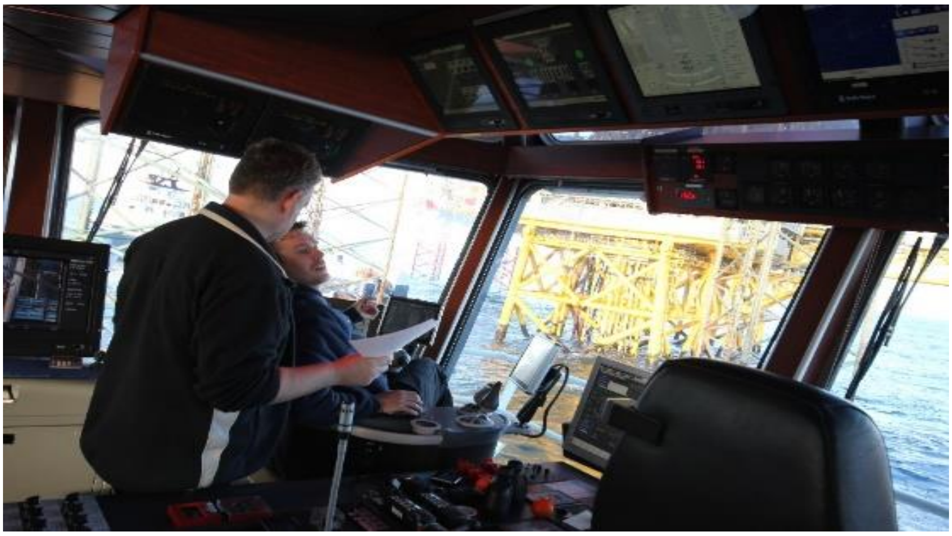

Figure 12: the new approved service form and checklist for operator. One operator has to change his task and work on changing requests from the oil platform (Photo: Yushan Pan, 2015)

[18] Quay – A word in the working language of marine operators. A quay is part of a harbour.

Ali reconfirms the mud type orally. He picks up the satellite phone and asks the company for permission to change the mud type. This kind of change is related to the economic interests of the oil and shipping companies. As the captain, Ali must report this information before undertaking any action. When he gets permission, he has to sign the form and return it to the oil Platform By email. After signing the form, he talks to Tom about how much mud the vessel could provide to the platform. When Ali goes back to scan the form and send the email, Tom presses the emergency stop, as the platform tells him that some cargo has been placed wrongly, which causes the balance of the vessel to shift. Tom cannot execute the operation by himself, so he chooses to shut down all operations because the ship is already significantly unbalanced. In addition, the chef in the kitchen complains that his equipment is strewn everywhere because the vessel is imbalanced. Ali quickly runs back to his seat from the office area through the narrow channel to help Tom. He picks up the communication device to coordinate with the oil platform to take back the cargo.

4.5.1.3 Vignette 3: A complete cooperative work of maritime services at sea

Vignette 3 was recorded during my study at sea. The previous two vignettes were separated because of the task context of the shipping and oil companies. Thus, the third vignette is used to show the marine operators working cooperatively in marine operations on the bridge of an offshore supply vessel. In addition, this vignette combines different marine operations to provide a better understanding of actual cooperative work at sea. The purpose of this vignette is to show how awareness is created during the actual cooperative work. I believe that this awareness is important to shaping the design of cooperative systems in the maritime domain.

A DP operation is used before and during operations to enable an offshore vessel to position itself in a proper location at sea. The DP system consists of artefacts, including the DP system, a DP checklist (added artefact) and a telescope (added artefact). Two operators on the offshore vessel (the chief, Emil and the first officer, Andre) interact with the displays and operate levers that are integrated with two operational chairs in the workspace. The workspace of an offshore vessel is different when it is under navigation, as it is designed for offshore operations at sea. The first officer follows the plan received from the oil company to prepare to position the vessel under Platform A on the Norwegian sea. On the vessel, he fills in the checklist *for DP preparation by reading the compass to record the vessel's current position and the time (see Figure 13). He then walks to a computer, which is not a part of the workspace, to check the weather, sea waves and wind direction according to the Norwegian Meteorological Institute, which is the Norwegian weather-forecast provider. He checks the plan from the oil company against his marine journal log, and he writes down necessary notes to remember the types of services which are needed for Platform A. He then completes the checklist. It is important to note that the checklist is paper-based. Moreover, it is not a part of the workspace.*

Figure 13: DP preparation (Photo: Yushan Pan, 2015)

The first officer does not immediately sit down to start his work. Instead, he picks up a communication device and dials a number to call the engine room. He asks the engine room about the engine's status, as he needs to be aware of whether the vessel is in the proper condition for his operation. The engine room repeats his questions and confirms the operational conditions, including the weather conditions, with both the first officer and the chief officer. The engine room is also responsible for safe operation requirements, as the DP operation must be done according to strict requirements for sea waves and wind. Then the first officer marks the engine status in the margin of the checklist and starts to position the vessel.

The first officer moves the vessel slowly and stops again. He passes the operation to the chief officer, picks a telescope and says, 'Could you please help me to hold my operation? I need to check where the rig is. I cannot see it because the roof of the ship's bridge is blocking my line of vision'. The chief officer stops checking the service plan from the oil company and holds the DP operation. The first officer walks to the window of the ship's bridge in the marine operational area and uses the telescope to look for the platform's rig. He puts down the telescope and guides the chief officer orally to move the vessel gradually. Simultaneously, he talks with Platform A to ensure that his guidance is correct. Platform A needs to confirm that the vessel is in the appropriate position for the offshore operation—that is, for loading cargo from the platform to the vessel. In addition, the AIS and DP systems help the operators determine how much water and mud are needed to respond to the changed request. Emails from the oil platform are in front of the DP and AIS systems. In this case, the marine operators do not need to walk back and forth to check emails.

The vignettes were used as resources during the workshop with the systems developers.

4.6 **Maritime simulators**

Maritime simulators are designed to simulate marine operations at sea. The aim of the simulators is to train marine operators in all kinds of challenges cases so as to increase their skills in working at sea. Thus, maritime simulators are highly similar to the workspace on a vessel, including the displays. Figure 14 shows a row of displays (white circle). These displays are AIS simulation systems, and they correspond to AIS systems in real workspaces in the bridge of a ship at sea. Four displays (white rectangle) at the left and right chairs are DP simulation systems that correspond to DP systems in the workspace on the bridge of a ship at sea.

Figure 14: Workspace in maritime simulators, including DP and AIS simulation systems. (Photo: Offshore Simulation Centre AS, 2016)

Marine operators must work cooperatively in the simulators as if they were at sea. The simulators are used to train marine operators regularly in accordance with the safety regulations of the International Maritime Organisation (IMO). In my study, the maritime simulators were used as research platforms by the NTNU. These simulators are occasionally revised by systems developers after maritime training (notes from meeting with systems developers, July 3, 2016).

Having described the workspace at sea and the simulator on land, I now describe the setting of the workshops[19]. These workshops occurred from late October, 2015, to October of 2016. Three workshops with the systems developers[20] were organised to discuss the incorporation of the real-world, cooperative work practices of marine operators and associated cooperation issues into the design of simulators. The workshop setting was a small meeting room with a whiteboard placed on one wall. Systems developers from the industry who had similar backgrounds in mechanical and automation control participated voluntarily. The workshops were conducted in three sessions from the fall of 2015 to the spring of 2016. The first two workshops

[19] I describe in detail the workshop in Chapter 5.

[20] As I described in the previous section, I met them on the vessel in the harbour.

lasted six hours each, and the third workshop lasted two hours. In the workshops, I presented my fieldwork at sea in the form of vignettes, and I worked with the systems developers to translate these vignettes. The first two vignettes were based on situations that I recorded in my fieldwork. As previously discussed, the third vignette was constructed to illustrate a complete marine operation on an offshore supply vessel. Moreover, the vignettes showed normal work procedures and presented a safety issue encountered during the marine operations.

4.7 Summary

In this chapter, I explained my reasons for doing fieldwork at sea. Following this, I described my research activities. A brief introduction to the participants was presented before I described the workspace on the ship's bridge, including the DP systems, the AIS systems, the physical environment, the communication devices, the alarm clock and the calculators the marine operators use daily. I provided examples of the marine operations in three vignettes. The aim was to demonstrate the cooperative work of the marine operators to a broad audience which might lack maritime experience. After describing the fieldwork at sea, I described the workshops I conducted with the systems developers. With an overview of empirical setting in present study, the next chapter presents the methodology used in this interpretive research.

5 Methodology

This chapter discusses the choice of ethnography in Section 5.1, including the research paradigm of interpretivism. Section 5.2 describes the methods applied in the present study, including the participant observations, notes, interviews, photos and workshops that were conducted in the fieldwork. Section 5.3 presents an analysis of the gathered material. The chapter concludes in Section 5.4 with a discussion of the ethical considerations of the study.

5.1 Methodology

This study uses a 'folk explanation' approach (O'Reilly 2012), which allows researchers to study and talk about people's everyday lives and their work. No assumptions or measurable properties were made while conducting this study. Furthermore, no oppositions, conflicts or contradictions were detected in the in-depth analysis (Myers and Klein 2011).

According to Walsham (1993, pp. 4–5), this paradigm is interpretive:

> Interpretive studies generally attempt to understand phenomena through the meanings that people assign to them and interpretive methods of research in IS [information systems] are aimed at producing an understanding of the context of the information system, and the process whereby the information system influences and is influenced by the context.

Consistent with Walsham, it is possible to understand work practices through the ways in which people give meaning to the artefacts they use in their work context. This paradigm enables the researcher to understand how people give meaning to their work. According to the interpretive paradigm, human sense-making emerges from situations (Kaplan and Maxwell 1993). Hence, the paradigm is relevant to the goal of the present study: that is, to determine the ways in which marine operators work on a ship's bridge so as to work with systems developers on the meaning of design simulators.

Ethnography is often described as interpretive. Ethnography was originally developed in the field of anthropology, from which it found its way to contribute to CSCW (Blomberg and Karasti 2013). Ethnographic methods lend themselves to an interpretivist stance (O'Reilly 2012). They concern reflection about and understanding of everyday life (Hammersley and Atkinson 1986). Blomberg et al. (1993) suggest four main principles of ethnography: natural settings, holism, description and members' points of view. These principles are defined as follows:

Natural setting

> Ethnography is grounded in the field work. By this we mean that there is a commitment to study the activities of people in their everyday settings. This requires that the research be conducted in a field setting as opposed to a laboratory or experimental setting. The underlying assumption here is that to learn about a world you do not understand you must encounter it first-hand. (p. 215)

Holism

> This emphasis on natural settings derives in part from a belief that particular behaviours can only be understood in the everyday context in which they occur. To remove a behaviour from the larger social context is to change it in important, non-trivial ways. This concern with how particular behaviours fit into the larger whole is often referred to as holism. (ibid, p. 215)

Description

> Based on fieldwork ethnographers develop a descriptive understanding of the lifeways of the group studied. Ethnographers describe how people actually behave, not how they ought to behave. (ibid, p. 215)

Members' points of view

> Ethnography involves understanding the world from the point of view of those studies. Actor-network theory anthropologists attempt to understand how people organize their behaviour and make sense of the world around them. With the realization that one can never truly get inside the head of another as close to an insider's view of the situation as possible. With such an orientation, ethnographers are concerned with describing behaviour in terms relevant and meaningful to study participants. (ibid, p. 215)

Ethnographers use these four principles to study people in their everyday lives and settings. The ethnographer seeks to understand how the relationships between people are embedded in the social and technical fabrics of their everyday lives. However, the ethnographer does not judge what people should do but only describes what they do (Forsythe, 1999). Moreover, an ethnographer creates an understanding of the world from the findings of his or her fieldwork. This point is relevant to the present study, as the marine operators' points of view on the use of operating systems is useful to explaining their cooperative work at sea. In the present study, the ethnographic method enabled me to observe and describe how the operators made meaning of the operating systems, artefacts and their combinations.

5.1.1 My role in ethnography and design

In an overview of ethnography, it is important to present its relationship with design. Blomberg et al. (1993) suggest that we consider ethnography and its relationship to design. Consistent with this, I do not aim at deciding what should be designed in the maritime sector and how operators should work. I am interested rather in understanding the combinations of operating systems, artefacts and their relations in a given setting and linking them to simulator design. Thus, in the present study, ethnography is chosen because it plays a role in design. In addition, ethnography allows a researcher to engage with operators in an effort to understand their work from their own viewpoint. Importantly, design does not happen by itself: The ethnographer must create space for it (Simonsen and Kensing, 1998).

Moreover, as discussed by Blomberg et al. (1993), a trained ethnographer undertakes the analysis of technology in use, the results of which are presented to designers, who then have the task of identifying the relevant aspects of their project. Such collaboration between an ethnographer and designers facilitates the designers' interpretations (Simonsen and Kensing 1998). Simonsen and Kensing (1998, p. 24) explain: 'A team of designers, who have integrated an ethnographic style into their design approach, work in a team with users. Together they conduct an analysis and co-design an artefact'. Consistent with this, it was also vital for me to return my fieldwork at sea as close-up (Jacobsen 2014) descriptions of the professional in different domains. The ethnographic vignette is not something one carries out fieldwork simply to 'write up'. The challenge is to write up the scene-setting events in an appropriate way (Humphreys and Watson 2009). In this study, I am able to provide systems developers with close-up (Jacobsen 2014) descriptions of how safe cooperative work is accomplished and thereby build a 'dialogue' (Randall 2018) between users and developers who were unable to meet each other. With respect to my fieldwork, the use of ethnographic vignettes can point out specific issues to the systems developers, articulating for them what, how and when different actors enrol in a network and how actor-network dynamics change.

As is clear from my lengthy description of the relationships between ethnography, the actor network and the vignette, there is no obviously useful material in the maritime with which to conduct this project. As discussed in Chapter 1, I aimed to use CSCW insights to suggest a translation process for the maritime sector. In this, I was unsuccessful, as maritime systems developers demand specific approaches to assess simulator-based training. However, I was asked how my fieldwork could contribute to designing new assessment methods for design purposes (maritime simulator meeting notes, May 21, 2015). Such questions are outside the scope of my concerns regarding simulator design. In addition, as discussed, if I consider the safety concerns that arise in cooperation, then I must argue that one fruitful way to take safety concerns in cooperation into account is to conduct fieldwork in the maritime domain. Hence, my role in the present study is twofold: 1) I am a researcher who is engaged in the field of marine operations so as to determine how to achieve safe cooperative work among marine operators; and 2) I am also a researcher who has participated in the design process of maritime simulators so as to work with systems developers to create a common way of doing things. Thus, the present study can be seen as a design-relevant ethnographic study (Randall 2018). In the study, I engage with marine operators and systems developers in different domains and, through collaborating with them, offer suggestions to support safe cooperative work among marine operators.

In this manner, I found a way to communicate properly with systems developers. However, to fruitfully support safe cooperation, we need an excellent understanding of the practice-based (Schmidt 2018) cooperative work of marine operators in the present study, as they are professionals who work on a ship's bridge and are trained in maritime simulators. They know much more about safety as a result of their everyday work practices than anyone else. If it is possible to visualize theoretical discussions regarding how artefacts (Pan 2016a) and technical-systems structures (Pan 2016b) help accomplish safe cooperation, then we may produce a useful 'dialogue' (Randall 2018) with systems developers in the design process. Thus, a review of how to visualise empirical data becomes obligatory. Thus, I thought that if systems developers cannot understand ethnographic outcomes, I must consider the interaction (Jackson 1995) between the problem domain (difficulty in using ethnographic outcomes) and the solution systems (systems developers' synthesis). Inspired by software engineering, I have chosen to reconceive and refine my ethnographic outcomes to something resembling the existing techniques which are available in the engineering field. In addition, my refinement can provide the foundations upon which expertise could be built to connect the marine operators and systems developers through a 'dialogue'.

With the lengthy presentation of ethnography, design and their relationships, I will introduce the methods section, which helps make the present study complete. Thus, in the following section, I describe the methods I applied when I engaged with marine operators at sea to investigate their cooperative work in their everyday lives. Also, I present my work with systems developers on land to help them unfold those insights in their designs in a way that is familiar to them.

5.2 Methods

In this section, I introduce the methods used in this study. I then introduce the workshops with the systems developers, which were held on land.

Ethnographic methods include observations, interviews and the taking of notes and photos. The methods used in the present study include engaging in participant observation, conducting different types of interviews, taking photos and holding informal discussions. These methods help to create a more complete picture (Crang and Cook 2007) of the work practices of marine operators. It is acknowledged that what people say and what they do are not the same (Blomberg et al., 1993). Thus, my conversations were always coupled with my observations. In addition, the notes and photos I took helped me to recollect (Blomberg et al., 1993) the events in which I participated. The workshops were held on land, as I intended to build an understanding of how systems developers can be used to make sense of the ethnographic outcomes of their work practices.

Table 1 shows the timeline of my fieldwork. In the table, *S* represents the data that was gathered from the field trips at sea, and *L* represents the data that was collected from the workshops held on land with the systems developers and other stakeholders. The colours indicate the data collection process at sea (light grey) and on land (grey).

Note that different teams of operators participated in this project[21]. However, their work tasks were the same during the period of my study at sea.

[21] There are two teams on the vessel. Each team has deck crews, a chief officer, first officers, chief and engine officers, and so on. The teams work on the vessel in six-hour shifts.

Table 1: Timeline of methods applied, research locations, participants, and aims, indexed by year

WHERE	YEAR	STAGE	DATA	WHOM	METHODS	AIM
Ships' bridge on the offshore supply vessel in the North Sea	**2015**	Fieldwork	S	Marine operators	Observer participants, interviews and photos	Fieldwork
Group room at NTNU	**2016**	Workshop	S + L	Systems developers	Interviews, observations, engineering design process diagrams, vignette and photos at sea	Translation of ethnographic outcomes

5.2.1 Observer participant at sea

In the spring of 2015, fieldwork was conducted on 56 days spread over six voyages for a total of 633 hours. During this fieldwork, the observer-participant method was used in sessions of varying duration and at various times of the year. The observer-participant method is used to understand a group of individuals and their practices over an extended period of time (Madden 2013).

According to Blomberg et al. (1993),

> Maintaining the strictly observer role is difficult and frequently requires being given some culturally appropriate role that allows the observer to "hang around" and observe[22]. Some have characterized this role as that the observer participant, where the participant component is simply the culturally appropriate status given to the ethnographer. (p. 131)

I was permitted to follow the marine operators during their operations. I also sometimes helped to deliver papers from one marine operator to another on the bridge. Though I could not participate in the marine operations because I lack maritime skills, my role as an observer-participant was helpful, as I could participate in the workspace on the ship's bridge. Hence, I did not merely observe the marine operators in their workspaces on the ship's bridge. In addition, it was possible for me to interview them during their operations at sea. I was also invited to their dining room every day, where I held interviews before I returned to my sleeping cabin on the vessel. During the interviews, I took notes to gain a picture of their work.

5.2.2 Notes at sea

The observations of the marine operators' cooperative activities and communications were documented in a notebook in Chinese. I noted the communication because I had the opportunity to listen to the communications between marine operators on the bridge and other crew members on board. To protect against forgetting when a communication occurred, I also took photos during my communications and noted in

[22] Blomberg et al. (1993, p. 131). While unobtrusive observation may be desirable, there are ethical issues that surround observing or videotaping people for study without their awareness. To the greatest extent possible, study participants should be informed about observations or videotaping of their activities.

my notebook when they occurred, who was talking and the purpose of the communication. If the marine operators on the bridge cooperated with the deck crew, I also noted the work of the deck crew as I stood behind the window to observe them, though I was not allowed to go on the deck. Most importantly, I always took notes during my interviews with the operators.

5.2.3 Interviews at sea

The interviews took place between January and June of 2015. Most of the interviews with the operators lasted about two hours, though some were an hour and a half in duration. As a researcher, I did not record interviews, but I did document them in the notebook. The questions I asked allowed the operators to shape the discussion of their work in their work context (Blomberg et al., 1993; Crang and Cook 2007; Madden 2013). Madden (2013) defines this type of question as open-ended:

> An open-ended question leaves the response open to the discretion of the interviewee and is not bounded by alternatives provided by the interviewer or constraints on length of response. (Madden 2013, p. 70).

Open-ended questions also give the participants space to tell about their work and how they make meaning of it (Blomberg et al., 1993; Crang and Cook 2007). This method enabled me to understand the marine operators during our conversations about their work.

The marine operators were interviewed in two locations: the workspace on the ship's bridge, where I asked as many questions as I could during their operations; and in the dining room, where the marine operators were willing to discuss their concerns about their work. On the days when I was on board, I asked the marine operators an introductory question that led to a topic: What is today's task? How is your work today? How do you cooperate with other operators? In other words, How do you help others in your operations? All interviews were conducted in English. In addition to the observations, the interviews and the notes strengthen the quality of my data by correcting my questions and clarifying my misunderstandings. In addition, showing the photos to the operators helped me to clarify uncertainties about their work.

5.2.4 Photos at sea

During the observations and interviews at sea, I took 206 photos to record the systems, artefacts and who cooperated. For instance, I photographed the artefacts and the systems marine operators use daily. In addition, I took photos of the logs with ‘scratch notes’ (see Figure 15) (Madden 2013) of a specific timeframe, the names (their roles) of the marine operators, the offshore operating systems, the alarm clock, the calculator and the paper forms. I also produced a rough drawing to help me remember when a photo was taken, what happened and who was involved (Crang and Cook 2007).

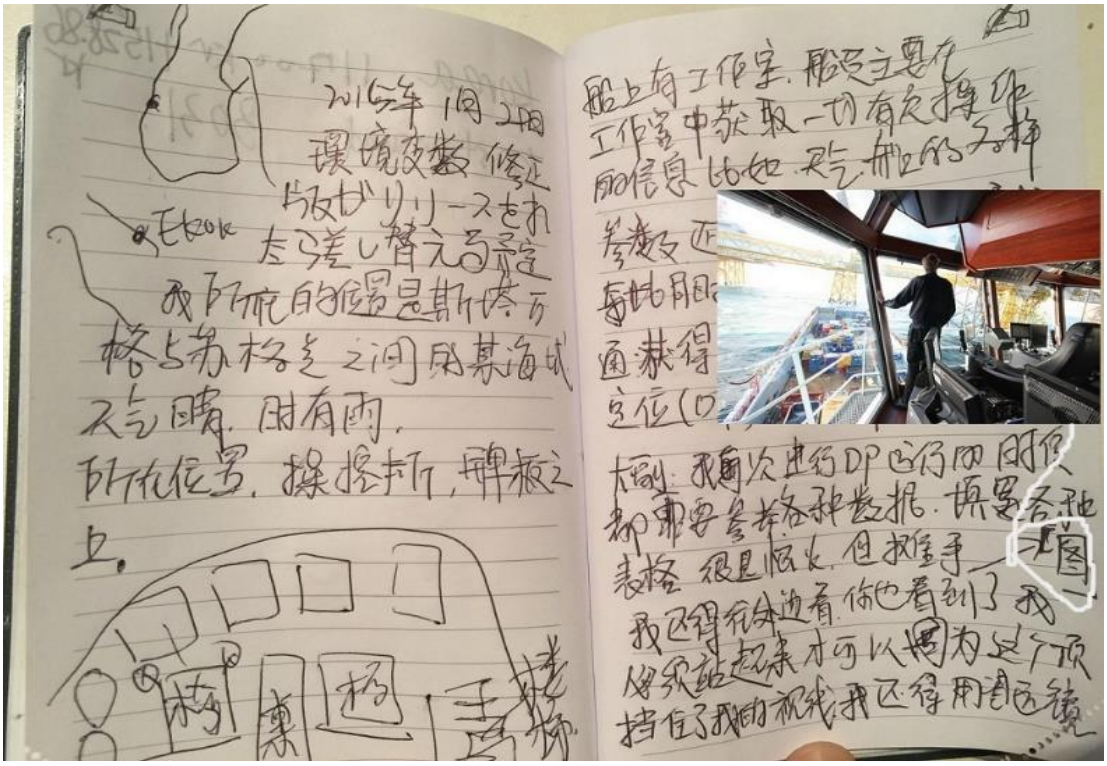

Figure 15: A photo of the log showing notes (Photo: Yushan Pan, 2015)

The photos were later anonymised consistent with the regulations of the *Norsk senter for forskningsdata* [Norwegian Centre for Research Data] (NSD). The rest of the photos (see Figure 16) show the ship bridge without the operators. They were used to explain the marine operations to non-maritime professionals and for publication.

Figure 16: Photos of the field work at sea (Photo: Yushan Pan, 2015)

5.2.5 Workshop

The workshops were held on August 24, 2015; February 18, 2016; and August 5, 2016. The participants were systems developers in the maritime simulation companies. During the workshops, my fieldwork included talking, observing and taking notes about the work practices of the systems developers. The purpose of the workshops was to work with the system developers to interpret ethnographic outcomes. According to Craddock et al. (DSDM, 2014), in the software-engineering field,

> A workshop is a structured approach to ensure that a group of people can reach a predetermined objective in a compressed timeframe, supported by a facilitator. Workshops often use low-tech visual aids such as flipcharts, brown paper, whiteboards, sticky notes, and stickers.

During the workshops, vignettes[23], photos and diagrams[24] were presented to the systems developers. We explored together how to visualise the ethnographic outcomes. Thus, my role in the workshops was that of a facilitator, interviewer and contributor. I also acted as a translator. In the workshops, I also provided input from my observations of the cooperative work on the vessel. This was an important element in working with them as we sought to find a way to translate the insights gained from the ethnographic outcomes into the engineering language used in their work.

During the workshops with systems developers, the conversations were conducted over 14 hours. I also talked with them at lunch from time to time. Moreover, I visited their companies six months after the workshops were completed. When the systems developers and I worked together in the visualising process, we conversed. I asked them questions, and they asked me questions. The engineering-process diagram[25] (Pahl et al., 2007) was also used by the systems developers, as they wanted to ensure that our visualising process did not misinterpret the system's technical features.

The interviews also provided many opportunities for new ways of seeing and understanding cooperative work in visualising processes. I took notes during the workshops as part of my analysis. I sometimes designed diagrams and figures in conjunction with the systems developers while I observed them. In addition, the process of creating visual diagrams encouraged the systems developers to draw with me. In this process, I translated the human to non-human interactive relationships among the marine operators, artefacts, and systems into actor networks. I also showed how the concept of awareness could help the systems developers to visualise the interactive relations among marine operators, systems and artefacts in each specific marine operation.

[23] Similar ones were used in the empirical setting. See Chapter 4.
[24] See Chapter 6. I used the diagrams to translate the ethnographic outcomes before I worked with the systems developers.

[25] An engineering process diagram is a diagram commonly used in the general engineering field (i.e., chemical, process, hardware, and software engineering) to indicate the general flow of devices, software models, and equipment (Pahl et al., 2007, p. 34).

5.3 Analysing the material gathered

My data analysis focused on the data gathered in the fieldwork at sea. The data analysis began with thematic indexing coding (Madden 2013) to find themes related to the meaning of the cooperative work of the marine operators and their use of artefacts to support their safety during their cooperation. I sought to determine how the marine operators made sense of their cooperative work. I paid attention to specific terms and wrote them in my native language, such as *cooperate* (协作), *collaboration* (合作), *together* (一起), *jointly* (共同), *needs help from* (需要…的帮助), *partner* (搭档), *assist* (协助), and the relevant context regarding safe (安全) cooperation. I also marked the themes chronologically according to different events in the fieldwork. However, I used Chinese text to emphasize cooperation issues as themes, such as *one* (壹), *two* (贰), *three* (叁), *four* (肆) and so on. According to Madden (2013),

> Coding of field notes refers to the manner in which we index and identify themes in our notes which are of relevance to the questions we wish to ask in our ethnographic project. There is a potential for tension here between the idea that data consists of facts that will speak for themselves and that data consists of information that we actively create meaning from as a consequence of our own intellectual and theoretical predispositions. (Madden 2013, p. 139)
>
> A theme is what you like make it: it could be a large sociological category, a group behaviour, and individual behaviour, an aspect of the physical setting or an observation of a mood or feeling, it all depends on the way which the ethnographer wants to interrogate or 'unpack' his or her data as to which themes, codes or topics will be chosen to identify and organize the data. (Madden 2013, p. 142).

Thus, by identifying themes, coding helps to determining the meaning of the data gathered in the interviews, observations, discussions and photos regarding the cooperative work of the marine operators, the offshore operating systems and the artefacts in the workspaces on the ship's bridge. The focus was on how and when the actor networks were established to conduct what marine operations. The coding process also identifies the actors in the actor network and who joined or left the network and for what reason. The analysis of the data collected during the fieldwork at sea provided an important resource for translating the ethnographic outcomes to communicate with the systems developers in the workshops on land. The following section addresses the ethical issues considered in the present study.

5.4 **Ethical Considerations**

In 2014, though the empirical material collected in the fieldwork at sea did not contain sensitive methods or sensitive data, the present study was nevertheless approved by the NSD to ensure everyone that all materials are to be kept confidential. Moreover, permission to conduct the fieldwork and workshops was obtained from the NSD, NTNU, the simulation company and the shipping company. Written consent and oral consent were obtained from the marine operators and the systems developers before the interviews and observations were conducted, and the notes and photos of personal communications were taken during both the fieldwork and the workshops. In addition, all participants were assured that their participation was voluntary and that they could withdraw from the study at any time. Moreover, the confidentiality of the data and the anonymity of the participants was assured. The names of the marine operators, systems developers and the shipping company are not included in the data. However, because few research institutions and simulation companies in Norway focus on maritime simulators, it is possible that some participants may nevertheless be identified.

5.5 **Summary**

In this chapter, I presented my choice of ethnographic study in the present study. Due to my dual work – conducting fieldwork and translating ethnographic outcomes – I described my role in ethnography and design research. I also explained how the chosen methods are used for collecting research data and how the gathered material are analysed. Finally, I end up the chapter with the ethnical considerations.

6 From themes to diagrams

This chapter presents the process of translating the ethnographic outcomes. This process can itself be seen as an analysis in this project. The *prelude* in Section 6.1 explains the analysis of the ethnographic study at sea. The *intermezzo* in Section 6.2 describes the translation of the ethnographic outcomes prior to the workshops. The *aria* in Section 6.3 discusses the workshops with systems developers to determine how the translation of the ethnographic outcomes could be used in their work. Section 6.4 provides reflections on the study. Section 6.5 reflects on the generalisability of the approach and findings. Section 6.6 provides a brief summary of the chapter.

6.1 Prelude – Understanding of cooperative Work

Prior to the translation I performed, it was important to answer the following question: What resources are used in safe cooperation on a ship's bridge at sea? Answering this question involved examining how marine operators give meaning to cooperative work on a ship's bridge. Therefore, two vignettes are analysed to answer the following questions: the first asks how cooperative work is accomplished; the second asks what resources are used by the marine operators to ensure safe cooperation. As discussed in Chapter 4, I also constructed a third vignette, which I intended to use to show the systems developers a complete cooperation at sea before the workshops were held.

6.1.1 Vignette 1: DP operations

In Vignette 1 (see Section 4.5.1.1), the operators working on the ship's bridge systems use multiple artefacts. The operators—Andre, Emil, and other crewmembers who were located in different places on the vessel—worked together with the bridge systems. The DP operating systems require the recording of all the information Andre needs to transmit access to the communication channel. The recorded information is a core point on the checklist, which has to be filled in for each DP operation. The checklist should also be present during all DP operations. The status of the containers should be reported so as to ensure that the balance of the vessel is maintained the operation. In addition, the engine status must be reported. Otherwise, the vessel may be too close to the platform, which increases the risk of colliding with it. The container's pressure should be displayed in the ship bridge systems to pipe water or mud successfully. These attributes of DP systems require the following changes in the cooperative work because they require work tasks for Andre, Emil and the crewmembers both on deck and in the engine room: Andre must connect with the engine room, and Emil has to know the information required for the DP operation. Andre must connect with the engine room and the deck crew members to determine the information required for the DP operations. The operators in the engine room and on the deck—Andre, and Emil—must work together to maintain these lines of communication in DP operations. For example, in checking the distance between the vessel and the platform, it is important to check the engine. Emil records this information on the checklist before starting the DP operation. Andre must connect with the deck crew to turn on the container's valve on the deck and to assist the operator in monitoring the crane on the platform. Hence, the checklist in the DP operation links to all other actors, both human and non-human, in different locations; such links build the DP operation as a network. The relationships of the human and non-human actors are important (Callon 1986b; Latour 1994).

In the DP operation, awareness (Schmidt 2002) exists in connection with action. On the bridge, Andre and Emil know that their peers are doing their work to cooperate with them, as they have informed them of this fact. Andre and Emil know the setting, understand the processes and issues and know what could happen during their operations. Andre knows that he cannot see the pipe pressure on the display because it is too far away and because it does not show an accurate figure. This awareness of specific work practices (Schmidt 2002) helps us to interpret and understand the context of the systems, the artefacts, and the operators' work process in which they influence and are influenced by the work practices. Thus, understanding cooperative work is achieved by following the interactions in a network during the operations to determine how the operators determine which artefact to use based on their work experience (Pan et al., 2015). As situations change in the work practice, they successfully accomplish marine operations.

In addition, two important artefacts in the network must be discussed. Andre uses his clock to set an alarm to ensure the vessel's safety, which expands the interactive relationship. Similarly, Emil must stand near the window (see Figure 3) and tell the platform crew member to lower the crane when the checklist is finished. Neither of these actions are part of the ship's bridge system or of the training course onshore, as the simulators do not require the calculation of the quantity of water and mud used to balance the vessel. Only the researcher's insights about the work practices in the field revealed the problem in the system and its solution in the cooperative work practice. The researcher demonstrated that the DP systems—both the system and its modifications—work together to finish a task. Such problems occur not because of the system itself but because of the complex operation procedures and the interactive relations of the human and non-human actors (Pan 2016a, b).

Thus, the alarm clock and the calculator are part of the network. Andre waits for the alarm, and he also uses the calculator while he waits to ensure the safety of the vessel. The DP system is only a part of the marine operations; the ship bridge system may have many other systems. When the platform pipes oil to the vessel or exchanges mud at the same time during the maritime operation, the operator has to maintain the DP operations for a long time because the waves and the winds may cause the vessel to become unbalanced. The alarm clock is an artefact that may help align the tasks of Andre and other crewmembers. It may help align the tasks of Emil because they all are in ready mode and are waiting for inquiries from the operator on the platform. The design of the simulators needs to consider such dynamics. Hence, based on the findings of the analysis, the work of the non-human actors is merged into the network to ensure the safe accomplishment of the work. Thus, the cooperative work in the network was determined by identifying the need to add non-human or human actors to the network (Paper 1).

6.1.2 Vignette 2 – A service changing request from the oil platform

This vignette (see Section 4.5.1.2) includes several components that are connected in the network during operation procedures. The network is connected when Tom and Ali check the paper-based checklist. Tom, Ali, and the paper-based checklist are actors in the network, all of which share an interest in this task. Tom wants Ali to check and approve the checklist. Ali examines the checklist and gives final approval. The checklist needs to present all the information required by the operators. The checklist connects to both Tom and Ali. However, in this process, the network is still in the DP operation. The network expands when Tom picks up a communication device. It is easy to see the point at which the communication device participates.

Tom is interested in getting information from the engine room because it is important to know the status of the vessel. The engine room operators become connected to the existing network via the communication channel. These operators share their knowledge with the bridge operators, as this is required by the work procedure. However, they also want to share this information with other people, though they are not required to do so:

> Engine operator: We want to let others know the engine status of the vessel. It is important for everyone to know since we do not want to put others at risk during offshore operations.

Thus, all members of this network have the common goal of safe operation.

When the vessel is positioned, the network is reshaped. The engine operators leave the network because their tasks in the main operation are finished. At the same time, the platform operators join this network. At this point, the actors are Tom, Ali, the platform operators, the AIS systems, the containers on the platform and the vessel. In this study, this network is termed the 'host actor network' (see Paper 2). *The host actor network* refers to the DP operation.

Tom has to balance the vessel during the operation; that is, he monitors the status of the containers under the deck via the AIS and obtains information from Ali about the weight of the containers. Information from the AIS and container are important because this information allows Tom to determine how to operate the DP and AIS systems, such as by manually changing information in the AIS systems, running the DP operations and communicating with the platform during the operations to coordinate the positions of the containers on the deck. This network seems structured; however, when a new task is introduced into this straightforward operation process, the network must be reconfigured. When the platform operators ask Tom to change the mud, this request breaks the host actor network, thus forcing Ali to consider several factors from the company's point of view—particularly the costs of the quay and the everyday expenses at sea. When he decides to email the company to ask for permission to change the mud, his work is not involved in the host-actor network. For example, the platform operator requested that the mud be changed, and Tom had to change it. However, Ali had a different task because he needed final approval before changing the mud. If Ali had gone back to call the company, the host-actor network would have broken down because of Tom’s new task. The email, the new checklist, the company on land and the narrow channel expand the host actor network into a complex process. Because the platform and the vessel are connected, it is difficult to stop Tom while the containers are being raised and lowered on the platform. Tom must stay in the host actor network until he presses the emergency-stop button because of a platform error: The wrong container was being lowered.

When Ali undertakes other tasks, such as running via the narrow channel on the ship’s bridge, checking emails, making a new checklist and calling the company on land, a parallel actor network is established, which is termed the ‘parallel actor network’ because its advent does not prevent the operation of the host actor network (see Paper 2). However, this network weakens the host actor network and compels the operators to take more risks. When Ali joins the parallel actor network, Tom, who is in the host actor network, faces difficulties and cannot handle the rapidly increasing amount of work. That is, he cannot not operate the vessel and pump water or mud between the platform and the record container.

Both the DP and AIS systems are unable to receive and process any information from the outside, such as requests to change the mud from the platform. Ali must respond to this request to finish the offshore operation. When he finishes his work and goes back to his seat to help Tom, he brings the new permission from the company and lets Tom know how much mud the vessel can provide the platform. At this point, the parallel actor-network ends. However, when Ali returns to the host actor network, Tom has to reconfigure the mud process to keep the vessel balanced while the mud is changed. Hence, all of the actors in the old host actor network must reconfigure their work practices in performing the new operations. Before this reconfiguration, there is a break between the parallel actor network and the reconfigured host actor network which results in an emergency stop because the wrong container is being loaded (Paper 2).

To fix this problem, the actors had to cooperate to return the wrong container and maintain the vessel’s balance. The DP, AIS, Tom, Ali, the paper-based checklist, the mud, the container and the platform reformulated their roles to reach the common goal of safety considerations (Pan and Hildre 2018). Because uncertainties happen all the time in oilfields, the switch from the host actor network to the parallel actor network occurs frequently. The result is the high workload on the bridge and increased safety issues. The actor network is dynamic (Callon 1986a) and unavoidable (Hanseth and Monteiro 1998). In this vignette, when the actors reconfigured the host actor network, its actions changed. Every interest of new actors was new and had to be retranslated. When the old host actor network was broken and reconfigured, Ali had to stop his original work to bring the computer, the printer, the narrow channel and so on into his new work. The analysis of the parallel actor-network and the reconfigured host actor network have revealed two problems. First, the operators on the bridge face different challenges in reaching the required workspaces around them, such as the computer, printer and the email systems. However, the current systems cannot help them respond to changing requests. Extra artefacts from daily work and life must be brought in to assist them in the DP operations (see Paper 1). It was observed that the moveable chair was useless during the offshore operations. Ali just ran back and forth. Ali and Tom stated the following:

> Ali: If any changes have to be made, like changing water or mud type, I just quickly run to the computer, check the email, print, and talk to the company. I do so because we have limited time to work each day. We have to [be concerned with] the waves and wind, and I also need to make sure Tom can use this time to handle everything. So we have to save time; otherwise, we will waste thousands of krone per day without doing anything. I never use the moveable chair because it is too slow. Tom cannot wait that long for me. Actually, I want to have a small digital device that can help me to check and print without moving, but [unfortunately] there is no such technology, like something on my mobile phone.
>
> Tom: Sometimes we have to leave the operational area together because I have to observe the container from the platform when Ali cannot help me. It is the most dangerous moment because I need to balance the vessel by shifting water or mud from each side, right or left, to ensure the vessel is ready to take the container. I cannot work on that many tasks at the same time.

When the network became a reconfigured host actor network, the workspaces and the operational systems were not able to support safe operation procedures. The current operational systems (i.e., DP and AIS) could not support the operators' needs to check emails and print out checklists in the operational systems area. To finish this task, the operator had to leave the host actor network to join the parallel actor-network. It was not possible to avoid reconfiguring the host actor network, as the requests were introduced into the operation. Hence, analysis of this vignette reveals that, though the chair, computer, email and printer should have been participants in the host actor network, they were not. Based on this finding, further research is required to investigate the redesign of the ship's bridge to consider the disruptions of individual actors in the workspaces and to maintain their connections to others in the entire network (Pan 2016a).

> Ali and Tom: We would prefer to only have displays in front of us without the chair. When we are trained onshore, we never think this is a problem. But now as you can see, we are struggling with our work.

6.1.3 Researcher's insights into the design of maritime simulators

These insights into how cooperative work is accomplished through the resources that are designed for unanticipated use (Robinson 1993) show that they can be applied in the redesign of maritime simulators.

Randall et al. (2007) argue that a product should enable a user to achieve his or her goals and that the investigation should be an assessment of how user's make meaning of the use of technology. Thus, the present ethnographic study has revealed that the design of a useful maritime simulator should consider the ways in which activities take place at sea. The findings also reveal that the work practices and artefacts the operators use every day are valuable resources for the design process. The analysis of the cooperative work has revealed the marine operation's dynamics (Pan 2016a) and its relationships across its own boundaries, such as the host actor network (Paper 2), the parallel actor-network and the reconfigured host actor network. The analysis shows that the DP systems were used only to position the vessel. In addition, the operators used other resources to help them judge whether they could perform the DP operation, such as checklist, weather, engine and the distance between the vessel, the calculator, the alarm clock and the platform (Paper 1). Hence, DP systems do not work alone. The operators need to use the DP systems in collaboration with the AIS systems in the context of their work. Every actor in the actor network has a role to play. The non-human actors are used both to coordinate the cooperation and are parts of the actor network and its features in the technical system.

Hence, it is important that researchers who work in the field have the ability to show the relationships between different actor networks, as has been addressed in previous studies on ethnography and design (Blomberg et al., 1993; Blomberg and Karasti 2013; Khovanskaya et al., 2017; Randall et al., 2007). However, the demonstration of the relationships between ethnography and design requires a method to work with systems developers. As presented in the literature, this insight contributes directly to narrowing the distance between ethnographic outcomes and systems developers' solutions (Randall et al., 2007). The translation of ethnographic outcomes does not explain the phenomenon of the problematic situations that arise in cooperative work. However, they show how to work on design by considering work practices (Baxter and Sommerville 2011). Therefore, the insights must be added to reworking the ethnographic analysis so that systems developers can use the findings (Blomberg et al., 1993; Khovanskaya et al., 2017; Randall et al., 2007; Simonsen and Kensing 1998). Thus, researchers should translate their findings and work cooperatively with systems developers.

In this vein, I argue that the simulator is not introduced to an organisation. Marine operators can avoid safety problems because they practice their daily tasks in a manner which solves them via cooperation. In fact, operators are able to explain how safe cooperative work is achieved and how to use this insight to shape technology in their organisations. I would also argue that cooperative systems are designed to support safe cooperative work rather than to force operators to adapt to avoid safety issues. Barely focusing on a highly reliable human organisation is insufficient; it is important to focus on utilising operators' cooperative work practices in safety-critical technology to work on design. Thus, the translation of ethnographic outcomes is not a process of seeking technical solutions but of introducing a new angle that goes beyond analysing the high reliability of organisational culture (Weick 1987) to focus on creating 'dialogue' (Randall 2018) with systems developers when dealing with safety cooperation.

6.2 **Intermezzo – Translation of ethnographic outcomes**

As described in the prelude in Section 6.1, DP operations are fundamental to the vessel observed in the present study. This work involves the complex cooperation of the AIS systems and the artefacts. Though AIS systems are used to assist DP operations during maritime services, they have specific tasks in marine operations. However, operators do not need to operate AIS systems because they are automatic. Thus, I narrowed the focus to the DP systems to determine whether I could translate the ethnographic outcomes to help in the design of such systems. However, the DP and AIS systems work in cooperation.

Because my background is in software engineering, I chose a familiar language: the unified modelling language (UML).

> The UML is a general-purpose, developmental, modeling language in the field of software engineering, that is intended to provide a standard way to visualise the design of a system. (Booch et al., 2005, p. 496)

The UML can be used beyond conventional software modelling to establish a central, holistic product representation. Furthermore, the use of a UML-based central product model is facilitated by the many modellers who are already familiar with the widespread and standardised UML modelling language, such as mechanical engineers (Reichwein 2011). In this study, such familiarity was imperative, as most maritime systems developers are in the mechanical and automation field. To ensure that my work could make sense to those with different competences, the UML was chosen.

In performing the translation, I checked the results of the analysis of my fieldwork to understand how the actors build their interactive relations with the surrounding resources. I focused on the resources that were used in a safe cooperation. As discussed in the previous section, the actor network is especially helpful for framing insights into informal constructs (Schmidt 1997), which supports the identification of the actors and the artefacts they use in the operations. In constructing relationships, the factor of awareness (Schmidt 2002) is important to determining how interactive relations are created between actors. Awareness is constantly achieved in collaboration with others in the immediate environment (Schmidt 2002). Hence, I could explain how an operator, an artefact or a system created awareness of special cooperative work. Through this awareness, I linked the actors in an actor network by tracking the coherent activities of one actor to the activities of another until the cooperation was completed. The actor network shows that the cooperative systems in marine operations can be connected by focusing on how the DP operations are related to other operations. For example, when the first officer needed to fill in the DP checklist for running DP operations, he did not need to check the engine status in relation to the process of the DP operation. However, he was aware that the engine could obstruct his work if it stopped or work incorrectly, thereby raising the possibility of unsafe events. Therefore, he called the engine room to check the status. This process can be described as follows: I am an actor in the network, and I care about the information that is important to my work. I need such information to inform my work, which is taking place under conditions of safety (Paper 3). Therefore, in visualising an activity and its relationship with other activities, the first officer creates an actor network. According to Latour (2005b), the 'actor itself can be an actor network'. Thus, the actor network consists of three components as part of the function of the DP systems: the checklist, the engine status and the weather (see Figure 17).

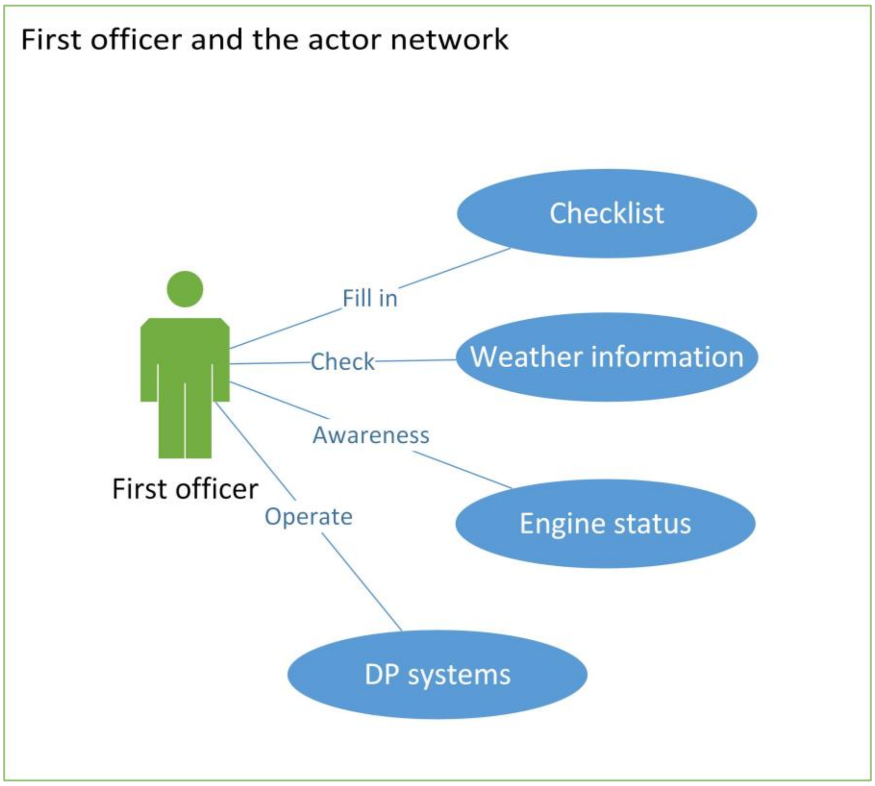

Figure 17: First officer, awareness, and the actor network of activities

However, the purpose of visualisation is not simply to add components to the current systems. It is also important to consider how visualisation is associated with other activities in the actor network (Paper 3). For example, if the first officer cannot check the engine status directly, he calls the engine room for help. The engine room needs to answer his inquiry. In addition, he also needs to double-check information about the weather, which is provided by his colleague and which both the ship's bridge and the engine room require. The engine room double checks the weather because it is concerned about safety. The engine room needs to confirm that the officers on the ship's bridge follow the instructions of DP operations regarding weather conditions. In this case, the DP systems offer a rich picture, moving from one visualised actor to the relationships among the actors who cooperate in accomplishing an operation (Vederhus and Pan 2016). This picture is provided in Figure 18.

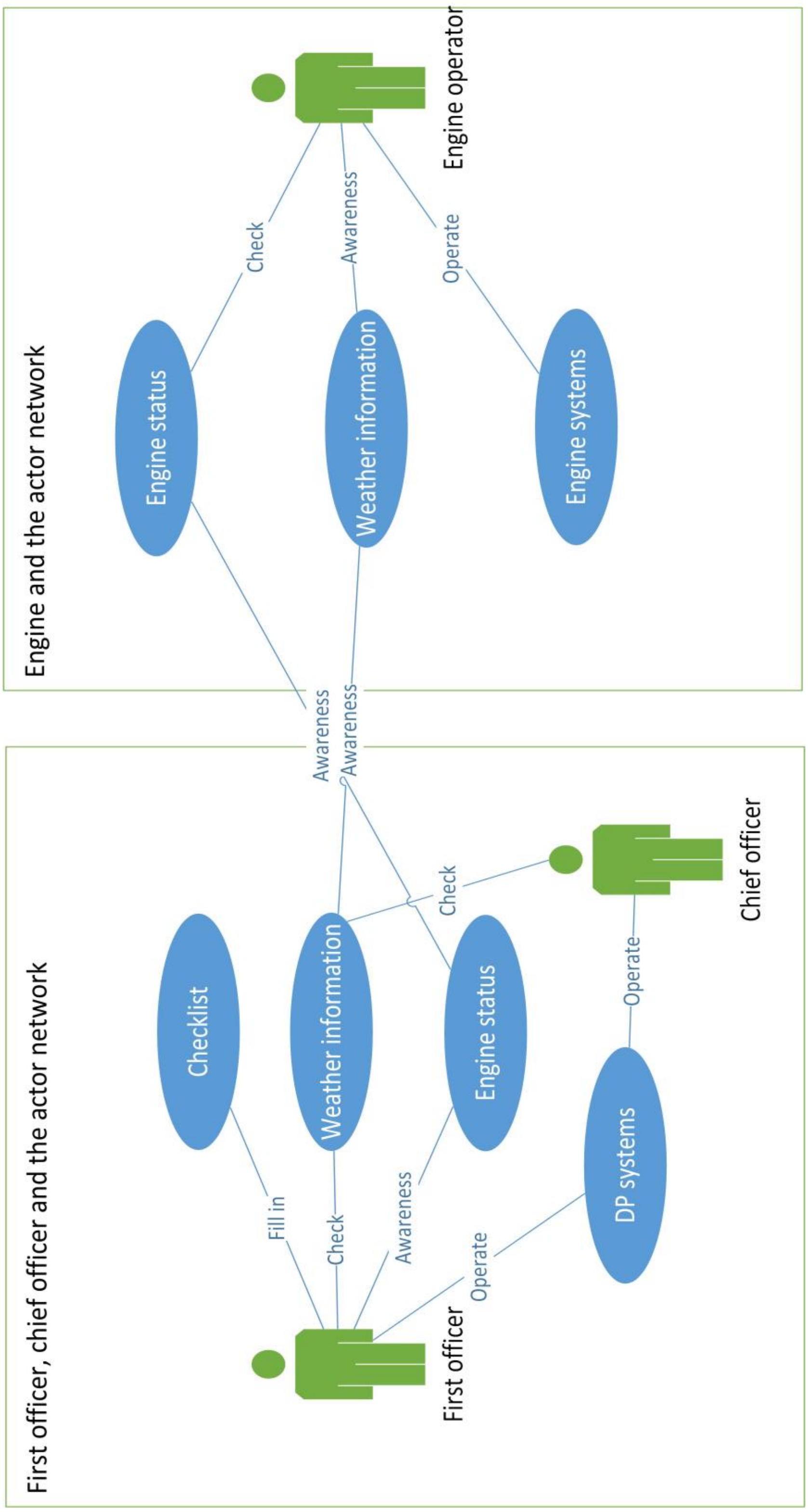

Figure 18: First officer, chief officer, engine and their combined actor network

After the first officer has processed the information about the weather and the engine status, he then needs to hand his job over to his colleague to find a rig to assist the vessel in moving into its proper position. The platform also engages in the actor network by communicating with the first officer's colleague. In this case, the first officer is concerned about whether he can successfully find the rig and help guide his colleague to position the vessel correctly. The colleague is aware that his ability to position the vessel depends on the oral guidance received from the first officer. The platform operator needs to be aware that both officers are involved in positioning the vessel at the right point under the rig, so the continuous communication between the platform and the first officer does not end until the vessel is in the correct position (Pan 2015). The common goal of these activities is safety, which is the concern of all actors during DP operations. By considering the awareness in the actor network, it is not difficult to link the actors and their interactions in the actor network as shown in Figure 19. These diagrams include the operators and their interactive relations with the DP systems so as to provide a detailed visualisation of how the operation is accomplished.

The operators told detailed stories about operations in their living and working via their languages, behaviours and reflections on their daily work. The researcher engaged in their workspace learned from them, which led to reflections on design. Through the visualisation, the researcher was able to integrate social activities that were outside the features of the DP systems. Thus, the findings of this study contributed new insights to the systems' ability to help operators complete their operations, and it identified the actors in the network, the activities, the participants, the systems, the artefacts and the purpose. These findings enabled the researcher to understand the design of maritime simulators from the systems developers' perspective. The findings revealed problematic areas that may need to be redesigned. Hence, the translation process converted text-based ethnographic outcomes into visual diagrams that show where technical solutions (i.e., non-humans) are needed in the maritime simulators. Based on these findings, the researcher could contribute to helping the systems developers find technical solutions through the actor-network diagrams.

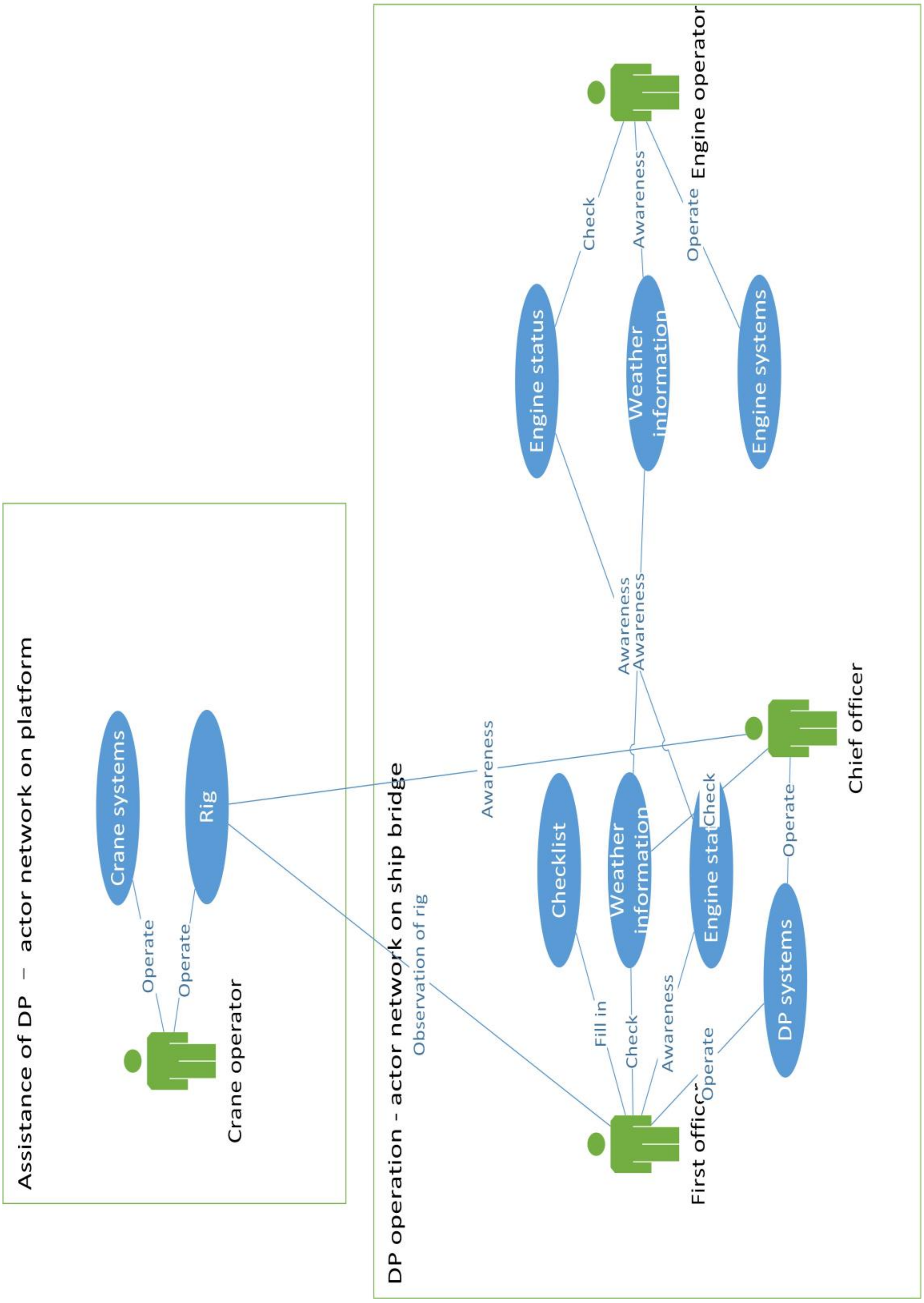

Figure 19: The process of making different actor networks for systems developers: how actors work together

As discussed in the literature review, such work has the potential to introduce new insights into the maritime domain by highlighting the importance of the marine operators' cooperative work and the need to consider it in the design process. The collaboration in systems design involves development teams, users and designers. Importantly, researchers can report the findings regarding the cooperative work of users and talk directly to systems developers regarding technical solutions to design problems. The translation of ethnographic outcomes (Blomberg et al., 1993; Khovanskaya et al., 2017; Randall et al., 2007) responds to the call to educate systems developers to gain a knowledge of ethnography (Sharp et al., 2016) and thereby learn how to work with the researcher. In this approach, it is possible to link the complexity of human activities and technology to reshape technology for a design purpose. System design does not need to be confined to the management level to model human activities (Checkland and Poulter 2010). Researchers can investigate the technical level to discuss social-technical solutions.

Hence, to discuss the diagrams with the systems developers to determine whether the translation makes sense to them and can be used in their work, prior to working with systems developers, I held discussions with technicians[26] at the university and scientists[27] who visited the department from Stanford University. The purpose was to confirm that I had not misunderstood the technique I applied. During the discussions, I modified the diagrams slightly based on comments by the technicians and scientists.

6.3 Operatic Aria: Working with Systems Developers

While working with systems developers, I showed the diagrams I created prior to the workshops and explained how I made them. I then presented the vignettes to the systems developers and asked them to make visual diagrams of them.

However, when I explained the diagrams to the systems developers, they asked me about the line between marine operators and the technical systems in my visual diagrams. The systems developers showed me an engineering process diagram of DP systems (see Figure 20). This question was significant for the methodology used in the research community (Bannon 2011; Guzdial 2013; Sebe 2010). According to de Souza et al. (2016, p. 2),

---

[26] The technicians worked on maintaining the maritime simulators at the university.
[27] The scientists who worked on mechanical engineering and engineering design for various simulators at Stanford University.

> The methodologies being called for should be able to articulate technical factors with personal, social, and cultural factors, not only with respect to the use of technology, but also with respect to its design and development.

This is why I went into the field to understand how people made meaning of their work, as it is important to understanding technology use in reality. However, it is also important to respect those who work on design and development. Therefore, I put the systems developers in the users' place to alert the scientific field. I introduced them to actor network theory and the concept of awareness. I emphasised that when I make diagrams to show the cooperative work among DP systems, artefacts, engines and operators, I do not distinguish human and non-human actors. I explained that they are all connected through their interactive relationships in an actor network. Therefore, the first issue encountered in working with systems developers was to answer their question about the line between the human and the non-human actors, which helped them to derive meaning from the visualised diagrams in their work.

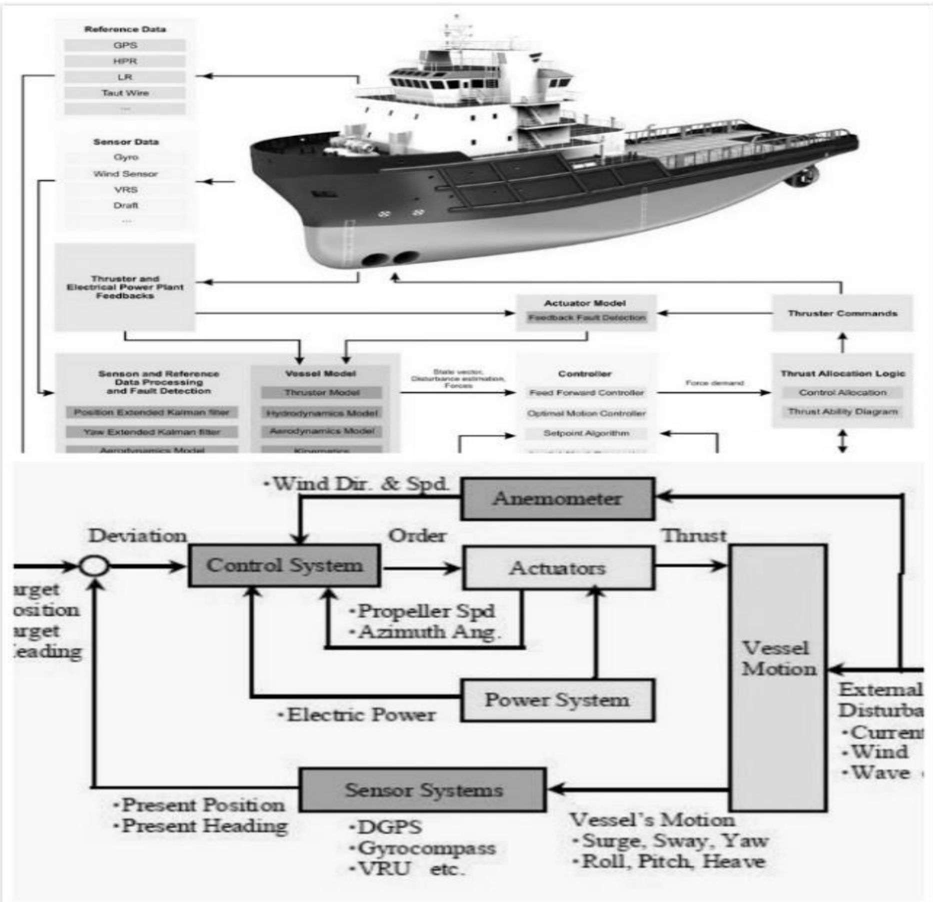

Figure 20: The engineering-process diagram of DP systems (Copyright: OSC AS, used with permission)

6.3.1 Blurring the social and technical border

Before I answered the question about the line between the marine operators (social) and technical systems (technical), I explained that, according to ANT, both humans and non-humans are ‘actors’ (Latour 2005). The emphasis is not on who they are but how they are connected in a new social-technology world. The systems developers then suggested using UML because this language is used to model a system without distinguishing humans and non-humans. It instead focuses on interactive relationships between them (Rumbaugh et al., 2004). However, they focused on the trigger[28] between humans and non-humans, because it is with non-humans that a method is designed to respond such triggers (Matha 2008).

I used Vignette 2 (see Section 4.5.1.2) to explain that when a change request is sent from the oil platform, the cooperative work between the two marine operators on the ship’s bridge is accomplished. We identified the theme in three different cooperative works:

1. The DP operator works on the DP but needs assistance from the deck crew and crew on the oil platform.
2. The deck crew on the vessel assists the DP operator by lifting the container onto the deck and communicating with the oil platform.
3. The operator works on the AIS systems and cooperates with the DP operator.

For example, in Vignette 2, both officers are aware of their actions in interacting with the DP and AIS systems and with other people on the deck and the platform. Tom needs to know information regarding the crane position before positioning the vessel correctly. To accomplish this task, he needs help from the deck, the platform and his colleague, Ali. Information about the AIS system also needs to be confirmed by Tom, such as the status of the containers for liquids, stripping, tank and bulk systems. All these factors build the actor network from Tom’s position. Ali needs to check the container’s information and monitor the container operations and report information to Tom.

[28] A Trigger indicates an event that initiates an action (and might arise from completion of a previous action) by an actor (Matha 2008).

Tom works with other actors in the network and manipulates the DP systems and the supporting artefacts (i.e., forms and checklists). The current DP systems support his activity by checking the information from the AIS system. However, it is impossible for him to process the information that must be provided by the other actors, such as Ali, the platform crew, and the deck crew, all of whom have to communicate with him during the dynamic positioning operation. Tom has to make his work visible and public by means of the communication artefacts. The DP systems must to some extent support his work, though this is outside the task of the dynamic positioning systems. However, without his activities, the DP operation is pointless regarding safety operations. The purpose of the visual diagram is to point out where the appropriate technical solution can be placed to support the cooperative work of the marine operators. Moreover, the visual diagram links the salient issues to the technical systems by showing what is missing. The diagram also outlines the interaction between the deck crew and the container systems and Ali and the AIS systems regarding their interactions with other actors and their activities. We also outlined the actor network by integrating the social interactions into the mechanical actors by connecting human and non-human actors in the actor network by weakening the system borders between the social world and machine world (see Figure 21).

With this understanding, the focus of the design paradigm[29] is shifted to both social activities and technology for the social-technical understanding of how social and technology are merged in the awareness-based interactive relationships in the actor network. This new focus contributes to the literature on design in the maritime domain by emphasising that safety involves not only the application of engineering and techniques within the constraints of operational effectiveness and time but also requires the cooperation of the actors in the network. Safe cooperation among marine operators, technologies and artefacts can also help to shape the technology to avoid needless risks. This insight brings the use of technology into design and responds to a ‘hard challenge’ (Cartensen and Schmidt 2003) by showing how to deal with the conceptualisation of fieldwork and providing typification (Cartensen and Schmidt 2003) to explain that conceptualisation. The following section describes how the

[29] The term ‘design paradigm’ (Warren 2000) is used in the design professions, including industrial design and engineering design, to indicate an archetypal solution. It can be used either to describe a design solution or to describe an approach to design problem solving.

system developers in the present study made sense of the translated ethnographic outcomes in their design process.

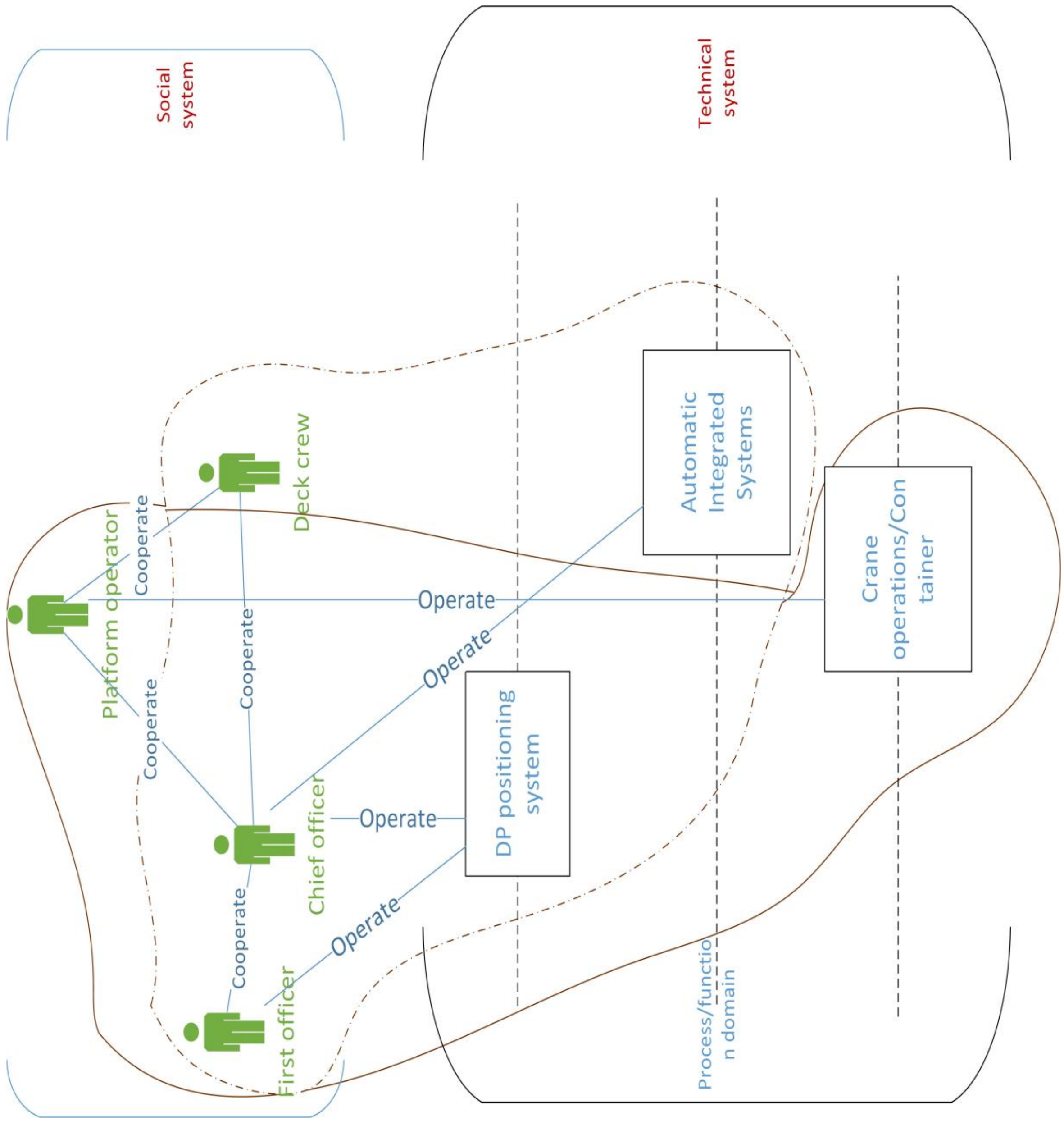

Figure 21: The DP, AIS, officers, deck crew and platform crew created the actor network. Solid line indicates actor network of DP operations. Black dotted line indicates actor network of crane operations.

6.3.2 Assembling the translation process into the engineering-process diagram

The systems developers could then make sense of how a social-technical world is built. As discussed above, in the design of an object, features are arranged to enable the trigger that human activities can be involved in the functions of technical artefact (Rumbaugh et al., 2004). Hence, it is important to know how developers will use the visual diagrams. During the translation process, we checked with each other to determine the ways in which the translated diagrams are relevant to the engineering process diagram. We were particularly concerned to determine that we did not misuse a critical feature, as the diagrams were to show where a technical solution is needed. The systems developers suggested that, if they unpacked the boxes in the process diagram and determined the relevance of the translated ethnographic outcomes to the existing technical methods, then they could rearrange technical solutions to correspond to the insights the researcher provided. Hence, the diagrams were not used to change their work practices but as supplements to help them to determine whether the features in the systems could respond to the marine operators needs during their cooperative work.

Hence, in the workshops, the system developers used the translated ethnographic outcomes as artefacts to determine whether changes are needed in the maritime simulators. For example, severing the oil platform requires that the DP and AIS systems work with the marine operators. The functions of the DP and AIS systems should thus be designed to support each other regarding the problematic areas indicated by the interactive relations among marine operators, artefacts and systems in the translated diagrams. In addition, because the actor network is dynamic, different actors may be involved in different actor networks in diverse marine operations. The translated diagrams show the systems developers how every cooperative task is completed. For example, the translated ethnographic outcomes help to open the DP process box (see Figure 22), thereby to help systems developers design solutions which allow the marine operators to check weather information and engine status. Moreover, the diagram also enables the DP system provide feedback from the crane to support the operator, thereby facilitating the accurate and quick positioning of the vessel. When the DP systems need to cooperate with AIS, the diagram could add the AIS box and tell the systems developers what is needed to support the cooperation. For example, when AIS systems show the DP operator the balance status of the vessel, the DP operator performs the operation carefully.

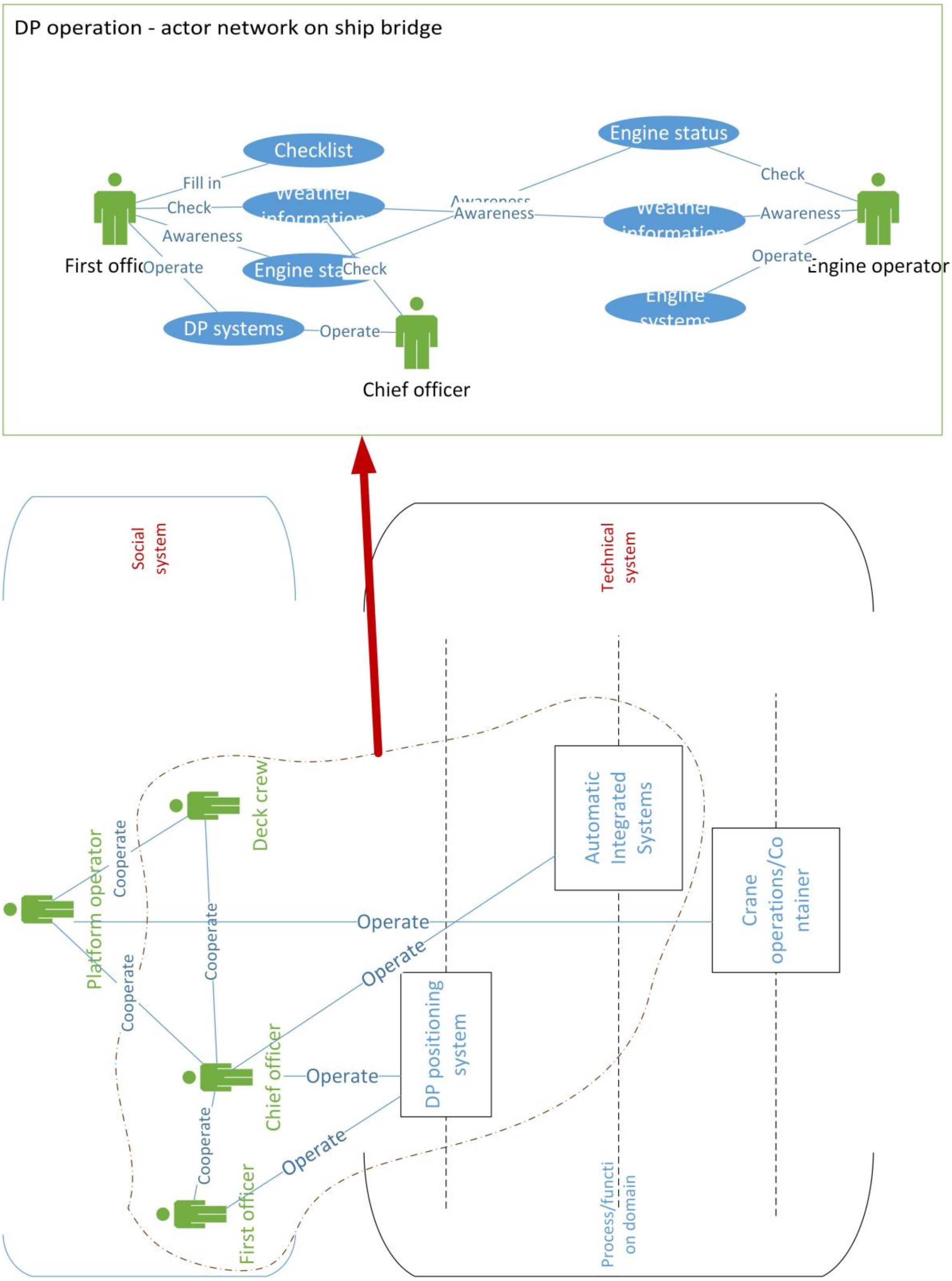

Figure 22: A translation diagram of dividing the engineering process into components

Through metaphors and storytelling, the translation was effective in enabling the innovative product platforms to eliminate the barrier between the technical and social systems in pragmatic and workable diagrams. The researcher showed how to bring the cooperative work of marine operators into the design process as a way of blurring the boundary between the social and technical worlds by showing the work practices in the diagrams and comparing them to help the systems developers open up their engineering processes to rearrange technical solutions. Hence, visualising the actor network to represent ethnographic outcomes involves deconstructing and rearranging technical solutions as constituent pieces (Pahl et al., 2007) and reformulating them in social-technical systems. As previously discussed, the researchers constitute institutional and political (Bjørn and Boulus-Rødje 2015) influences on systems design. Thus, regarding the use of technology, the workshops were conducted with respect to the people who worked on design. The workshops encouraged them to use the translated diagrams in their work. The systems developers benefited from the critical insights provided by the researcher regarding human influences on technology, and they used those insights to create a comprehensive account of the cooperative situation (Bjørn and Boulus-Rødje 2015). In addition, I respected the systems developers' engineering work but played the important role of co-worker to offer useful insights in creating solutions with them. This outcome can be considered an alternative solution that adds new insights to the visualisation when working on an interdisciplinary project.

By presenting vignettes and visualised diagrams, it was possible to use a language to work with systems developers and explore our collaborative attempt to respond to the 'social construction of technology' (Law 2009). Consistent with ANT, I believe there is no *a priori* between marine operators, artefacts, and operating systems. Cooperative work occurs such that every actor contributes to marine operations. Actors do not stand alone but are connected through social meanings and work practices as actor networks. Thus, in CSCW, awareness helps to link the actors through their activities. Most importantly, via the researcher, awareness also creates a link between users and systems developers.

Non-human actors are included to provide a solution to help systems developers create technical solutions. This makes room for artefacts and operating systems to show their activities in the actor network (Pan 2016b). This inclusion is important if systems developers are to understand how to design maritime simulators. In addition, their inclusion helps me to erase the line between human and non-human actors. Hence, there will be no pre-existing cooperative work of marine operators. These crucial changes are used in thinking about how to create a technology to support interactions between people and maritime simulators and to rearrange the technical solutions used in flat organisations (Michael 2017).

6.3.3 Reflections on working with systems developers

In the workshops, I felt that my main work was to translate the ethnographic outcomes for the systems developers. However, the translation process itself also created meaning. In the final workshop, I discussed why I considered both human and non-human actors to be important in the actor network. It is interesting to understand how non-human actors provide 'triggers' in the actor network and how they might be reflected in design, which led to the topic of computational artefacts. Thus, I led a discussion about the terms *artefact* and *computational artefact* (Christensen and Harper 2016; Schmidt and Bansler 2016) for the purpose of broadening the *modus operandi* of the systems developers (Paper 5).

The purpose of the model is to explain or visualise my understanding of how the cooperative work of marine operators could be integrated into an object-oriented view of systems modelling. I explained that, in our workshop, the UML did not distinguish between humans and non-humans. However, the discussion of methods and attributes emphasised that the use of the DP, AIS and artefacts was absent from the design process. In the technical world, the term *objects* refer to names, attributes and methods (Nygaard and Dahl 1978; Jacobson et al., 1992; Rosenberg and Stephens 2007). Moreover, procedures can access and often modify the data fields of the objects with which they are associated. All are simultaneously objects and artefacts, regardless of their designations. The systems are designed by using objects that interact with one another (Abadi and Cardelli 1996; Narayan et al., 2008).

The model shown in Figure 23 was built to explain why human activity is important.

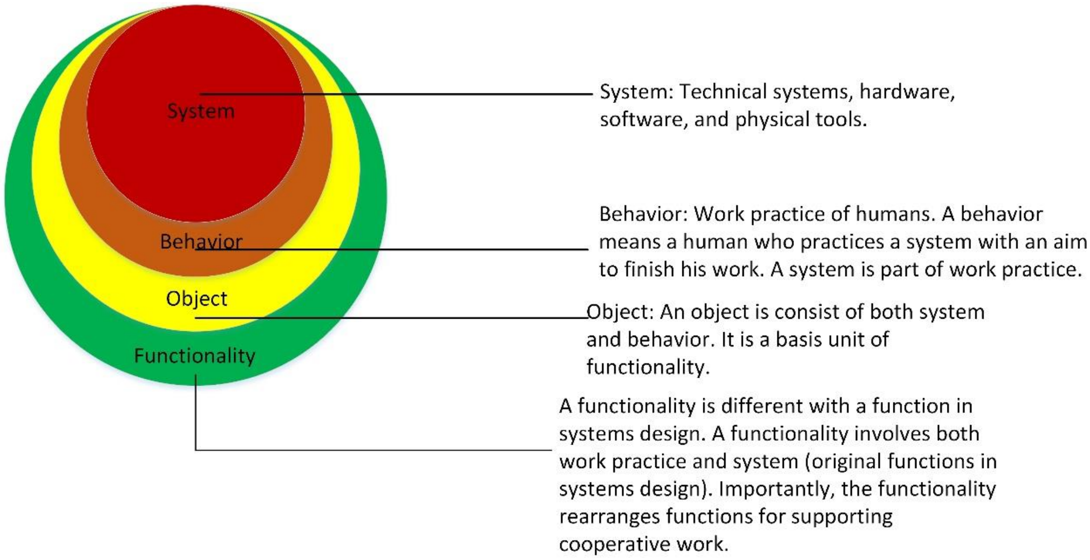

Figure 23: The model used to expand the *modus operandi* of systems developers (see Paper 5)

When I talked about systems in the workshops with the systems developers, I pointed out that the system in the model is a metaphor for the object. That is, the system includes the technical systems—such as the DP and AIS systems, artefacts and operators—which gives meaning to the system. The names, attributes and methods in the system were designed to support the use of technology. Based on this insight, the systems developers arranged a technical solution to make the use of technology possible. Schmidt and Bansler (2016) suggest designing a system as a computational artefact in which a system (or technical artefact) is not just an artefact but is also a social-technical system. To accomplish this, the work practices and their social meanings should be considered in the design process.

Importantly, the translation process brought social meaning and work practices into the design process. For example, a system (i.e., an artefact or object, such as a DP system; see Figure 20) consists of several elements: a control system, an anemometer, sensor systems, a power system and actuators. All these elements have different attributes and methods that function to support DP operations. However, by translating ethnographic outcomes, each box in the engineering diagram can be unfolded to show the systems developers that the methods they provided in each box may be enhanced by including social meaning and the work practices employed in a cooperation-friendly system. Hence, I suggest a social-technical solution (see Figure 24) that considers the work practices of marine operators to formulate new attributes and methods to represent the internal mechanism (Schmidt and Bansler 2016) of a system.

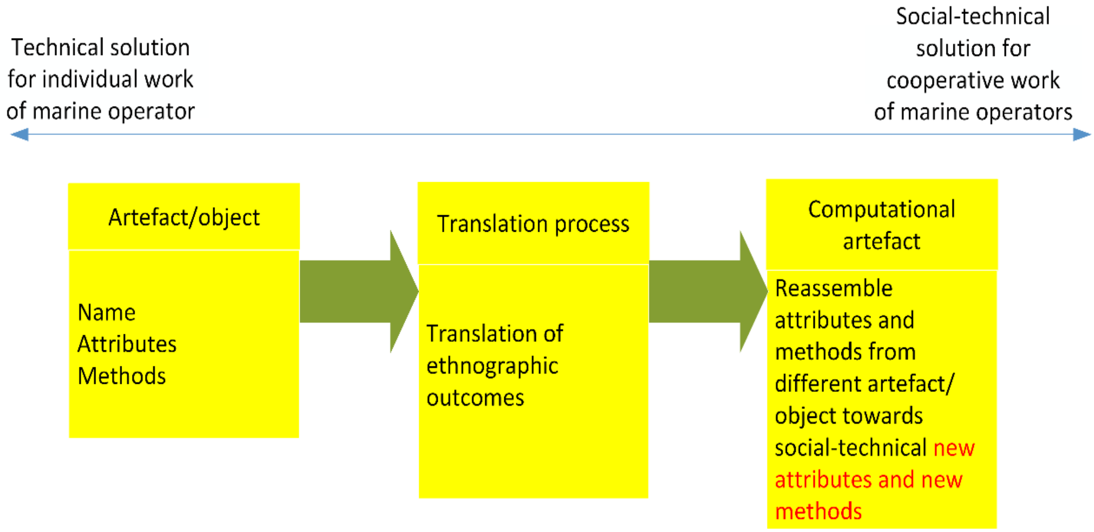

Figure 24: From a technical solution to a social-technical solution to supporting cooperative work

To investigate this idea further, it is necessary to bear in mind that artefacts never have a fixed meaning (Stevens and Pipek 2018). Instead, an artefact changes its forms with regard to the marine operator or operational systems, so an artefact can 'speak for others but in its own language' (Callon 1986b, p. 26). This is also true of the translation process, in which it is important to connect and combine humans and non-humans and link them with others. As Latour (1988, p.32) puts it:

> I use translation to mean displacement, drift, invention, mediation, and creation of a link that did not exist before and that to some degree modifies two element or agents.

In this way, I would describe the computational artefact in the present study as translating and examining the various functions technical artefacts acquire over time. It directs analytic attention to the stage prior to the engineering design work to allow both researchers and systems developers to more deeply investigate the existence of a technological artefact. It is also interesting to know how a heterogeneous array of elements, technical artefacts, functions of technical artefacts and notions of what sort of cooperative work environment is needed can support the cooperated marine operators. Then we can image new cooperating systems as a combination of interesting components in computational artefacts. A researcher who gains insights from the fieldwork can decide what kind of inner mechanism should be used to frame systems design. For example, in the present study, the clock and alarm on a ship's bridge are not isolated artefacts outside of DP and AIS systems. They are rather extensions of DP and AIS systems, as operators need them. They act in certain ways to enrol the actor network to bring the important functions so as to attempt to make marine operators accountable for safe cooperative work. In this case, if we review technical artefacts as constituents of (rather than supplements to) social worlds, then, as Latour (1996 p. 194) says,

> The name of the game is not to extend subjectivity to things, to treat humans like objects, to take machines for social actors, but to avoid using the subject object distinction at all to talk about the folding of humans and non-humans.
>
> What the new picture seeks to capture are the moves by which any given collective extends its social fabric to other entities.

In this vein, if the marine operations are understood to be about collaborations between humans and non-humans, then marine operations can be broken down into a set of actions described by little scripts[30] which are distributed across and embodied by the heterogeneous artefacts which compose the social world (Shiga 2007). In this manner, the computational artefact is produced via the attribution of collective actions to a relatively few places (Callon and Law 1995) inside of a cooperative system. In such a system, humans and non-humans begin to gain the ability to perform actions through the newly arranged and designed mechanism to support safe cooperation.

In addition, in this study, I address the capacity of humans to resist those who attempt to order, engineer or design interactions between humans or between humans and non-humans. Moreover, I also address actions that consist of artefacts outside of human and non-human bodies. This approach adds a new dimension to this question posed by Latour (1994):

> If artefacts are social relations, then why on earth has society to pass through them to inscribe itself onto something else?

This new dimension involves looking beyond the issue of how social relations are mediated by artefacts to examine the fundamental question of why artefacts proliferate in human society (Shiga 2007) and the technologies surrounding it.

---

[30] Schmidt (1997) also discusses the scripts with regard to the status of formal constructs in cooperative work.

Computational artefacts result from the delegation of social roles that create provisional bonds between actors to non-humans (Latour 1984). Hence, marine operators, DP, AIS and various marine operational systems involved in safe marine operations can be closely related within various forms of the same elementary, human-non-human relationship represented by the extension of social meanings to the computational artefact. In this case, in Latour's view (1993, p. 379), the technology can be understood in the following terms:

> A shifting network of actions redistributing competences and performances either to humans or non-humans to assemble into a more durable whole an association of humans and things, and to resist the multiple interpretations of other actors that tend to dissolve this association.

Computational artefacts act not just because my research says they do but, referring to Latour's view, computational actefacts are combined as associated networks for us to scrutinise the overlaps with technologies between human and non-human actions to arrange and regulate safe cooperation. In my view, systems developers can work on technological design because they design the internal mechanisms of systems on a daily basis. In this case, a computational artefact helps researchers support systems developers by translating work practices and social meaning. Furthermore, such activity helps organise socio-technical relations.

Reviewing previous studies, when dealing with the complexity of cooperative work, researchers have focused on human activities without taking technology into account. The present study contributes to the literature by demonstrating that systems developers can include both human and non-human actors in the same model. This differs from the idea that non-humans are materials (Bjørn and Østerlund 2014) in cooperative work. Materials (e.g., artefacts) are not bonded to humans through human activities because the technical solutions apply to the activity of a specific human actor. It may be insufficient to show systems developers how materials play an important role in the cooperative work of humans. Thus, both researchers and systems developers can be challenged when introducing technical changes to make a good social-technical system. Hence, I strongly believe that we need to do fieldwork to involve end users in the design process (Randall 2018) with a focus on end-user development (Betz and Wulf 2018; Stevens and Pipek 2018; Stevenes et al., 2018). In addition, I also care that systems developers have the ability to build a technology with full consideration of its intended use. That means that it is worth respecting the safe cooperative work of marine operators; however, it is also necessary to help systems developers gain more insight into implementing social factors in their engineering work.

Schmidt (1997, 2000) argues that it is not sensational news when actors' interdependence have causal aspects, as all actions and interactions are intentional and material. Thus, an important contribution of the present study is that its findings have implications for how actors can be treated objectively and materially in the design process and how systems developers can contribute professional knowledge when working with researchers. With this new understanding of computational artefacts, the workshop helped the systems developers to redesign the DP systems. I visited them six months after the completion of the workshops. The systems developers had redesigned their old engineering-process diagrams (see Figure 25). They also reported that the new DP systems could simulate cooperative situations similar to the work at sea to prepare the marine operators. In addition, they incorporated a work procedure into the design, which allows systems to upgrade the DP systems in response to operators' cooperative work in reality, thereby ensuring sustainability (visit and meeting at company, October 9, 2016).

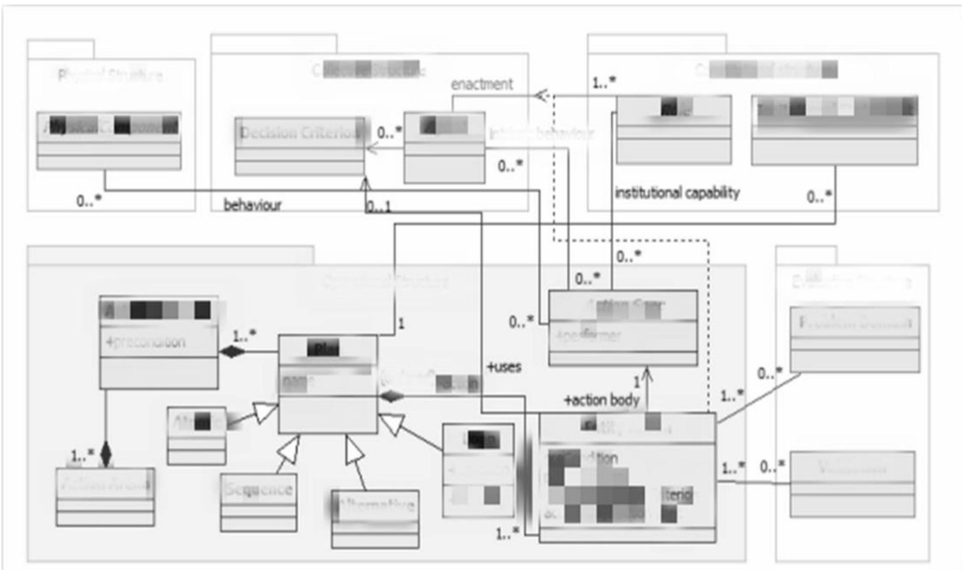

Figure 25: Systems engineers' version (UML model) of cooperative systems, including the shapes of the systems, interactive relations and the connections between them. The diagram is not an exact replica because of the need to protect confidential and proprietary information (Copyright: OSC, used with permission)

In summary, in my research, I show that ethnographic outcomes can be used to inform design. Previous researchers have called for a format for designers (Baxter and Sommerville 2011; Sharp et al., 2016). Also, previous studies have focused on dealing with the relations between ethnography and design to gain an understanding of the real-world context, including social and work settings (Blomberg et al., 1993; Khovanskaya et al., 2017; Randall et al., 2007; Simonsen and Kensing 1998), thereby to explore an approach to establishing a common-sense (Forsythe 1999) link between ethnographers and designers. Moreover, Randall et al. (2018, p.6) write as follows:

> Most tellingly, this common-sense basis is exactly what ethnographic observers are drawing upon to make their inferences about what is going on.

I agree with this statement, as it is proper that ethnographic observers can draw upon their own knowledge to seek various approaches. They can also interpret what is going on. However, I argue that 'dialogue' (Randall 2018) should not be used to redefine the design process in the engineering field. Instead, 'dialogue' (Randall 2018) should supplement the knowledge gained through CSCW and ANT to enhance system design and provide a better framework for considering human values when seeking technical solutions in cooperation with people who design systems, machines, and technologies. This will lead to success in end-user development (Betz and Wulf 2018; Stevens et al., 2018; Wulf et al., 2015) and enhance the competence of system developers. Furthermore, the distances between researcher and designer or ethnographer can be shortened though a 'dialogue' (Randall 2018). In this manner, a dialogue requires researchers to conduct fieldwork for analysis with the purpose of working with their collaborative partners in other fields. In the case of the present study, the researcher serves the two parties (marine operators and systems developers) at different times and in different places.

6.4 **Summary**

This chapter opened with a detailed presentation of how the cooperative work of marine operators is accomplished. The analysis demonstrated the importance of cooperative work of marine operators in the design process since it helps investigating unfold safe cooperation for systems developers who do not have experiences at sea. Next, the chapter discussed the process of translating ethnographic outcomes. The process was then used to illustrate the relations between technical and socio-technical solutions. In line with this, the importance of bridging the use of technology and design and development was discussed, and the process of translating ethnographic outcomes was described (Blomberg et al., 1993; Khovanskaya et al., 2017; Randall et al., 2007; Simonsen and Kensing 1998). The chapter ends up with a reflection on working with systems developers to contribute a theoretical approach of simulator design.

7 Reflection and Generalisation of the Research Endeavour and Research Role

This chapter presents the reflection and generalisation of my research endeavour and role. Sections 7.1 reflects on my role in the project. Section 7.2 considers the generalisability of the approach and the findings of the present study.

7.1 My role in the present study

As mentioned, I have a multidisciplinary background in applied mathematics and software engineering, which I obtained at the Norwegian University of Science and Technology before my enrolment at the Department of Informatics, UiO, in the Design group. I also have experience from industry (software applications), which regularly requires me to prepare hands-on solutions for users. Thus, for the present study, I also treat systems developers as users. This leads me to think that, if I label myself as an informatics researcher (Dahlbom 1996) who is engaged with the maritime domain, I must serve both marine operators and systems developers to prepare solutions for them. Besides, if I see the maritime simulator as an artefact, then I must take the challenge to balance the design and use of that artefact (Bratteteig 2007). As Bratteteig (2007, p. 71) explains,

> Research on design in IS needs to build knowledge about the forming and meaning-making of digital materials (software and hardware) and about the work that goes on in a use context when users habituate a new artefact. It seems unethical to leave out any one of these knowledge area. The challenges of balancing design and use, humans and machines, and process and product encourage a multidisciplinary approach to research on IS design, and suggest inclusion of many different sciences in our theoretical and methodologies repertoire. The Scandinavian IS research community has a long tradition in doing just that.

Consistent with this, it is essential to emphasise a professional self-interest and offer a restructuring of this professional self-interest so it can benefit society. My role in this project is to build knowledge to balance design and use by respecting both marine operators and systems developers. I was keen to understand the relations of maritime operational systems, the cooperative work achieved by marine operators and the work process followed by systems developers for development purposes. However, Suchman (2002) argues that there is no easy solution to the challenge of balancing technology design and use because of the difficulty caused by the division of professional labour and the presumptions about knowledge production. Our traditional intellectual positions and associated practices challenge us to do more than produce results that can be handed off to our collaborators.

However, such a challenge does not mean that an ethnographer is not able to contribute to engineering-oriented projects such as maritime-simulator design. Instead, a researcher who uses ethnography can offer descriptions and interpretations and thereby contribute to an understanding of the work phenomena (van der Waal 2009). Also, a trained researcher can bring his or her knowledge to bear on the shared problem of how to develop new grounds (Suchman 2002, Forsythe 1999) for simulator design. This is a sense-making process for balancing design and use. I would add that my ethnographic outcomes from the study at sea and my translation of ethnographic outcomes on land address both the obvious divide between professional system developers and marine operators and, as my experience with practice-based CSCW research makes clear, the various divides within the specialised worlds of both (Suchman 2002). It is a process of finding my place and voice in discontinuous worlds to enable myself to move and be moved (Suchman 2002), thus to offer multidisciplinary to research regarding simulator design in the present study.

I still remember the first time I read a design-relevant ethnographic article (see Procter et al., 2011, for example). I was wondering if the current competencies of system developers allow them to use such brilliant analyses from the design-relevant ethnographic research field. Now it is not difficult to answer this question. As a researcher, I have learned to understand various perspectives by observing marine operators and listening to them discuss their work practices. The day-to-day observations and interviews put me in a position where I can work between insiders and outsiders to interpret the flow of events (Forsythe 1999). Such a view is fruitful because, in a natural setting, cooperative work is complexly influenced by the context in which it occurs (Shilton 2012, Whilson 1977). Researchers within the CSCW field strive to uncover cooperative work not just to determine the phenomena of who, what, where and when (which an outsider can observe) (Berg 2004) but also to interpret how people make sense of these phenomena (Wilson 1977). In this manner, unexpressed meanings can be learned through ethnographic fieldwork (Wilson 1977), which can be used to strengthen quantitative techniques for systems design. In this vein, as a researcher between qualitative and quantitative worlds, I sense that there is probably a way to depict the connection between design-relevant study (ethnographically based) and systems design (technically oriented) (see Figure 26).

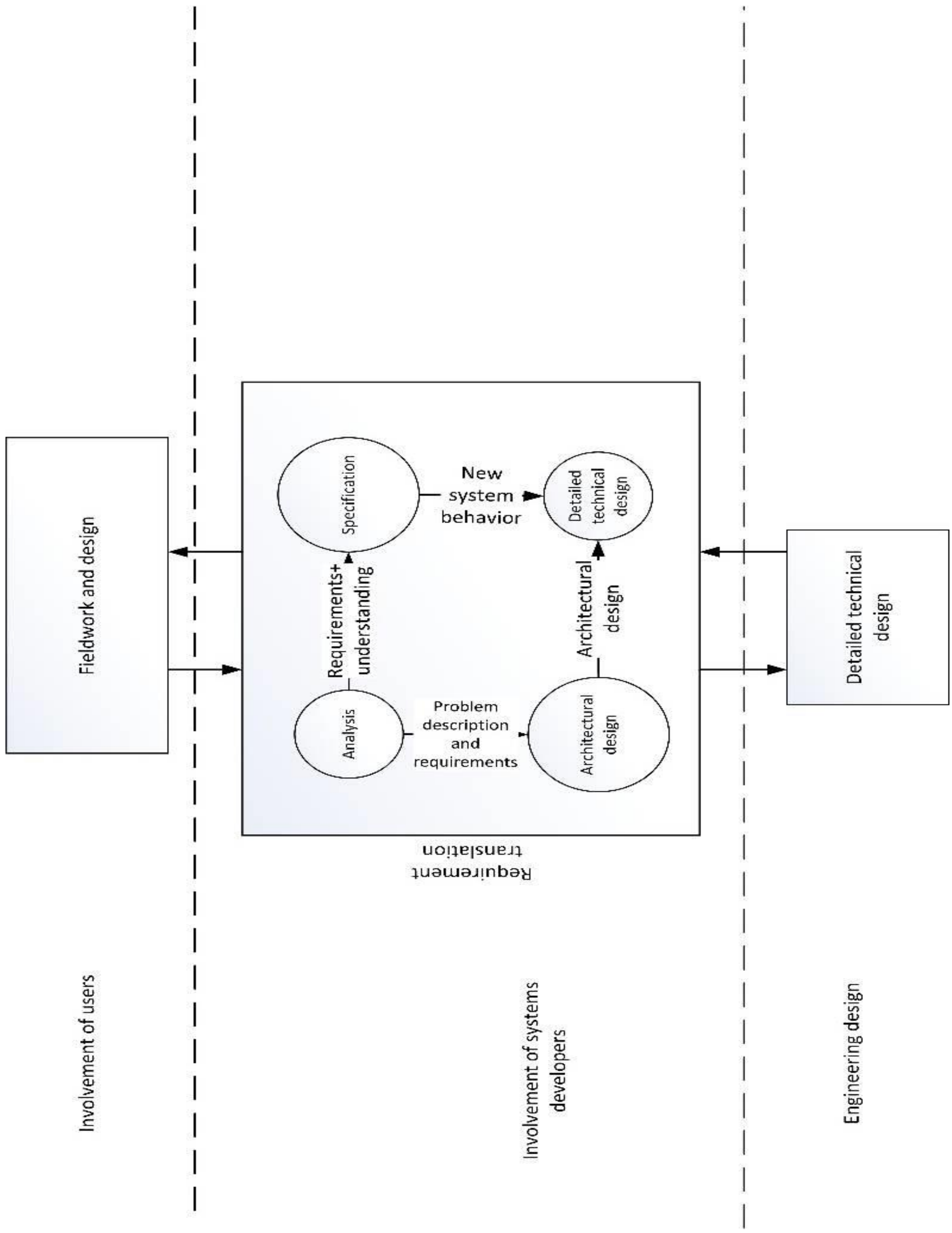

Figure 26: Requirement translation layout in the design process of the present study

While preparing the figure above, I knew that a requirement specification in the software-engineering field could be used to inform design. In the context of the present study, requirement specification needs to be further translated as ‘the invention and definition of a behaviour of a solution system (technical) such that it will produce the required effects in the problem domain’ (Bray 2002). In addition, an object-oriented analysis of artefacts and their interrelationships is one way to identify an alternative systems architecture for easy use. In this manner, according to Suchman (2002), we can understand that technology is an artefact whose architecture relies on the continuous reproduction of meaning and usefulness in practice. A researcher can mediate relations between designers and users (for example, between marine operators and systems developers) to translate his or her ethnographic outcomes directly to a design team. In this case, a researcher helps to reduce the distance between operators and systems developers. Thus, the problem lies neither in ethnographic work nor in design research work; it rather involves building a bridge which serves the division of professional labour (Suchman 2002, Haraway 1988).

7.2 Reflection on the generalisability of the study

To reflect on my study, I note that ethnographic fieldwork and software engineering are two disciplines with different perspectives on systems design (Dourish and Button 1998). For software engineering, the design approach can be generative because systems developers are used to generating systems behaviours when developing systems components (Dourish and Button 1998). For example, developers can formalise the size of windows, fonts, display procedures and, most importantly, databases. The results of much of what systems developers do every day (such as creating system architectures, developing use case models and writing programming codes) are based on the description in the requirements specification, which is provided by requirements engineers via various ‘formalised’ formats (Kotonya and Sommerville 1998). In contrast, design-relevant ethnographic research focuses more on analysis (Randall et al., 2007), facilitating ‘dialogue’ (Randall 2018) and investigating and explaining situational work practices (Randall 2018). However, as discussed, though it is a challenge to formalise ethnographic views as fixed formats for engineering work purposes, the ethnographer can re-engineer the design process investigated in the present study.

Some people might argue that, to generalise research findings to a boarder audience, it is important that research be conducted in similar settings (Wilson 1977). Otherwise, it is impossible to generalise the research findings—in particular of quantitative studies. I would argue that, though design-relevant ethnographic research (such as my work) may not succeed in producing general, context-independent knowledge (Flyvbjerg 2006), it would nevertheless be good to know that my aim is to open readers' eyes to show individual examples that occur in marine operations. The present work, on the one hand, aims at updating our knowledge regarding whether maritime simulators can support cooperative work. On the other hand, the present study suggests a possible solution to the redesign of simulators. I might be less concerned with making generalisation for a broad audience via a large test as in quantitative research. Rather, my study involves specific examples with which quantitative research might not be able to concern itself with. In general, the present study can be seen as valuable, concrete and context-dependent knowledge (Flybverg 2006) for the maritime domain and as a study in visualisation by making use of various methods with analytical concepts. That is, notably, in the present study, research methods themselves are useful for working on simulator design. For example, the photos, notes, vignettes and visualised diagrams used in the present study exhibit the meaning of their values in workshops regarding why they would be chosen to work with systems developers. It may sound unrealistic to use ANT in any projects; however, ANT and other concepts used in the present study are useful resources in the 'dialogue' (Randall 2018) with which to enable researchers who encounter similar situations during systems design. Therefore, researcher may explore a route towards a scientific innovation through their competence. My work and other visualisations of empirical data in various forms provide good examples. For further examples, please consider the work done by Checkland and Poulter (2010), Henderson (1999), Clarke (2005) and Petroski (1992, 1996). These examples and my own work can serve as an outcome of the design-relevant ethnographic study to offer socio-technical solutions for systems design.

Finally, given the success of my qualitative study in the maritime domain, the present study could provide a basis for others who also focus on designing simulators for safety-critical environments. Thus, I find it worthy to repeat three crucial issues in this study as take-away to the readers:

- The design-relevant ethnographic study shows how the safe, cooperative work of marine operators is achieved. It is important to emphasize the overlooked safety concerns in cooperation with systems developers. With this, researchers can address safety concerns in collaboration with systems developers so as to seek hands-on solutions with which to support safe cooperative work.
- Visualisation is vital to the translation of ethnographic outcomes, as it helps bridge the distance between two different fields of knowledge: maritime operations and systems development. It is possible to translate design-relevant ethnographic outcomes in ‘formalised' formats with which systems developers are familiar. In this manner, the visualised diagrams become ‘formalised’ formats that serve as methods for merging different perspectives on systems design (Dourish and Button 1998) between ethnographic fieldwork and software engineering.
- It is key to use existing methods to make ‘dialogue’. Researchers could consult concepts and theories in extant knowledge to make meaning of the visualisation—such as the combination of ANT, awareness and computational artefact through a familiar engineering language (e.g., UML)—to illustrate a ‘how-to’ approach. Furthermore, research methods such as photos, notes, visualised diagrams and ethnographic vignettes are useful resources for making sense of the ‘dialogue’ between social and technical worlds.

In this vein, though we may need to exert some effort to shorten the distance between design-relevant ethnographic studies and synthesis solutions, my research opens a room for other researchers who face similar situations when designing systems to support safe cooperative work. Example areas include air-traffic control, nuclear power plants, vessel traffic service and other similar settings in which safe cooperative work is significant and needed to achieve tasks in simulators.

8 Concluding remarks

This chapter concludes the present study. Section 8.1 summarises the ways in which the findings of this study have answered the research question. Section 8.2 points out the implications of the outcomes for the academic world. Section 8.3 discusses the implementation of the research outcomes. Section 8.4 concludes by recommending future research.

8.1 How did I answer the main research question?

How can the outcomes of ethnographic studies of the cooperative work of marine operators be used to inform the design of maritime simulators? The answer to this question depends on the type of vessel that was used as the study setting. Computer-supported cooperative work concerns specific cases rather than general observed phenomena. However, my answers can still be used in two ways. First, I refer to my work as interpretive because it aims to learn about the social meanings and work practices of marine operators which emerge in the context of specific situations at sea. Thus, the study at sea yielded qualitative findings about the observed phenomena, which I constructed based on the collection of the related data on the marine operations. Second, the observed phenomena unfolded in a natural setting and thus shows the natural work procedures of cooperative work. This effort constituted valuable knowledge that other researchers could duplicate by observing the same or similar phenomena.

Hence, the findings show that it is possible to use the cooperative work of users in the design process. Actor-network analysis helps to illustrate that both humans and non-humans act in actor networks for several specific achievements in marine operations. Such analysis shows both researchers and systems developers how and where a task is achieved in a particular situation and who is involved. Such demonstrations enhance UML by indicating that both communications and information exchanges have specific sequences when technology is in use. In this vein, cooperative work is the resource used to build up communications and information exchanges from a bottom-up process to connect vital actors in the networks (Cordella and Shaikh 2003) and visualise the networks as UML formats. It affects our making of systems models/architectures and affects the way systems developers understand cooperative work (Paper 5). Though I believe there is no unique way to do visualisation, I must add that translation work is a knowledge-building process for researchers who use ANT, CSCW and engineering languages to serve a positive picture of cooperation. Moreover, we may still need to do more things conductive to the development of relations between social and technical worlds.

Hence, it is important that the ethnographer merge insights into the social aspect of systems design with the technical solutions of systems developers. By illustrating the relationships between technical and social aspects regarding systems design, the ethnographer can inspire systems developers to investigate a how-to method as a socio-technical solution, which is useful to helping systems developers rearrange technical solutions that match work practices in the real world. Moreover, if the ethnographer can point out problematic areas through ethnographic outcomes via visual diagrams, he or she can enable systems developers to rearrange their technical solutions (RQ2). Thus, the contribution of the study is twofold: It suggests how to investigate technology use on one hand; on the other hand, the study shows the process of achieving design and development regarding the investigation of technology use.

8.2 Contributions to academia

The study reveals the challenges of cooperating with industries to create scientific outcomes. It is increasingly challenging to implement scientific outcomes in practice. This study emphasises the collaborative nature of marine operations and marine operators who are supported not only by computer-based systems. The role of non-human actors and the role of human actors in the design process must be considered.

The goal of my work is to seek an approach to designing cooperative systems. This position regards the relationship between my own disciplines – applied mathematics, software engineering – and the design of information systems as a foundational, analytic concern rather than simply as a practical one, and it accordingly emphasizes how it is that the ethnographic position on the problem of social order can inform, re-specify and re-conceptualize the requirements of modelling cooperative systems. My study shows how to translate ethnographic outcomes for the benefit of systems developers. In this study, the translation of the ethnographic outcomes enabled the systems developers to understand that the researcher did not aim to change their work but rather offered a supplement that would enable them to identify problematic areas in current systems and rearrange technical solutions to support the cooperative work practices of users. This is important to showing that, when the work practices of marine operators meet the work practices of systems developers, the process of translation could show that ethnographic studies can contribute to 'good designs' (Baxter and Sommerville 2011), such as system and software designs (Sharp et al., 2016). However, such a process contributes by borrowing systems developers' work practices to extend them into researchers' insights for how to design cooperative systems. Though it is necessary to train developers how to do ethnography, I still believe they should come along with a trained ethnographer. The reason is that ethnographers need to translate their insights so that they are useful to those who do not have expertise in the field. Importantly, this study shows a process of working with different practices to design a technical solution. Researchers are doing field studies to learn about technology use. They can also bring their insights back from the field to work with developers. In this case, they are just talking to systems developers. They become parts of a development team, thereby contributing to translating social aspects of work practices into technical solutions. This may contribute to the question raised by some researchers: How can systems be broken down into designable units that are suitable for use in engineering work? And how can researchers show developers the meaning of 'interactional what' from the field (Button et al., 2015)? Thus, the finding of the present study could have implications for how qualitative researchers may contribute to the application of engineering work.

This being the case, in most safety-critical industries, it means that, unfortunately, researchers do not seem to prepare well to engage with industrially oriented research. Researchers draw on a repertoire of knowledge and skills to make sense of problem situations and to create possible concepts and solutions which are investigated as alternatives. The use of these possible concepts and solutions depends as much on professional skills and practical experience as on the contingencies of the situation. The solution must match the problem. However, in the field of systems design, the issue is between research and its application (D'Mello and Eriksen 2010), architectural research (Sylvest 2017) and the use of digital technologies (e.g., in schools) (Salavati 2016). Research and its practices are divided, perhaps because the balancing of designs and uses, humans and machines and processes and products are not achieved. Design and development require actions that must be sufficiently structured to achieve multiple kinds of collaboration, participation and construction. The present study uses paradigms from qualitative and quantitative fields. Within this, the use of technology and its design and development should be launched in a learning process in which researchers and practitioners reflect, act and offer feedback to each other to make knowledge useable in the field (Schön 1984).

I find that it is also desirable that researchers, when a performing design-relevant ethnographic study, take note of how artefacts are used and ask why they are used in this way (Randall et al., 2018). I would also argue that, based on such 'why' questions, it is also necessary to explore 'how' questions. For example, how to provide a solution for redesigning a computational artefact if it is not properly used. Investigating an artefact and providing analytical results should not be the final goal of design-relevant study; researchers should also circle back to help systems developers gain knowledge from their analyses.[31] In most cases, the analysis will need to be translated and transferred to an engineering format for easy use by systems developers (Bray 2002). All these activities are practice-based. Researchers, ethnographers, designers and systems developers involved in a design-relevant study should expand their knowledge boundaries to understand one other's strengths and weaknesses.

Furthermore, it is important to bear in mind that researchers are not the only practitioners involved in technology development. Researchers need to know that everyone in the project is practicing his or her skills to achieve completion of the study. As Randall et al. (2018, p. 10) say,

> 'Practice', then ought to provide a lens of a more inclusive character through which we can understand the complex, interwoven, and evolving interdependencies of purpose, rationalities, rules, procedures, technologies, and interactions. The findings that emanate from such analytic work will be the basis for what we now call 'practice-based computing.'

[31] Randall et al (2007, p.151) also present similar idea of bridging the distances between designers and systems developers. Still, more efforts are needed to address such issue properly (Randall 2018).

Along these lines, we need to acknowledge the contribution of systems developers, who also practice their skills to help end users and researchers (to some extent) achieve what is expected of the project. Developers have their own purposes, rationales, engineering rules and procedures for developing the inner mechanism of an artefact or – on a larger scale, of a technical system. Thus, bridging the distance between investigation and design is not only a matter of involving users in the design process (Randall 2018); it also means effectively involving systems developers in the design process.

Hence, the study shows that, in the practice-based CSCW field, the *W* should be understood to represent the collaborative work of the researcher, designer, end user and systems developer. To properly undertake a design study, an analytical purpose alone is insufficient. It is necessary also to involve various professionals in the design process, with a focus on both end users and system developers, thereby to establish 'dialogues' (Randall 2018) for all. My role and my use of CSCW, ANT and UML is just an example. I do believe that 'dialogues' require looking at how the relations among ethnography, design, end-user development and systems design can be exploited in more design projects so as to chart a course from analytical reasoning to developing new technologies. I hope to report on these investigations in the future.

Also, this study shows the academic maritime field that social aspects of designing cooperative systems can help provide a better social-technical solution with which to support the cooperative work of marine operators. In this manner, training on cooperative work in updated simulators that can better support marine operators can increase the learning outcomes of the marine operators. The academic maritime field can benefit from a social-technical approach to the sustainable redesign of marine products. In this case, I believe it can guarantee an economic development process rather than one of endlessly testing and changing simulators without better learning about work practices of marine operators in reality. In turn, the outcome of the study sheds light on product design, thereby to produce more useful products in the maritime domain. Moreover, the distances between the vessels and the simulators are outlined in a loop in which they can support each other. They will never be developed separately without corresponding.

In conclusion, my work contributes to the literature where I previously identified a gap. It also provides researchers with insights regarding how to work with the outcomes of ethnographic studies in highly complex domains—such as in maritime operations. In turn, the work itself contributes to expanding he insights regarding the technical development of maritime products in the maritime academic field.

8.3 Some words about the maritime domain

The methodology applied in the study may be unfamiliar to readers with an engineering background. Moreover, quantitative researchers may have doubts about conducting qualitative research over the relatively short period of four years, and they may have concerns that the study is biased by the shared opinions of the researcher and the systems developers. However, such concerns may be based on a misunderstanding (Pan et al., 2014). That is, ethnography has been conducted since the 1970s in systems development and evaluation in the computer science and IS fields (Forsythe 1999). The methodology is powerful for investigating cooperative work practices observed in fieldwork (Forsythe 1999). Thus, industry might need to know how to address the implementation of research outcomes from qualitative studies in natural settings. Consistent with this, it is necessary to introduce ethnographic knowledge to engineering professionals (Lee 2016). However, the industry should open a platform which allows ethnographers to cooperate with systems developers. Doing ethnography is not only about asking people what they do. It is also more than observing what people do. Ethnography is the process of learning in depth about real-world social situations. Hence, ethnographers problematise certain phenomena to detect consistent patterns of thought and practices (Forsythe 1999). Thus, ethnographers investigate relationships between patterns of thoughts and practice and make important comparisons before they make suggestions about design and improvement. Thus, the findings of ethnographic research, such as the present study, could benefit the marine industry by reducing the costs of maintenance and redesign and introducing valuable resources as early as possible in the design process.

8.4 Future work

As discussed in the methodology chapter, this study focused on the DP and AIS systems that are used in marine services operations. Other types of systems are used in marine operations at sea. Though the systems developers have accepted the translation process and used it in their design work, interactions between the marine operators and the non-operating systems—such as walking back and forth through the narrow channel on a ship bridge, which introduced some challenges—were excluded from the design of cooperative systems. Though the settings in the workspace at sea and the maritime simulators are similar, their physical environments differ. Just because the simulators do not include narrow walk channels, should it be understood that there are no risks in the cooperative work conducted during marine operations when the marine operators walk back and forth to check for information in the office areas? I revisited the data collected in the fieldwork at sea to determine whether the narrow walk channel was a safety issue. However, because of the limited timeframe, this study could not consider such problems. Moreover, it was not possible to find a suitable professional who focused on the physical layout of the ship's bridge. Therefore, future research should explore such issues in collaboration with systems developers—particularly those with expertise in the physical structure of ships.

Because I aimed to show systems developers 'how to' skills, I conducted workshops with them which raised the challenge of verifying my work. However, as discussed, my work is just a part of marine operations. Future studies could focus on the usefulness of systems developers in designing maritime simulators and in training marine operators in those simulators. A future study could investigate the ways a programming language may support the use of translated ethnographic outcomes (Hofstader 2006). Though such topics are beyond scope of the present study, I recommend that future studies address them. The outcomes of such future studies could validate the outcomes of the present study.

Lastly, bringing marine operators out of the operation loops at sea and into simulators has become increasingly attractive. Thus, future research may consider the remote control of marine operations in which marine operators would remain on land rather than work on vessels at sea. The findings of this study could benefit the design of a remote-control centre for unmanned ships by offering insights into the design of a useful control room for the operators. This research direction might be important in the maritime domain in the near future.

9 Bibliography

Aanestad M (2003) The Camera as an Actor Design-in-Use of Telemedicine Infrastructure in Surgery. Computer Supported Cooperative Work 12(1):1–20.

Abadi M, Cardelli L (1996) A Theory of Objects. System Requirements. Springer:London.

Abokhodair N, Vieweg S (2016) Privacy & Social Media in the Context of the Arab Gulf. In: Proceedings of the 2016 ACM Conference on Designing Interactive Systems- DIS ’16. Brisbane, Australia. June 04-08. 672–683.

Ackerman MS, Dachtera J, Pipek V, Wulf V (2013) Sharing knowledge and expertise: The CSCW view of knowledge management. Computer Supported Cooperative Work 22(4-6):531–573.

Ahmed T, Tripathi AR (2010) Security policies in distributed CSCW and workflow systems. IEEE Transactions on Systems, Man, and Cybernetics, Part A: Systems and Humans 40:1220–1231.

Akeel UU, Bell SJ (2013) Discourses of systems engineering. Engineering Studies 5(2):160–173.

Alcaidinho J, Freil J, Marland K, Wu C, Wittenbrook B, Valentin G, Jackson M (2017) Mobile Collaboration for Human and Canine Police Explosive Detection Teams. In: CSCW’17. Portland, USA. Februray 25 – March 01. 925–933.

Alexander P, Silvis E (2014) Actor-network theory in information systems research. Information Research 19(2):1–14.

Backalov I, Bulian G, Cichowicz J, Eliopoulou E, Konovessis D, Leguen JF, Rosen A, Themelis N (2016) Ship stability, dynamics and safety: Status and perspectives from a review of recent STAB conferences and ISSW events. Ocean Eng. 116:312–349.

Baker CC. b, McCafferty DB. c (2005) Accident database review of human-element concerns: What do the results mean for classification? In: International Conference- Human Factors in Ship Design, Safety and Operation, RINA. London, UK. February 23-24. 65–71.

Banks M (2007) Using visual data in qualitative research. SAGE:London.

Bannon L (1992) From Human Factors to Human Actors- The Role of Psychology and Human-Computer Interaction Studies in Systems Design. In: Design at Work. Hillsdale: Lawrence Erlbaum Associates, 25-44.

Bannon L, Schmidt K, Wagner I (2011) Lest we forget. In: Bødker S, Bouvin ON, Wulf V, et al., (eds) ECSCW 2011: Proceedings of the 12th European Conference on Computer Supported Cooperative Work. Aarhus, Denmark. September 24-28. 213–232.

Bannon LJ (2011) Reimagining HCI: toward a more human-centered perspective. Interactions 18:50–57.

Bansler J, Havn E, Mønsted T, Schmidt K, Svendsen JH (2013) Physicians' Progress Notes. In: Bertelsen OW, Ciolfi L, Grasso MA, Papadopoulos GA (eds) ECSCW 2013: Proceedings of the 13th European Conference on Computer Supported Cooperative Work. Paphos, Cyprus. September 21-25. 123–142.

Barnett M, Gatfield D, Clair P (2003) A Research Agenda in Maritime Crew Resource Management. Proc of the Intl. Conference on Team Resource Management in 21st Century. Southampton Solent University. 1-22.

Baxter G, Sommervile I (2011) Socio-technical systems: from design methods to systems engineering. Interacting with Computers 23(1):4–17.

Bentley R, Hughes J, Randall D, Shapiro D (1995) Technological support for decision making in a safety critical environment. Safety Science 19(2-3):149–156.

Bentley R, Rodden T, Sawyer P, Sommerville I (1992) An architecture for tailoring cooperative multi-user displays. In: CSCW'92. Toronto, Canada. November 01-04.187–194.

Berg B (2004) Action Research. In: Qualitative research methods for the social sciences. 5th ed. Pearson Education Inc., Boston.

Berg M (1997) On Distribution, Drift and the Electronic Medical Record: Some Tools for a Sociology of the Formal. In: Proceedings of the Fifth European Conference on Computer-Supported Cooperative Work. Lancaster, UK. September 07-11. 141–156.

Betz M, Wulf V (2018) Toward Transferability in Grounded Design: Comparing Two Design Case Studies in Firefighting. In: Wulf V, Pipek V, Randall D, et al., (eds) Socio-Informatics: A Practice-based Perspective on the Design and Use of IT Artefacts. Oxford University Press, Oxford, 459–487.

Beyene T, Hinds PJ, Cramton CD (2009) Walking Through Jelly: Language Proficiency, Emotions, and Disrupted Collaboration in Global Work. Working paper 09-138. Harvard Business School.

Biran AB, Pulido RL (2013) Ship Hydrostatics and Stability. Elsevier Academic Press: Oxford.

Bjørn P, Boulus-Rødje N (2015) The multiple intersecting sites of design in CSCW research. Computer Supported Cooperative Work 24(4):319–351.

Bjørn P, Ciolfi L, Ackerman M, Fitzpatrick G, Wulf V (2016) Practice-based CSCW research: ECSCW bridging arocss the Atlantic. In: CSCW '16. San Francisco, USA. February 27 – March 02. 210–219.

Bjørn P, Østerlund C (2014) Sociomaterial-Design: Bounding Technologies in Practice. Springer International Publishing: Cham.

Bjørn P, Rødje K (2008) Triage drift: a workplace study in a pediatric emergency department. Computer Supported Cooperative Work 17(4):395-419.

Blomberg J, Giacomi J, Mosher A, Swenton-Wall P (1993) Ethnographic field methods and their relation to design. In: Participatory design: principles and practices. Lawrence Erlbraum Associates, London, 123–155.

Blomberg J, Karasti H (2013) Reflections on 25 years of ethnography in CSCW. Computer Supported Cooperative Work 22(4-6):373–423.

Bly S, Harrison SR, Irwin S (1993) Media spaces: Bringing people together in a video, audio, and computing environment. Communications of ACM 36(1):28-47.

Bødker S, Klokmose CN (2012) Dynamics in artifact ecologies. In: NordiCHI. Copenhagen, Denmark. October 14-17. 448–457.

Booch G, Rumbaugh J, Jacobson I (2005) The Unified Modeling Language User Guide. Addison-Wesley: Upper Saddle River, NJ.

Bossen C, Jensen LG (2014) How physicians “achieve overview”: a case-based study in a hospital ward. In: CSCW 2014. Vancouver, Canada. February 15- 19. 257–268.

Bowers J, Botton G, Sharrock W (1995) Workflow from Within and Without: Technology and Cooperative Work on the Print Industry Shopfloor. In: Proceedings of the Fourth European Conference on Computer-Supported Cooperative Work. Stockholm, Sweden. September 10-14. 51–66.

Bratteteig, T. Design Research in Informatics. Scandinavian Journal of Information Systems 19(2):65-74.

Bray IK (2002) An Introduction to Requirements Engineering. Pearson Education Limited: Essex.

Bucciarelli, LL (1988) An Ethnographic Perspective on Engineering Design. Design Studies 9(3):159-168.

Butler S, Diskin D, Howes N, Jordan K (1996) Architectural design of a common operating environment. IEEE Software 13(6):57–65.

Button G, Crabtree A, Rouncefield M, Tolmie P (2015) Deconstructing ethnography: Towards a Social Methodology for Ubiquitous Computing and Interactive Systems Design. Springer International Publishing: Cham.

Cabitza F, Locoro A, Simone C (2016) “You Cannot Grow Viscum on Soil”: The “Good” Corporate Social Media Also Fail BT- COOP 2016: Proceedings of the 12th International Conference on the Design of Cooperative Systems. Trento, Italy. May 23- 27. 57–74.

Callon M (1986a) Some elements of a sociology of translation: Domestication of the scallops and the fishermen of St Brieuc Bay. In: Law J (eds) Power, action and belief: A new sociology of knowledge? The Sociological Review. 196–223.

Callon M (1986b) The sociology of an actor-network: The Case of the Electric Vehicle. In: Callon M, Law J, Rip A. (eds) Mapping the Dynamics of Science and Technology. Palgrave Macmillan: London. 19–34.

Callon M (1987) Society in the Making: The Study of Technology as a Tool for Sociological Analysis. in Bijker, Wiebe E.; Hughes, Thomas P.; Pinch, Trevor J. (eds.) The Social Construction of Technological Systems. New Directions in the Sociology and History of Technology. Cambridge, MA: MIT Press

Callon M (1991) Techno-economic networks and irreversibility. Sociological Review 38(1):132–161.

Callon M (1999) Actor-network theory: The market test. Sociological Review 47(S1):181–195.

Callon M, Law J (1995) Agency and the hybrid collectif. South Atlantic Quarterly 94(2):481–507.

Carstensen PH, Schmidt K (2003) Computer Supported Cooperative Work: New Challenges to Systems Design. In: Itoh I, Komatsubara A, Kuwano S. (eds) Handbook of Human Factors, In Japanese Asakura Publishing, Tokyo, pp 619–636.

Carlton JS (2007) Ship Resistance and Propulsion. Cambridge University Press: Cambridge UK.

Carstensen P, Sørensen C (1996) From the social to the systematic. Computer Supported Cooperative Work 5(5):387–413.

Checkland P, Poulter J (2010) Soft Systems Methodology. In: Systems Approaches to Managing Change: A Practical Guide. Reynolds M, Holwell S (eds.). Springer: London. 191–242.

Christensen LR (2013) Implications for CSCW. In: Coordinative Practices in the Building Process: An Ethnographic Perspective. Springer:London.121–132.

Christensen LR (2006) Work practice between the real and the really made up. In: Proceedings of the first international workshop on physicality. Lancaster University, Lancaster, UK. February 6 – 7.16–20.

Christensen LR (2014) Techno-anthropology for design. In: What is techno-anthropology. Aalborg Universitetforlag: Aalborg, Denmark.

Christensen LR, Harper R (2016) The many faces of computational artifacts. In: 12th International Conference on the Design of Cooperative Systems. Trento, Italy. May 23 – 27. 93–106.

Clarke A (2005) Situational Analysis: Grounded Theory After the Postmodern Turn. SAGE:Thousand Oaks.

Cohen, Andrew L, Cash D, Muller MJ (2000) Designing to support adversarial collaboration. In: CSCW'00. Philadelphia, USA. 31–39.

Cordella A, Shaikh M (2003) Actor-network theory and after: what's new for IS research? In: European Conference on Information Systems. Naples, Italy. June 19-21.1-12.

Costa NA, Holder E, MacKinnon SN (2017) Implementing human centred design in the context of a graphical user interface redesign for ship manoeuvring. International Journal of Human-Computer Studies 100:55–65.

Crabtree A, Mortier R (2015) Human Data Interaction: Historical Lessons from Social Studies and CSCW. In: Boulus-Rødje N, Ellingsen G, Bratteteig T, et al., (eds) ECSCW 2015: Proceedings of the 14th European Conference on Computer Supported Cooperative Work. Oslo, Norway. September 19-23. 3–21.

Crang M, Cook I (2007) Doing ethnographies. SAGE:London.

D'Mello M, Eriksen TH (2010) Software, sports day and sheera: Culture and identity processes within a global software organization in India. Information and Organization 20(2):81–110.

Dahlbom B (1996) The New Informatics. Scandinavian Journal of Information Systems 8(2):29–48.

Dankert R (2017) Using Actor-Network Theory (ANT) doing research. https://ritskedankert.nl/using-actor-network-theory-ant-doing-research/. Accessed 6 Nov 2017.

de Laet M, Mol a. (2000) The Zimbabwe Bush Pump: Mechanics of a Fluid Technology. Social Studies of Science 30(2):225–263.

de Souza C, Fontoura de Gusmao Cerqueira R, Marques Afonso L, Rossi de Mello Brandao R, Soares Jansen Ferreira J (2016) Software developers as users: semiotic investigations in human-centered software development. Springer International Pulishing AG: Switzerland.

de Vries L, Hogström P, Costa N, Mallam S (2017) Designing for safe operations: promoting a human-centred approach to complex vessel design. Ships Offshore Struct 12(8):1016–1023.

Dourish P (1997) Extending awareness beyond synchronous collaboration. CHI'97 Workshop on awareness in collaborative systems. https://www.dourish.com/publications/chi97-awareness.html. Accessed 7 Dec 2017.

Dourish P (2006) Implications for design. In: Proceedings of the SIGCHI conference on Human Factors in computing systems. Montreal, Canada. April 22-27. 541–550.

Dourish P and Button G (1998) On "Technomethodology": Foundational relationships between ethnomethodology and system design. Human-Computer

Interaction 13(4): 395-432.

DSDM (2014) Workshops. In: DSDM Handbooks on The DSDM Agile Project Framework. p Ch. 9. https://www.agilebusiness.org/content/workshops. Accessed 6 Nov 2017.

Dunn WR (2003) Designing Safety-Critical Computer Systems. Computer (Long Beach Calif) 36(11):40–46.

Emery FE, Trist EL (1965) The Causal Texture of Organizational Environments. Human Relations 18(1):21–32.

Endsley MR (1988) Situation awareness global assessment technique (SAGAT). In: Proceedings of the national aerospace and electronics conference. Dayton, USA. 789–795.

Endsley MR (1995) Toward a Theory of Situation Awareness in Dynamic Systems. Human Factors and Ergonomics Society Annual Meeting 37(1):32–64.

Endsley MR (2015) Situation Awareness Misconceptions and Misunderstandings. Journal of Cognitive Engineering Decision Making 9(1):4–32.

Ewenstein B, Whyte J (2007) Visual representations as "artifacts of knowing." Build Research & Information 35(1):81–89.

Fitzpatrick G, Ellingsen G (2013) A review of 25 years of CSCW research in healthcare: contributions, challenges and future agendas. Computer Supported Cooperative Work 22(4-6):609–665.

Flyvbjerg B (2006) Five Misunderstandings About Case-Study Research. Qualitative Inquiry 12(2):219-245.

Foley SN, Jacob J (1995) Specifying security for CSCW systems. Proceedings of the Eighth IEEE Computer Security Foundations Workshop. Kenmare, Ireland. June 13-15, 1995. 136–145.

Forsythe DE (1999) "It's Just a Matter of Common Sense": Ethnography as Invisible Work. Computer Supported Cooperative Work 8(1-2):127–145.

Forte A, Andalibi N, Greenstadt R (2017) Privacy, anonymity, and perceived risk in open collaboration: a study of Tor users and wikipedians. Computer-supported cooperative work 2017. Portland, USA, February 25 – March 01. 1800–1811.

Gasser L (1986) The integration of computing and routine work. ACM Transactions on Information Systems - Special issue: Selected Papers from the Conference on Office Information Systems 4(3):205–225.

Ghosh AK, Badillo-Urquiola K, Guha S, LaViola JJ, Wisniewski PJ (2018) Safety vs. Surveillance: What Children Have to Say about Mobile Apps for Parental Control. Proc 2018 CHI Conf Hum Factors Comput Syst. Montreal, Canada. April 21-26. 1-14.

Goulden M, Greiffenhagen C, Crowcroft J, McAuley D, Mortier R, Radenkovic M, Sathiaseelan A (2017) Wild interdisciplinarity: ethnography and computer science. International Journal of Social Research Methodology 20(2):137–150.

Grinter R (2003) Recomposition: Coordinating a Web of Software Dependencies. Computer Supported Cooperative Work 12(3):297–327.

Guiochet J, Tondu B, Baron C (2003) Integration of UML in Human Factors Analysis for Safety of a Medical Robot for Tele-Echography. Proc 2003 IEEE/RSJ Intl. Conference on Intelligent Robots and Systems. Las Vegas, USA. October. 1-6.

Gutwin C, Greenberg S (2002) A Descriptive Framework of Workspace Awareness for Real-Time Groupware. Computer Supported Cooperative Work 11(3-4):411–446.

Guzdial M (2013) Human-centered computing: a new degree for Licklider's world. Communications of the ACM 56(5):32–34.

Hachani S, Gzara L, Verjus H (2013) A service-oriented approach for flexible process support within enterprises: application on PLM systems. Enterprise Information Systems 7(1):79–99.

Hammersley M, Atkinson P (1986) Ethnography: Principles In Practice. Third edition. Routledge: Abingdon, Oxon

Hanseth O, Aanestad M, Berg M (2004) Guest editors' introduction: Actor-network theory and information systems. What's so special? Information Technology & People 17(2):116–123.

Hanseth O, Monteiro E (1998) Changing irreversible networks: institutionalisation and infrastructure. In: European Conference on Information Systems. Association for Information Systems. Aix-en-Provence, France. June 4 – 6. 1–8.

Hanseth O, Monteiro E (2015) Socio-technical webs and actor network theory: Understanding Information Infrastructure. Aging (Albany NY) 7:956–963.

Haraway D (1988) Situated Knowledges: The Science Question in Feminism and the Privilege of Partial Perspective. In Feminist Studies 14(3):575-599.

Hardy J, Lindtner S (2017) Constructing a Desiring User: Discourse, Rurality, and Design in Location-Based Social Networks. In: CSCW'17. Portland, USA. February 25 – March 01.13–25.

Harper RR, Hughes JA, Shapiro DZ (1991) Harmonious working and CSCW: Computer technology and air traffic control. In: Studies in Computer Supported Cooperative Work. Elservise Science Publishers (North-Holland): Amsterdam. 225–233.

Harvey C, Stanton NA (2014) Safety in System-of-Systems: Ten key challenges. Safety Science 70:358–366.

Heath C, Luff P (1991) Collaborative activity and technological design: Task coordination in London Underground control rooms. In: Proceedings of the Second European Conference on Computer-Supported Cooperative Work. Amsterdam, the Netherlands. 65–80.

Heath C, Svensson M, Hindmarsh J, Luff P, vom Lehn D (2002) Configuring Awareness. Computer Supported Cooperative Work 11(3-4):317–347.

Heimeier S (2013) Design Practice Methods Explore and share design methods: Actor-network theory. http://www.designpracticemethods.rmit.edu.au/systematic-methods/actor-network-theory/. Accessed 29 Mar 2017.

Henderson K (1999) On Line and On Paper: Visual Representations, Visual Culture, and Computer Graphics in Design Engineering. MIT Press: Cambridge, Massachusetts.

Hepsø V, Botnevik R (2002) Improved Crane Operations and Competence Development in a Community of Practice. PDC'02. Malmö, Sweden. June 23 – 25. 63–73.

Hevner A, Chatterjee S (2010) Design Research in Information Systems: Theory and Practice. Integrated Series in Information Systems. Springer Science+Business Media, LLC. Springer: New York, Dordrecht, Heidelberg, London.

Hildre HP (2010) AMO- Infrastruktur- Laboratorier. Ålesund University College. Ålesund, Norway.

Hine C (2008) Systematics as Cyberscience: Computers, Change, and Continuity in Science. MIT Press:London.

Hjorth F (2015) Complexity and ambivalence in ship safety inspection- The view of Swedish Port state control officers. Doctoral thesis. Linnæus University, Sweden.

Hofstader J (2006) Model-Driven Development. In: Microsoft Dev. Netw. https://msdn.microsoft.com/en-us/library/aa964145.aspx. Accessed 16 May 2017.

Hoyle R, Das S, Kapadia A, Lee AJ, Vaniea K (2017) Viewing the viewers: publishers' desires and viewers' privacy concerns in social networks. In: CSCW 2017. Portland, USA. February 25 – March 01. 555–566.

Hughes JA, Randall D, Shapiro D (1992) From ethnographic record to system design-Some experiences from the field. Computer Supported Cooperative Work 1(3):123–141.

Humphreys M, Watson TJ (2009) Ethnographic practices: from 'writing-up ethnographic research'to 'writing ethnography.' Organ Ethnogr Stud complexities everyday life 40–55.

Hutchins E (1994) Cognition in the wild. MIT Press: Cambridge, MA.

IEEE (2011) ISO/IEC/IEEE International Standard- Systems and software engineering-- Life cycle processes--Requirements engineering. Software and Systems Engineering Standards Committee. IEEE Computer Society.

Inspectie Leefomgeving en Transport (2015) Guideline for maritime simulators. The Human Environment and Transport Inspectorate. The Netherlands.

Jackson MA (1995) Requirements and specifications: A lexicon of software practice, principles and prejudices. Addison-Wesley: Wokingham.

Jacobsen AJ (2014) Vignettes of interviews to enhance an ethnographic account. Ethnography and Education 9(1):35–50.

Jacobson I, Christerson M, Jonsson P, Overgaard G (1992) Object-Oriented Software Engineering: A Use Case Driven Approach. Addison-Wesley Progessional: Redwood City, CA.

Jeffay, K., Lin, J.K., Menges, J., et al (1992) Architecture of the artifact-based collaboration system matrix. In: Proceedings of the ACM Conference on Computer Supported Cooperative Work (CSCW'92). Toronto, Canada. November 01 – 04. 195–202.

Johnson CW (2004) The Team-based Operation of Safety- Critical Programmable Systems in US Commerical Aviation and The UK Maritime Industries. In: Human Error, Safety and Systems Development. Kluwer Academic Press: Dordrecht, the Netherlands.

Jones MR (1998) Information systems and the double mangle: Steering a course between the Scylla of embedded structure and the Charybdis of material agency. In: Information Systems: Current Issues and Future Challenges. Helsinki, Finland. December 10-13. 287–302.

Kaplan B, Maxwell J (1993) Qualitative Research Methods for Evaluating Computer Information Systems. In: Anderson JG, Aydin CE (eds) Evaluating the Organizational Impact of Healthcare Information Systems. Health Informatics. Springer, New York, NY. 30–55.

Kaplan SM, Tolone WJ, Bogia DP, Bignoli C (1992) Flexible, active support for collaborative work with {ConversationBuilder}. In: Proceedings of the 1992 ACM conference on Computer-supported cooperative work. Toronto, Canada. November 01-04. 378–385.

Karlsson T (2011) The importance of structured briefings and debriefings for objective evaluation of ARPA simulator training. Master Thesis. Chalmers University of Technology, Sweden.

Khovanskaya V, Sengers P, Mazmanian M, Derrah C (2017) Reworking the Gaps between Design and Ethnography. In: Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems. Denver, USA. May 06- 11. 5373–5385.

Kimnbull L (2009) The turn to service design. In: Julier G, Moor L (eds) Design and

Creativity: Policy, Management and Practice. Oxford University Press: Oxford. 157–173.

Kongsberg (2017) Maritime simulator. https://www.kongsberg.com/en/kongsberg-digital/maritime simulation/. Accessed 4 Jan 2017.

Kotonya G, Sommerville I (1998) Requirements Engineering: Processes and Techniques. John Wiley and Sons Ltd: Chichester.

Kuutti K (2013) 'Practice turn' and CSCW identity. In: ECSCW Adjunct Proceedings. Paphos, Cyprus. September 21- 25. 39–44.

Labour B (1996) Aramis or the love of technology. Harvard Univ. Press: Cambridge, MA.

LaPorte TR, Consolini PM (1991) Working in Practice But Not in Theory: Theoretical Challenges of "High-Reliability Organizations." Journal of Public Administration Research and Theory 1(1):19–48.

Latour B (1994) Pragmatogonies: A mythical account of how humans and non-humans swap properties. American Behavioral Sciences 37(6):791–808.

Latour B (2005a) Reassembling the social-an introduction to actor-network-theory. Oxford University Press: Oxford.

Latour B (1990) On actor-network theory. A few clarifications plus more than a few complications. Finn Olsen "Om aktor-netvaerksteroi Nogle fa afklaringer og mere end nogle fa forviklinger"- Philos 25:47–64.

Latour B (2004) On using ANT for studying information systems: a (somewhat) Socratic dialogue. In: The social study of information and communication technology : innovation, actors and contexts. 62–76.

Latour B (1999) On Recalling ANT. Sociological Review 47(S1):15–25.

Latour B (2005b) From realpolitik to dingpolitik or how to make things public. In: Making things public: Atmospheres of democracy. MIT Press: Cambridge, USA. 14–41.

Latour B (1988) The Pasteurization of France. Harvard Univ. Press: Cambridge, USA.

Latour B (1996) Pursuing the discussion of interobjectivity with a few friends. Mind, Culture, and Activity 3:266–269.

Latour B (1984) The powers of association. Sociological Review 32:264–280.

Latour B (1993) Ethnography of a High-Tech Case. About Aramis. In: Technological Choices: Transformation in Material Culture Since the Neolithic. Lemonnier P (eds.). Routledge: London and New York. 372–398.

Latour B, Jensen P, Venturini T, Gruwin S, Boullier D (2012) The whole is always smaller than its parts. A digital test of Gabriel Trade's monads. British Journal of Sociology 63(4):590-615.

Law J (2009) Actor network theory and material semiotics. In: The New Blackwell Companion to Social Theory. Turner B (eds.). Wiley-Blackwell: West Sussex. 141–158.

Law J (1992) Notes on the theory of the actor-network: Ordering, strategy, and heterogeneity. Systems Practice 5(4):379–393.

Law J (1999) After ANT: Complexity, Naming and Topology. Sociological Review 46(1):1–14.

Law J, Hassard J (1999) Actor network theory and After. Blackwell Publishing, Oxford.

Lee MJW (2016) Guest Editorial: Special Section on Learning through Wearable Technologies and the Internet of Things. IEEE transctions Learn Technol 9:301–303.

Lenberg P, Feldt R, Wallgren LG (2015) Behavioral software engineering: A definition and systematic literature. Journal of Systems and Software 107:15–37.

Lewin P (2015) Running head: Training effectiveness in maritime transport. Master Thesis. Buskerud and Vestfold University College, Norway.

Lu J, Zhang Y, Zhou Y (2010) A framework for adaptive optimization of remote synchronous CSCW in the cloud computing era. In: Lecture Notes in Computer Science. The 12th International Symposium. SSS 2010. New York, USA. September 20- 22. 452–467

Lundh M, Rydstedt LW (2016) A static organization in a dynamic context- A qualitative study of changes in working conditions for Swedish engine officers. Applied Ergonomics 55:1–7.

Lurås S (2016) Systems interwined: a systemic view on the design situation. Design issues 32(3):30-41.

Lurås S, Mainsah H (2013) Reaching hard-to-rearch users using online media to get a glimpse of work in marine contexts. ACM Interactions 32–35.

Lützhöft M (2004) "The technology is great when it works" Maritime Technology and Human Integration on the Ship 's Bridge. Doctoral Thesis. Linköpings University, Sweden.

Madden R (2013) Being Ethnographic: A guide to the theory and practice of ethnography. SAGE: London.

Maier MW, Rechtin E (2000) The Art of Systems Architecting. CRC Press: Boca Raton.

Mallam SC, Lundh M, MacKinnon SN (2017a) Integrating Participatory Practices in

Ship Design and Construction. Ergonomics in Design: The Quarterly of Human Factors Applications 25(2):4–11.

Mallam SC, Lundh M, MacKinnon SN (2017b) Evaluating a digital ship design tool prototype: Designers' perceptions of novel ergonomics software. Applied Ergonomics 59(Part A):19–26.

Man Y, Lützhöft M, Costa NA, Lundh M, MacKinnon S (2017) Gaps Between Users and Designers: A Usability Study About a Tablet-Based Application Used on Ship Bridges. The 8th International Conference on Applied Human Factors and Ergonomics. Orlando, USA. July 21- 25. 213-224.

Marx K (1845) Thesis on Feuerbach. In Marx-Engels. The Individual and Society. Progress publishers: Moscow.

Marx K (1867) Das Kapital. Zur Kritik der politischen Ökonomie [Das Capital. Critique of the Political Economy]. Erster Band. Dietz Verlag: Berlin.

Matha MP (2008) Object-Oriented Analysis and Design Using UML: An Introduction to Unified Process and Design Patterns. Prentice Hall, New Delhi.

McGraw G (1998) Testing for security during development: why we should scrap penetrate-and-patch. IEEE AES Systems Magazine 13(4):13–15.

Michael M (2017) Actor-network theory: Trials, Trails, and Translations. SAGE Publications: London.

Molland AF (2011) The Maritime Engineering Reference Book: A Guide to Ship Design, Construction and Operation. Molland A (eds.). Butterworth-Heinemann, Elsevier: Oxford, UK.

Monteiro E (2000) Actor-network theory and information infrastructure. Control Drift: they dynamics of corporate information infrastructures. Oxford University Process: Oxford, UK. 71–83.

Monteiro E, Hanseth O (1996) Social Shaping of Information Infrastructure: On Being Specific about the Technology. Information Technology and Changes in Organizational Work: Proceedings of the IFIP WG8.2 working conference on information technology and changes in organizational work. Univerity of Cambirdge. December 1995. 325–343.

Moeran B (2009) From Participant observation to observant participation. In Ybema S, Yanow D, Wels H, et al., (eds) Organizational Ethnography: Studying the Complexities of Everyday Life. SAGE: London. 139-155.

Murdoch J (1998) The spaces of actor-network theory. Geoforum 29(4):357–374.

Myers M, Klein HK (2011) A Set of Principles for Conducting Critical Research in Information Systems. MIS Quarterly 35(1):17–36.

Narayan G, Gopinath K, Sridhar V (2008) Structure and interpretation of computer programs. In: Proceedings- 2nd IFIP/IEEE International Symposium on

Theoretical Aspects of Software Engineering, TASE 2008. Nanjing, China. June 17- 19. 73–80.

NTNU (2016) Marine system design. In: NTNU, Mar. Technol. https://www.ntnu.edu/studies/msn1/marine-design-and-logistics. Accessed 29 Mar 2016.

Nygaard K, Dahl O-J (1978) The Development of the SIMULA Languages. ACM SIGPLAN Notices – Special issue: History of programming languages conference 13(8):245–272.

O’Reilly K (2012) Interpretivism. In: Key Concepts in Ethnography. SAGE Publications, London. 119–124.

Olaiya J (2002) Marine simulators: Technical and performance specifications- A Paradoxical Parallelism? In: IAMU proceedings : Third General Assembly of the International Association of Maritime Universities. Rockport, Maine. September 23- 26. 1-6.

Olsson E, Jansson A (2006) Work on the bridge- studies of officers on high-speed ferries. Behaviour & Information Technology 25(1):37–64.

Oxford University Press (2017) Oxford dictionary. https://en.oxforddictionaries.com/definition/artefact. Accessed 15 Nov 2017.

Ozcan K, Jorgenson D, Richard C, Hsieh G (2017) Designing for targeted-responder models: exploring barriers to respond. In: CSCW 2017. Portland, USA. Feburary 25- March 1. 916–924.

Pahl G, Beitz W, Feldhusen J, Grote K-H (2007) Engineering Design: A Systematic Approach, 3rd ed. Springer-Verlag: London.

Pan Y (2016a) Cooperative systems for marine operations using actor-network design: A discussion. In: Proceedings of the 2016 IEEE 20th International Conference on Computer Supported Cooperative Work in Design, CSCWD 2016. Nanchang, China. May 04- 06. 607-612.

Pan Y (2016b) Improving maritime technology: A cooperation technology perspective on cooperative artifacts. In: IEEE OCEANS 2016 – Shanghai, China. April 10- 13. 1–6.

Pan Y (2015) Suggestions on communications systems for offshore vessels. In: The 18th Annual International Conference Dilemmas for Human Services: Organizing, Designing and Managing. Växjö, Sweden. September 9- 11. 1-10.

Pan Y, Finken S, Komandur S (2015) Are current usability methods viable for maritime operation systems? In: ACHI 2015: The Eighth International Conference on Advances in Computer-Human Interactions. Lisbon, Portugal. February 22- 27. 161–167.

Pan Y, Hildre HP (2018) Holistic human safety in desiging safety marine operations. Journal of Ocean Engineering 151:378–389.

Pan Y, Komandur S, Finken S, Hildre HP (2014) An Analytical Review of Usability Evaluation for Ship Bridge Multi-Screen Complex Systems. Human Factors in Ship Design, Royal Institution of Naval Architects. London, UK. February 26-27. 109–114.

Papachristos D, Koutsabasis P, Nikitakos N (2012) Usability Evaluation at the Ship's Bridge: A Multi-Method Approach. In: 4th International Symposium on Ship Operations, Management and Economics. Athens, Greece. November, 8- 9.1-10.

Park JH, Lee D, Kim H, Yang YS (2004) Development of evacuation model for human safety in maritime casualty. Journal of Ocean Engineering 31:1537–1547.

Payne L (2017) Visualization in analysis: developing ANT Analysis Diagrams (AADs). Qualitative Research 17(1):118–133.

Perrow C (1985) Normal Accidents: Living with High Risk Technologies. The Academy of Management Review 10(2):366–368.

Petersen ES, Nyce JM, Lützhöft M (2015) Interacting with Classic Design Engineering. Interacting with Computers 27(4):440–457.

Petroski H (1996) Invention by design- how engineers get from thought to thing. Harvard University Process: Cambridge, MA.

Petroski H (1992) The Pencil: A History of Design and Circumstance. Alfred A. Knopf, Inc.: New York, USA.

Pine KH, Mazmanian M (2014) Institutional logics of the EMR and the problem of "perfect" but inaccurate accounts. In: Proceedings of the 17th ACM conference on Computer supported cooperative work and social computing- CSCW '14. Vancouver, Canada. March 14- 18. 283–294.

Pomeroy R, Jones B (2002) Managing the human element in modern ship design and operation. In: Conference Proceedings of Human Factors in Ship Design and Operation. London, UK. October 2002. 1-10.

Ponti M (2012) Uncovering causality in narratives of collaboration: actor-network theory and event structure analysis. Forum: Qualitative Social Research 13(1):Article 11.

Praetorius G, Hollnagel E, Dahlman J (2015) Modelling Vessel Traffic Service to understand resilience in everyday operations. Reliability Engineering & System Safety 141:10–21.

Procter R, Rouncefield M, Poschen M, Lin Y, Voss A (2011) Agile Project Management: A Case Study of a Virtual Research Environment Development Project. Computer Supported Cooperative Work 20(3):197–225.

Randall D (2018) Investigation and Design. In: Wulf V, Pipek V, Randall D, et al., (eds) Social Informatics- A practice-based perspective on the design and use of IT artifacts. Oxford University Press: Oxford. 221–241.

Randall D, Harper R, Rouncefield M (2007) Fieldwork for design: theory and practice. Springer-Verlag: London.

Randall D, Rohde M, Schmidt K, Wulf V (2018) Socio-informatics-Practice Makes Perfect? In: Wulf V, Pipek V, Randall D, et al., (eds) Socio-Informatics: A Practice-based Perspective on the Design and Use of IT Artefacts. Oxford University Press: Oxford. 1–20.

Rausand M, Utne IB (2009) Product safety- Principles and practices in a life cycle perspective. Safety Science 47(7):939–947.

Raval N, Dourish P (2016) Standing Out from the Crowd: Emotional Labor, Body Labor, and Temporal Labor in Ridesharing. In: CSCW '16. San Francisco, USA. February 27- March 2. 97–107.

Reichwein A (2011) Application-specific UML Profiles for Multidisciplinary Product Data Integration. Doctoral thesis. University of Stuttgart. Germany.

Ringland K, Wolf C, Dombrowski L, Hayes G (2015) Making "Safe": Community-Centered Practices in a Virtual World Dedicated to Children with Autism. In: CSCW 2015. Vancouver, Canada. March 14- 18. 1788–1800.

Robinson M (1993) Design for unanticipated use. Proceedings of the Third European Conference on Computer-Supported Cooperative Work. Milan, Italy. September 13-17. 187–202.

Rochlin GI, La Porte TR, Roberts KH (1987) The Self-Designing High-Reliability Organization : Aircraft Carrier Flight Operations at Sea. Naval War College Review 40(4):75–90.

Rooksby J (2013) Wild in the Laboratory: A Discussion of Plans and Situated Actions. ACM Transactions on Computer-Human Interaction 20(3):1–17.

Rosenberg D, Stephens M (2007) Use Case Driven Object Modeling with UML Theory and Practice. Springer-Verlag: New York.

Rumbaugh J, Jacobson I, Booch G (2004) Unified Modeling Language Reference Manual. Addison-Wesley: Reading, Massachusetts.

Sadeghi L, Dantan J-Y, Siadat A, Marsot J (2016) Design for human safety in manufacturing systems: applications of design theories, methodologies, tools and techniques. Journal of Engineering Design 27(12):844-877.

Sadeghi L, Mathieu L, Tricot N, Al Bassit L (2015) Developing a safety indicator to measure the safety level during design for safety. Safety Science 80:252–263.

Salavati S (2016) Use of Digital Technologies in Education The Complexity of Teachers' Everyday Practice. Doctoral Thesis. Linnæus University. Sweden.

Schmidt K (2018) Practice and technology, On the conceptual foundations of practice-centered computing. In: Wulf V, Pipek V, Randall D, et al., (eds) Socio-Informatics. Oxford University Press: Oxford. 47–103.

Schmidt K (2011) The Concept of ‘Work’ in CSCW. Computer Supported Cooperative Work 20(4-5):341–401.

Schmidt K (2002) The Problem with `Awareness’: Introductory Remarks on `Awareness in CSCW’. Computer Supported Cooperative Work 11(3):285–298.

Schmidt K (1997) Of maps and scripts- the status of formal constructs in cooperative work. In: the International ACM SIGGROUP conference on Supporting Group Work: the integration challenge. Phoenix, USA. November 16- 19. 138–147.

Schmidt K (2000) Distributed collective practices: A CSCW perspective. In: Distributed Collective Practices. Paris, France. September19 – 22. 1-7.

Schmidt K, Bannon LJ (1992) Taking CSCW Seriously. Supporting Articulation Work. Computer Supported Cooperative Work 1(1-2):7–40.

Schmidt K, Bansler J (2016) Computational artifacts: interactive and collaborative computing as an integral feature of work practice. In: COOP 2016: Proceedings of the 12th International Conference on the Design of Cooperative Systems. Trento, Italy. May 23- 27. 21–38.

Schmidt K, Simone C, Carstensen P, Hewitt B, Sørensen C (1993) Computational mechanisms of interaction: Notations and facilities. In Computational Mechanisms of Interaction for CSCW. Simone C and Schmidt K (eds.). Lancaster, England. 109-164.

Schmidt K, Wagner I (2004) Ordering systems: coordinative practices and artefacts in architectural design and planning. Computer Supported Cooperative Work 13(5-6):349–408.

Schön DA (1983) The reflective practitioner: how professionals think in action. MIT: Cambridge, Massachusetts.

Sebe N (2010) Human-centered computing. In: Nakashima H, Aghajan H, Augusto J (eds) Handbook of ambient intelligence and smart environments. Springer Science + Business, Springer US. 349–370.

Sendi Y (2015) Integrated Maritime Simulation Complex Management, Quality and Training Effectiveness from the Perspective of Modeling and Simulation in the State of Florida, USA (A Case Study). Master Thesis. University of Central Florida, USA.

Sellberg C (2017) Training to become a master mariner in a simulator-based environment: The instructors’ contributions to professional learning. Doctoral Thesis. Göteborgs Universitet, Sweden.

Sharp H, Yvonne D, de Souza CRB (2016) The Role of Ethnographic Studies in Empirical Software Engineering. IEEE Transactions on Software Engineering 42(8):786–804.

Shiga J (2007) Translations: Artifacts from an Actor-Network Perspective. Artifact 1(1):40–55.

Shilton K (2012) Values Levers: Building Ethics into Design. Science, Technology, and Human Values 38(3):374-397.

Shön DA (1984) The Reflective Practitioner: How Professionals Think in Action. Basic Books: New York.

Simonsen J, Kensing F (1998) Make room for ethnography in design: overlooked collaborative and educational prospects. ACM SIGDOC Asterisk Journal of Comuputer Documentation 22(1):20–30.

Silvis E, Alexander PM (2014) A study using a graphical syntax for actor-network theory. Information technology and people 27(2):110-128.

Smith S, Kempster S, Barnes S (2017) Up the ANTe: Understanding entrepreneurial leadership learning through actor-network theory. Industry and Higher Education 31(2):132–139.

Sørgaard P (1987) A cooperative work perspective on use and development of computer artifacts. DAIMI Report Series, 16(234). Århus Universitet, Denmark.

Star SL (1988) Introduction: The Sociology of Science and Technology. Social Problems 35(3):197–205.

Star SL, Strauss A (1999) Layers of Silence, Arenas of Voice: The Ecology of Visible and Invisible Work. Computer Supported Cooperative Work 8(1-2):9–30.

Stevens G, Pipek V (2018) Making use: Understanding, studying, and supporting appropriation. In: Wulf V, Pipek V, Randall D, et al., (eds) Socio-Informatics: A Practice-based Perspective on the Design and Use of IT Artefacts. Oxford University Press: Oxford.139–176.

Stevens G, Rohde M, Korn M, Wulf V (2018) Grounded design: A research paradigm in practice-based computing. In: Wulf V, Pipek V, Randall D, et al., (eds) Socio-Informatics: A Practice-based Perspective on the Design and Use of IT Artefacts. Oxford University Press: Oxford. 23–46.

Storni C (2012) Unpacking Design Practices: The Notion of Thing in the Making of Artifacts. Science, Technology, & Human Values 37(1):88–123.

Storni C (2015) Notes on ANT for designers: ontological, methodological and epistemological turn in collaborative design. International Journal of CoCreation in Design and the Arts 11(3-4):166–178.

Strauss A (1988) Work and the Division of Labor. The Sociological Quaterly 26(1):1–19.

Suchman L (1985) Plans and situated actions: the problem of human-machine communication. Xerox Corporation: Palo Alto, USA.

Suchman LA (2007) Human-Machine Reconfiguration. Plans and Situated Actions, 2nd edn. Cambridge University Press: Cambridge, UK.

Suchman LA (2001) Building bridges: practice-based ethnographies of contemporary technology. In: Schiffer MB (ed.). Actor-network theoryhropological Perspectives on Technology. University of New Mexico Press, New Mexico. 163–177.

Suchman LA (1997) From Interactions to Integrations. In: Howard S, Hammond J, Lindgaard G (eds) Human-Computer Interaction INTERACT '97: IFIP TC13 International Conference on Human-Computer Interaction. Sydney, Australia. July 14-18. 3.

Suchman LA (2002) Located Accountabilities in Technology Production. Scandinavian Journal of Information Systems 14(2): 91-105.

Sylvest M (2017) Social interactions in work environments: expanding building evaluation. In: Building Performance Evaluation. Springer: Cham. 155–171.

Tenenberg J, Roth W-M, Socha D (2016) From I-Awareness to We-Awareness in CSCW. Computer Supported Cooperative Work 25(4-5):235–278.

Teruel MA, Navarro E, López-Jaquero V, Montero F, González P (2013) Comparing goal-oriented approaches to model requirements for CSCW. In: Evaluation of Novel Approaches to Software Engineering. Beijing, China. June 8- 11. 169–184.

Traunmueller M, Marshall P, Capra L (2016) "...when you're a Stranger": Evaluating Safety Perceptions of (un)familiar Urban Places. In: Proceedings of the Second International Conference on IoT in Urban Space. Tokyo, Japan. May 24- 25. 71–77.

Twidale M, Rodden T, Sommerville I (1993) The designers' notepad: supporting and understanding cooperative design. In: Third European Conference on Computer-Supported Cooperative Work. Milan, Italy. September 13- 17. 93–108.

Van der Waal, K. Getting going: organizing ethnographic fieldwork. In Organizational Ethnography: Studying the Complexities of Everyday Life. SAGE: London.

Vederhus L, Pan Y (2016) Surface-to-seabed safety: advantages of simulator practice for subsea installation. International Journal of Safety and Security Engineering 6(2):301–309.

Vinck D (2003) Everyday Engineering: An Ethnography of Design and Innovation. MIT Press: Cambridge, Massachusetts.

Vitak J, Chadha K, Steiner L, Ashktorab Z (2017) Identifying Women's Experiences With and Strategies for Mitigating Negative Effects of Online Harassment. In: Proceedings of the 2017 ACM Conference on Computer Supported Cooperative Work and Social Computing- CSCW '17. Portland, USA. February 25 – March 01. 1231–1245.

Walsham G (1993) Interpreting Information Systems in Organizations. Organization Studies. Wiley: Chichester, New York.

Warren W (2000) Design Paradigms: A Sourcebook for Creative Visualization. John Wiley and Sons: New York.

Weick KE (1987) Organizational Culture as a Source of High Reliability. California Management Review 29:112–127.

Wikipedia (2018a) Craigslist. Online Resource. https://en.wikipedia.org/wiki/Craigslist Accessed 08 Aug 2018.

Wikipedia (2018b) Grindr. Online Resource. https://en.wikipedia.org/wiki/Grindr Accessed 08 Aug 2018.

Wilson P (1991) Computer Supported Cooperative Work: An Introduction. Springer: Netherlands.

Wilson S (1977) The use of ethnogrphic techniques in educational research. Review of Educational Research 47(1): 245-265.

Wisniewski P, Ghosh AK, Xu H, Rosson MB, Carroll JM (2017a) Parental control vs. teen self-regulation: Is there a middle ground for mobile online safety? Proc ACM Conf Comput Support Coop Work CSCW. Portland, USA. February 25 – March 01. 51–69.

Wisniewski P, Xu H, Rosson MB, Carroll JM (2017b) Parents just do not understand: Why teens do not talk to parents about their online risk experiences. In: Proceedings of the 2017 ACM Conference on Computer Supported Cooperative Work and Social Computing.. Portland, USA. February 25 – March 01. 523–540.

Wittgenstein L (2009) Philosophical investigations, Transl. G.E.M. Anscombe, P.M.S. Hacker and Joachim Schulte, Blackwell Publishing: West Sussex.

Wong S, Neustaedter C (2017) Collaboration And Awareness Amongst Flight Attendants. In: CSCW’17. Portland, USA. February 25 – March 01. 948–961.

Woodward J (1965) Industrial Organization: Theory and Practice. Oxford University Press: Oxford.

Wulf V, Müller C, Pipek V, Randall D, Rohde M, Stevenes G (2015) Practice-Based Computing: Empirically Grounded Conceptualizations Derived from Design Case Studies. In Wulf V, Schmidt J, Randall D (eds.). Des Soc Embed Technol Real-World. Springer: London, Heidelberg, New York, Dordrecht. 111–150.

Yaneva A (2009) Making the Social Hold: Towards an Actor-Network Theory of Design. The Journal of the Design Studies Forum 1(3):273–288.

Yarosh S, Bonsignore E, McRoberts S, Peyton T (2016) YouthTube: Youth Video Authorship on YouTube and Vine. In: Proceedings of the 19th ACM Conference on Computer-Supported Cooperative Work and Social Computing- CSCW ’16. San Francisco, USA. February 27 – March 2. 1421–1435.

Zytko D, Lingel J, Birnholtx J, Ellison NB, Hancock J (2015) Online Dating as Pandora’s Box: Methodological Issues for the CSCW Community. In: CSCW

2015. Vancouver, Canada. March 14-18. 131–134.

10 Appendix: Papers