Real time communication in shipbuilding

Master thesis by Dewi Wesselman
MSc Strategic Product Design & Science Communication
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DAMEN
‘If you want to feel secure - 
do what you already know how to do.  
But if you want to grow…
go to the cutting edge of your competence,  
which means a temporary loss of security.  
So, whenever you don’t quite know what you are doing  
know that you are growing…’

Viscott, 2003
Welcome to this master thesis end-report in which I will present the outcomes of my research for masters Strategic Product Design (SPD) and Science Communication (SC) performed at Damen Shipyards. Before presenting the findings from the research I would like to share the journey I have gone through in the last few months.

When I was looking for a graduation project, my dad attended me on a vacancy at the website of Damen shipyards for a graduation project about the application of Virtual Reality (VR) in the shipbuilding industry for detecting errors and for more effective communication between the engineering and production department. My first reaction was, no that is too technical for me. But after a few weeks I saw the vacancy again on another website, so I decided to save it for later and have a look at it. This was mentioned by Damen and they approached me for the assignment. What attracted me about the assignment is the application of new technologies in an industrial organization. Before graduation I wanted to learn more about the operational processes of an organization and what challenges are encountered there. Besides this I have lived half of my life in Kedichem, nearby Damen. I already knew the company and I believe that Damen develops beautiful, high quality products. After a few months I could start my graduation project at Damen, but with the request from the university to first explore why errors occur in the ship production phase.

It feels like yesterday that I walked on a Fast Yacht Support (FYS 08) of 69 meters for the first time, with one of the engineers. I was so overwhelmed and impressed by the size of the ship, the steel and how people are working and welding on the ship. Before starting at Damen I did not know anything about the shipbuilding industry and the complexity of the product and the process. I have seen the FYS 08, now called the “Game Changer” developing over time, just like I did during this project and I am so thankful for this opportunity.

This project is by far, the most complex project I have ever done. I have tried to meet the practical expectations from Damen, and the academic requirements from SPD and SC. During this project I have learned so much about the shipbuilding industry, the shipbuilding process, and how the industry is different from other industries and how employees as Damen all have a passion for ships. I also learned so much about myself, I have been struggling a lot with understanding the complexity of the international organization but facing your own strengths, weaknesses and uncertainties is also an important part of graduating. The main challenge for me was to manage all different expectations of the stakeholders involved in this project. There were moments I felt quite desperate, but I have learned to never give up and that everything will be fine in the end.

I hope you will enjoy reading this fully integrated report.

Dewi Wesselman
June 1, 2017
I could not have done this project on my own, I would like to express my gratitude to all the people who have contributed to this project.

First of all, I would like to thank Tom for giving me the opportunity do my research project for Damen, to learn about shipbuilding and how an international organization is operating.

Secondly, I would like to thank my supervisors from Damen, in the first part of the project Simon helped me a lot with understanding the shipbuilding process and connecting me to the right people. I would like to specially say thanks to Nick and Don who guided me in the second part of the project. Together you were a great combination of practical and academic knowledge, thank you supporting me, believing in me and helping me staying on track.

Besides this I would like to thank my supervisors from Industrial Design Engineering, Frido thank you for being my chair. The way you understand the interface between the engineering and production department really inspires me and helping me making sense of may data. I would like to thank Imre for the intense guidance and for pulling me through this project and giving me directions and handles to structure my somewhat chaotic brain. From Science Communication I would like to thank Steven for motivated for this project and believing in me. I would like to thank Maarten for guiding me when Steven way abroad.

Further I would like to thank the engineering team from Yacht Support, where I was located most of the time during this project for accepting me in you team, even though I was not really part of you project. Nick, Ron, Yali, Edwin and all others who have been part of the team, thank you for sharing you visions. I specially would like to thank Nick, Thomas, Gove and Chris for making time for me to conduct interviews and thank you for your input in my project. I am not sure is I would have been able to understand the interactions between engineers and production without our repetitive conversations. Besides this I would like to thank all Damen employees who helped me during my thesis research and put effort in explaining everything about the shipbuilding process.

I also would like to thank Robin from BAM and Robert from Fokker for providing input for my project. You gave me great insights about their way of working in other industries and how shipbuilding indeed is special. I would like to thank Frans from Alphatron for using the Alphaye to do tests with.

It has been great working with different types of professionals during this project with so much experience and knowledge. I have learned so much from you, but I am well aware that there is always more to learn and every body has his own vision on the reality based on its background.

This project has been quite a struggle for me and I would not have been able to do it without my friends, room mates at the “Boerderie” and the room mates of Chuan for believing in me.

A special thanks for my parents, Pascale en Gerard for your intense support. Thank you for my Twingo which made traveling to Damen much more pleasant. I am also grateful that you moved all my stuff from my room in Delft to my room in Kedichem when I was on holiday. You supported me so well and you tried to support me wit structure and relieve me from daily tasks so that I could fully focus completely on in my graduation project. You were always there for me when I was down and you gave me some good advices about taking care of myself.

At last I would Chuan for being there for me. You have experienced my struggles during this project the most. When I had troubles with myself I expressed my frustrations to you, thank you for your understanding and being patience with me.
Executive summary

This report presents the outcomes of a graduation project, completed with the intent to obtain a joint master title in both Strategic Product Design and Science Communication.

Problem as given
The graduation project is completed at Damen Shipyards. The main objective of the project is to explore how a communication process and tool can improve the collaboration between the engineering department and remote production departments of Damen Shipyards throughout the ship production phase.

Problem as taken
The importance of taking the challenges is underpinned by the following facts. The shipbuilding industry is described as a labour intensive industry, where typically small series of complex products are developed. Various errors and deficiencies occur in the ship production process, which causes delays, increased production costs, and frustrations amongst production employees. The root causes of these shortcomings are typically unclear, on the other hand, their elimination is strongly needed.

Based on the outcome of the orientation phase of the graduation project, the main research question is defined as follows: In what ways might the communication and collaboration between the engineering and remote production department be improved by the introduction of a new tool?

Approach
The research focuses on the collaboration between the engineering and production departments, in the ship production phase. A design-based research approach was used to investigate the collaboration between the product engineers and production foremen, and to define what barriers influence the collaboration. Multiple methods are used during the research project to gather data and information. Data obtained by observations, desk research, semi-structured interviews, and midstream modulation sessions were purposefully combined. Four key actors, namely two mechanical engineers and two production foremen, were involved six times in the midstream modulation sessions in order to discuss problems encountered in their daily tasks, and discuss their requirements for improved collaboration and to evaluate the proposed design. The findings of this explorative research are used to evaluate the existing situation and unearth opportunities for enhancement.

Findings
The investigation cast light on how key actors, such as project managers engineering (PME) from different disciplines (Mechanical, Electrical and Ship), and the Production Foremen (PF) from the production department communicate and collaborate. It became clear that errors in ship production might occur due to multiple various reasons. Typical examples are a pump that does not fit on its foundation, or the piping that cannot be connected to the pump.

At Damen Shipyards, the quality of production process depends on the quality of production information delivered by the engineering department. The quality of information is influenced by the level of practical knowledge of the engineers concerning production. Engineers develop drawings according to their own routines and thinking, and production professional follow their own routines with regards to handling the “as designed” information. The incomplete and imperfect production information should be completed and improved by the ship production phase, and the emerging problems are to be solved by the production team. Information about the “as built” situations is not always captured. The product engineers often “reinvent the wheel”, that leads to the feeling of not being listened to and frustrations on the side of the producers. This typically happens when a standard ship is built at a new yard, or a new production team gets involved in the building of a ship.

Requirements
Two guiding principles were formulated based on the findings associated with the current situation: (i) the interaction loops between engineering and production should be closed, and (2) mutual responsibility between engineering and production should be promoted. Solutions were envisaged by considering three preventive actions: (i) facilitation of problem detection, (ii) deeper analysis of problems, and (iii) coordination of measures for correcting the problem.

Solution
Based on the input received from engineers and production employees, real time video communication is chosen as an operative technical solution. The solution has been worked out in details, and tested with engineers and production foremen. Afterwards an iteration step has been taken towards a hand held device. To improve the collaboration activities, both structured and ad hoc real time communication between the engineering and remote production department were proposed.
These meetings are supposed to involve both the project manager of engineering (MES) and the production foreman to discuss the possible problems in production before they actually emerge. The above communication and collaboration enhancement measures contribute to creating a shared understanding between engineers and producers, and to increasing the shared responsibility. The core is social connectedness and to become aware of the situation of each other. The problems and solutions that are discussed during the real time communication sessions should be captured by taking pictures (or scanning) and should be collected in a central database and should be considered before starting a new project.

By doing so, the quality of the products can be improved and production work can be more effective. The human aspects, e.g. the feeling of the producers that their expertise is more valued and their feedback is considered, should not be underestimated. The added value for the engineers was formulated as understanding the problem easier when it is presented visually and real time, instead of sending emails. The added value for producers is a quick reaction from engineering, as well as the possibility of explaining problems easier and not having to make pictures, walking to the office or sending the pictures by email.

Implementation
The conclusion is that visual communication is useful to get a shared understanding of the ship related issues and to be able to discuss currently emerged and potential problems. Of importance is that solutions of emerged problems should be captured in a central database in order to be able to reuse the knowledge and information in follow up project. To do so time resources are needed, adjustments in the technical infrastructure and engineers and production foreman should be willing to change their current way of working, therefore change management is needed.

It is suggested for Damen Shipyards to complete a pilot experiment at a yard to test the use of real time communication and capturing of information in a central database. Further research should be conducted on the application of augmented reality to detect deviations between the real ship and the 3D model and a follow-up with real time communication between engineering and production. Production foremen already indicated they would see an added value in this.

Scientific relevance
The scientific relevance of this research is in exploring the shipbuilding process as a social process and in demolishing the barriers between engineers and production foreman that are typical for the shipbuilding industry. Barriers concern: (i) the completeness of information delivered by engineers, (ii) the practical knowledge of engineers and producers, and (iii) the problem solving activities by production.

In addition, the research contributes to enhancement of existing methods that can be used in the design process. In this research the midstream modulation method was used which can be considered as a novelty.
Glossary

List of abbreviations

DSGo  Damen Shipyards Gorinchem, the Netherlands
CLASS  Classification society
CYS  Contracting Yard Support
EN MES  Engineer Mechanical, Electrical, Ship
LOG  Logistics
MC  Material Coordination
PM  General Project Manager
Plan  Planner
PUR  Purchase
PME (MES)  Project Manager Engineering (Mechanical, Electrical, Ship)
PF  Production Foreman
DC  Design Check
BE  Basic Engineering
DE  Detailed Engineering
PS  Production Support
PBS  Product Breakdown Structure
WBS  Work Breakdown Structure
SPD  Strategic Product Design
SC  Science Communication
TU Delft  Delft University of Technology
MM  Midstream Modulation (sessions)

In the report quotes are included from interviewees, the quotes from participants are freely translated from Dutch into English and are displayed as followed:

“ I am a quote from the conducted interviews. ” - Engineer role (Participant number)
Information
Information is the message or data which is exchanged by means of a communication process and tools between two actors. Information can be ideas or facts about a situation, person, event, and is basis for knowledge.

Communication
Communication is a term that can be defined in multiple ways. Dimensions that influence the definitions are the level of abstraction, the intention and the normative judgement. Communication consist of three dimensions; a form, a function, and frequency and is connected to persons in time. To help the researcher investigate the research question, in this thesis project communication is defined as “those situations in which a source transmits a message to a receiver with conscious intent to affect the latter’s behavior” (Miller, 1966). A message can be an idea or information. In this definition the intention is explicitly that communication influences the behavior of the receiver. In this research communication is observed from a socio-psychological and socio-cultural standpoint (Littlejohn & Foss, 2010).

Knowledge
“Knowledge is justified true belief, individuals and social, tacit and explicit. An individual justifies the truthfulness of his or her beliefs based on observations of the world: the observations, in turn, depend on a unique viewpoint, personal sensibility, and individual experience” (Von Krogh, Ichijo & Nonaka, 2000). A person creates knowledge based on the interpretation of information. Both individuals and groups can hold tacit and explicit knowledge.

Awareness
Awareness is the “knowledge that something exists, or understanding of a situation or subject at the present time based on information or experience” (Cambridge dictionary, 2017). Human awareness consist of three dimensions; knowing/comprehending something, noticing/realizing something and guessing/assuming something. A shared situational awareness between team members is needed to understand consequences of actions and decisions (Endsley, 1995).

Collaboration
“...collaboration is the process of shared creation: two or more individuals with complementary skills interacting to create a shared understanding that none had previously possessed or could have come to on their own. Collaboration creates a shared meaning about a process, a product, or an event. In this sense, there is nothing routine about it. Something is there that wasn’t there before.” (M. Schrage, 1990). Collaboration is about using information and knowledge to create something new.
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PART I. Discover

The discovery phase marks the start of this research project. The discovery phase is a “phase of divergent though” during which a wide perspective is taken allowing a wide range of influences. The discovery phase aims to clarify the case of Damen and to identify problems that occur during the ship production phase.

The first chapter of the discovery phase gives a short introduction to the problem, the goal and research question. The second chapter describes the research approach and the methods used to follow the path from the problem to the final design. In chapter three, the Damen case is introduced and problems that occur during the ship production phase are described.
1. Introduction

This research project is an integrated graduation project for the masters Strategic Product Design (SPD) and Science Communication (SC) at Delft University of Technology, performed for Damen Shipyards Group in Gorinchem, the Netherlands. The content of this research project will be described in this chapter. First the problem that will be researched is introduced, followed by some context information about Damen. In section three the research goal and main research question is described. Section four describes the scientific relevance of this project and the chapter ends with the project approach and report structure.

1.1 Problem introduction

Various interconnected trends are observable in industry that influence the New Product Development (NPD) process of companies. Meta trends like globalization create new opportunities for companies, such as producing worldwide production. They provide companies with access to more diverse skills and experiences, and production can be performed at lower costs. Project teams are more often geographically separated, which makes teamwork more complicated. Project team members have to collaborate with other departments, and collaboration happens in different languages, time zones and between different cultures. Fewer synchronous face-to-face interactions occur and it is more difficult to establish a common ground between people. Lastly, there is a cultural incompatibility and language difference which makes it more challenging for project team member to collaborate.

In the NPD actors from different disciplines depend on each other, both for tasks and socially. The challenging relationship between the engineering department (from now on described as engineering) and the production department (from now on described as production) is a researched phenomenon (Smulders, 2006; Carlile, 2004). These researches describe problems in the transition of product information and knowledge from the engineering department to the production department. The two departments are highly specialized disciplines, and are characterized by their distinct type of knowledge, learning styles and activities, which leads to boundary tensions between the two departments. However, most innovation happens at the boundaries of different disciplines, which is a key ingredient for competitive advantage (Carlile, 2004). That is why the collaboration between the two departments is key for the product quality, lead time reduction and costs reduction.

In the past few decades, it has become more common that the engineering department and the production department are geographically separated, which makes the transition from engineering to production even more challenging. Existing researches focus on industries with high-volume product production. Less is known about the interface between the engineering of low-volume product production, such as the construction industry or the shipbuilding industry. This research project focuses on the shipbuilding industry, which is one of the most labour intensive industries with small series of complex products, leading to a complex collaborative environment between the engineering department and a remote located production department.

Damen Shipyards Group is used as a case to research the interface between the engineering department and a remote located, low-volume production location. Damen develops a wide range of ships, from one-off projects, semi-customized, and standardized small series of ships. In this project there is a focus on standard ships that have already been build multiple times at one yard, but are produced on a remote yard for the first time. These types can be compared with a first of series or a one-off ship.

Damen has formulated three main challenges concerning the NPD process of a ship that they would like to have researched. Firstly, errors occur during the ship production phase. Secondly, there are problems in the communication between the engineering department and the remote production department, and at last, there are some problems with monitoring the progress during the ship production phase. In figure 1 an overview is shown of the three challenges as described by Damen.
Therefore, their request is to explore the potential of emerging communication technologies including Virtual Reality (VR) and Augmented Reality (AR) for the production support. To understand why Damen wants to monitor progress during the ship production phase, error detection during production and why they need a more effective way of communication between engineers and production, orientation research is performed. From the orientation research it has become clear that manifestations of “errors” occur during the ship production phase, but there are multiple possible causes for these errors. Manifestation of errors in the ship production phase are defined in Dutch as “aanlopers” by Damen employees. An “aanloper” is a problem that is encountered by production employees during the ship production phase and is “iets waar we tegen aanlopen”. An example of an “aanloper” is given below by one of the production employees:

“On one of the boats we had a swimming pool, the engineers had decided that the drain pipes should go up and then down, but they did not think of a pump, a pump is needed to drain the water away if the pipes are designed this way” - Production employee 1.

Manifestation of errors that occur during the ship production phase, on a detailed level of a ship, for example on component or system level. These types of problems cause rework and downtime resulting increased lead times. Secondly, these manifestations of errors increase the ship production costs. Thirdly, these problems cause frustration among team members and they obstruct the shipbuilding process. The root cause of these errors is still unknown to Damen. The question is what causes these errors and how can they be detected in order to save money, time and to ensure quality of the ships, low production costs and a short lead time. There are many different causes for errors, for example, in the information used by production and interpretations of information by the production, as described by the examples below:

“Apparently at production they were not using the most up-to-date drawings, we were using revision 5, while they were using version 3.” - Engineer ship (ENG) 2.

“If they do not get a reaction quickly, a yard decides to fix it themselves with their interpretation. You want production to ask questions, and engineering to answers fast.” - Project Manager (PM) 3.

The quotes as described above are gathered during the orientation research with nine employees on different sides of the interface. The quotes give an indication of the problems that are encountered by Damen employees during the ship production phase. They give an indication that causes of problems lie in the information exchange and interaction between the engineering and production department. However, more in depth research is needed to understand the current situation of Damen in which errors occur, to be able to define the root cause of these errors.

1.2 Research goal and question

Based on the orientation research, the objective of this research project is to define the root cause of communication problems during the ship production phase and to provide Damen with a communication process and tool that improves the collaboration between engineering and production. The communication process should enable better collaboration between key actors in the project team, like between the Project Manager Engineers (PME) from the engineering department and the Production Foremen (PF) from the production department.

To be able to identify the existing boundaries on the interface between engineering and production, the situation within Damen is analyzed on an inter-actor level and inter-department level. Therefore, the main research question for this thesis project is formulated as:
In order to answer the main research question, eight sub research questions are formulated:

**Discover**
SRQ 1. What does the ship development process look like?
SRQ 2. Which key actors are involved in the ship production process?
SRQ 3. What manifestations of errors occur during the ship production phase?

**Define**
SRQ 4. What is already known about barriers for collaboration between the engineering and production department?
SRQ 5. What barriers can be define in the collaboration between actors during the ship production phase?
SRQ 6. Why is a communication process and tool needed between the engineering department and production department during the ship production phase?

**Develop**
SRQ 7. How can the current situation between engineering and production be improved?
SRQ 8. What communication methods can be used to improve the collaboration between engineering and production?
SRQ 9. How do engineering and production evaluate the proposed process and tool?

**Deliver**
SRQ 10. What is the added value of the proposed communication process and tool improve the collaboration during the ship production phase?

1.3 Research scope

The scope of this thesis project is two-folded:
1. From a company perspective, this thesis aims at defining guidelines for a communication process/product change which improves the collaboration between actors of the engineering department and production department/yard and that helps identifying and solving problems during the ship production phase.
2. From an academic perspective, on the one hand this research aims at contributing to the existing body of knowledge on the interface between the engineering department and low volume remote production department in a new product development process and on the other hand, the application of the method Midstream Modulation (MM) in the design process will be evaluated.

**Inter-actor level barriers and inter-department level**
Barriers for collaboration can be described on three levels, the actor level, project level and the company level (Kleinsmann & Valkenburg, 2008). On a (strategic) company level barriers are described based on how the product development is organized and how company resources are applied. On a (tactic) project level the barriers between departments with planning, budget, and monitoring are evaluated. On an (operational) inter-actor level the collaboration between engineers and production employees is described. This research project will have a main focus on the actor level and is explored from a social-psychological and social-cultural perspective which means the collaboration and communication between...
actors from the engineering and production department. Recommendations will also be given on company level (strategic).

**Series ships being build on a remote yard**

In series of ships, a distinction can be made between a first of series and many ships following. This research focusses on series of ships where the first is being build or when a standard ship is being build on a new yard. This means that the project team has no experience yet in building that type of ships.

**Collaboration between the Basic Engineering (BE) and a remote production department**

Research is conducted at Damen Shipyards in Gorinchem, the Netherlands (DSGo), but from the interviews it has become clear that similar problems occur in production abroad. The Basic Engineering (BE) of a ship is preformed at the head quarter in Gorinchem. In 95 - 99% of Damen’s projects, the BE and production are separated by distance, time, language and culture. This research focusses on the engineers located in Gorinchem that support production teams abroad.

**Error detection, indication and correction in the ship production phase**

Manifestations of errors are observable during the ship production phase. From the orientation research is has become clear that the communication and collaboration between development engineers and production employees is key to detecting, indicating and correcting errors in the ship production process. In this research a communication process will be developed and a tool will be proposed that improves the collaboration between the engineering and production during the ship production phase. It should be noted that prevention of errors would be more effective than curing them. But in order to prevent errors, there should be a focus on the collaboration between engineers and production during the engineering phase. Because of time constrains research only focusses on the communication process during the production phase to detect, indicate and correct errors. In figure 2 the scope of the research is shown.

**1.4 Scientific relevance**

As mentioned before not much research has been conducted on the boundaries between the engineering department and the production department in low-volume product development process, which characterizes the shipbuilding industry (Bruinessen, 2016). “Subsequent sections discuss potential models and tools that may improve insight in the
social dimension of developing innovative solutions, which is an interesting field of research that has not been explored within ship design.” This thesis project tries to fill that gap in literature by exploring the interface between the engineering department and remote production department in a shipbuilding context, and to discover how a communication process and tool can be used to improve the collaboration between the departments.

Throughout Europe, the integration of social, ethical, cultural, environmental and other societal considerations in innovation practice have become more important (Fisher et al., 2013, Guston, 2014). These considerations are at the essence of Responsible Innovation. Responsible Innovation (RI) is an emerging term in science and innovation policy across the globe and is characterized by including social, technical and economical aspects by integrating different stakeholders’ perspectives in the innovation practice and revolves around dimensions of anticipation, reflexivity, inclusion, and responsiveness. There are multiple mechanisms to do this. A mechanism for embedding these societal reflections in the innovation process is Social-Technical Integration Research (STIR) (Owen et al., 2012). Inclusion of social, technical and economical aspects demonstrated to have a positive effect on innovation practices. As part of RI, Socio-Technical Integration Research seeks the broader societal context of innovations by: “the explicit incorporation of activities devoted to broadening the social and ethical aspects that are taken into account during core scientific and engineering research and development (R&D) activities in such a way as to shape R&D pathways in socially desirable ways” (Schuurbiers 2011). STIR is a platform for an ongoing dialogue between the innovator/researcher (the author of this report) and technical experts during the innovation practice. This ongoing constructive dialogue is guided by the “decision protocol” (Fisher, 2007). Fisher and Mahajan notice the possible application of Midstream Modulation in the design process of the innovator: “Not only are such interactive methods consonant with academic engineering research practices, it appears that they could be applied to other engineering activities, such as design, and to other forms of lab based science.” (Fisher & Mahajan, 2006 p. 220). Midstream Modulation (MM) is used in this thesis report as a collaborative approach to seek the direct link between stakeholders’ viewpoints and innovation in the shipbuilding process. In this thesis project the researcher is encouraged to take into account relevant social considerations described by the stakeholders into account. Therefore, Midstream Modulation is used as a method in this research.

1.5 Report structure

This research is based on the design-based research approach. The design approach is used to get a full understanding of the complex and "wicked" problems and to come up with solutions that tackle these problems. “Design is a creative approach to problem solving with the power to tackle complex and pressing social issues. It is people-centred, getting straight to the heart of an issue to encourage new perspectives and generate powerful ideas.” (Design Council, 2003). Different design models could be used, such as the service design thinking model (Stickdorn et al., 2011) or the product innovation process model (Buijs, 2012). However, the use of the double diamond model developed by the UK Design Council (2005) was selected as it clearly indicates the diverging and converging activities during the design process. It allows seeking for additional information throughout the process and experiment, in order to come up with a solution.

The double diamond is divided in the phases: 1) Discover the context, (2) Define the current situation, (3) Develop the desired situation, and (4) Deliver the outcome of this research. The chapters in this report are related to these phases, in figure 3 an overview is shown of the phases and the connection to the chapters.
PART I
DISCOVER

The aim of the discover phase is to explore the context of in which problems occur. In this phase the Damen case is described and the shipbuilding process. It will give an overview of the involved actors during the ship development process. At the end of the discover phase an overview is shown of problems that occur in the ship production phase.

PART II
DEFINE

The define phase aims at getting a deeper understanding of the root causes of problems between the engineering and production department. In this phase it is determined how the collaboration between engineering and production in current situation can be improved. At the end of the define phase, design criteria and a direction for future communication process and tool are described.

PART III
DEVELOP

The objective of the develop phase is to come up with a communication process and tools that can be used by engineers and production foremen. Guidelines are described how engineers and production should communicate with each other to improve the collaboration. The process and tools are tested and evaluated.

PART VI
DELIVER

In the deliver phase the final concept is assessed, recommendations are given to Damen, Midstream Modulation as a method in the design process is evaluated and the overall project is evaluated.
2. Project approach

In the former chapter, the problem, goal and report structure are described. This chapter describes the approach of this thesis project in four phases; section 2.1 discover phase, 2.2 define phase, 2.3 develop phase and section 2.4 the deliver phase.

The shipbuilding process is a complex, labour intensive process in which different actors collaborate in order to build a ship, but barriers are encountered during this collaborative process. Little is known yet about barriers for collaboration in the shipbuilding process and the problem has not need defined yet, which means that explorative research is needed to be able to define the problem and to develop an approach to the problem. The main research question is formulated as:

How can a communication process and tool improve the collaboration between the engineering and production department during the ship production phase?

Based on the formulation of the main research question, a qualitative research approach is used during this research to be able to answer it. The casual description of improving collaboration by means of a communication process and tool should be discovered and evaluated in it context (Silverman, 2006). This approach is associated with the social constructivist paradigm, which argues that human beings construct their own social realities in relationship to others. This makes reality subjective (influenced by human behavior, experiences, beliefs and emotions). A quantitative approach might also provide an answer to the main research question, but then clear hypotheses and variables should be formulated. As the real problem could not yet be defined at the beginning of the research project, a qualitative approach is used to explore the problem and to come up with an approach to handle the problem afterwards. Quantitative research might be a proper follow-up after this qualitative research to be able to confirm the research findings. However, due to time constrains this is not possible in this thesis project. In this qualitative research abductive reasoning is involved, this is a from of reasoning with strong ties to inductive reasoning. Theoretical understanding of the context and people is grounded in the language, meaning and operatives of these people, it is a process of ‘guessing’ and ‘projecting’ and a trial and error process. An abductive approach differs from indicative reasoning based on the reliance on the explanation and understanding of a participant’s world view. Based on this, qualitative research is criticized to be too subjective and hard to generalize. The research process also tends to be inductive, by looking for patterns based on the collected data, but a certain degree of deductive reasoning also has been applied to the process. Existing theories are explored about the situation to see what is already known about the phenomenon. These theories have been used as a theoretical lens to analyze the situation at Damen.

Qualitative research creates a broader scope at the beginning of the project and narrows down during the research to be able to answer the research questions. More knowledge becomes available to the researcher which causes a co-evoluting problem space and solution space. This means that in the process the researcher learns more about the problem space, and also the solution space is shifting. Knowledge is captured, shared and enhance, followed by new insights and knowledge about both the problem and the solution. The continuous shift between problem and solution space is visualized in figure 4. First the communication process has been researched with barriers, afterwards solutions are proposed based on the design thinking approach, which consist of different phases in which the designer diverges (gaining insights and generating many options), clusters (‘making sense’ of the insights and ideas, building a shared understanding) and converges (decide which insights and ideas are relevant to the research scope). Design thinking is a multi-stage process for solving problems combined with a set of methods, the stages are described as discovery, define, develop and deliver based on the “Double diamond” UK Design Council (2005).

This is a mixed methods research to study the research problem (methodological triangulation) using observations, in-depth interviews, reviewing documents, a focus group and MM sessions to study the social phenomena. By using multiple methods, findings from one method can be checked with another method. For example, findings from observations are discussed in midstream modulation sessions and findings from a focus group complete data from the semi structured interviews. Besides these methods, varied data sources are used during the project to encourage data triangulation, including documents, interviews and observations. In this project, the process of data collection and analysis continued throughout the whole project, as new issues can emerge. The methods used give the participants a certain degree of
freedom and permit spontaneous responses more than pre-determined responses, environments are created during the project in which people could express their feelings and thoughts.

The research is performed at Damen Shipyards Gorinchem, the Netherlands (DSGo) in a period of 9.5 months. In this way, the project is an ethnographic research with an overt route which means that participants were aware of the research being performed. The researcher could interact with Damen employees, have direct observations, and experience and see the behavior of people. The researcher tries to see the social world from the point of view of the studied people, in this case engineers and production employees. Three projects are followed in Gorinchem; the project team of the Fast Yacht Support 69 meters which is number 8 of the series (FYS 08), the team of the Fast Crew Supplier 40 meters, who are building three ships in Gorinchem in a series of ten ships (FCS 02-03-04), and a Fast Crew Supplier of 50 meters which is number 80 in the series but the ship is being rebuilt into a FYS. These three projects were chosen based on the criteria of availability in Gorinchem and the projects should be part of a series of ships. Throughout the research, informal talks and meetings took place which gave insights and understanding in the culture of the organization which leads to subjective implicit knowledge and learning of the researcher. The researcher is the main instrument of collecting data, which makes it hard to replicate the research. In the next section, methods used the discover phase will be explained more into detail.

2.1 Discover phase

In the Discover phase, different research methods are used to understand the context in which the research takes place. As there was not a clearly defined problem in the defined assignment, first a problem had to be formulated. Different methods are used, like observations, unstructured interviews and midstream modulation sessions are used to get an understanding the “why” behind the assignment and to explore what problems Damen is facing. As a result of this phase, the research objective, scope and main research questions could be defined. In the following sections the methods are shortly described.

Figure 4: Flow of the researcher during the research project, switching between problem space to solution space.
Orientation unstructured interviews

Nine unstructured orientation interviews are performed with different actors that are involved in the ship development process. The interviews are performed to get an understanding of the shipbuilding process and problems that are encountered. To be able to formulate the research goal and research questions quotes are used to describe the problem, based on open coding (Glaser & Strauss, 1967). Interviewed actors are: (1) Engineer D&P, (2,3,4,5) 4x Project Manager, (6) Engineer, (7) Production foreman, (9) Planner. Figure 5 gives an overview of the interviewees and their location concerning the interface between the engineering and production department. These participants are selected based on probability sampling (Bryman, 2012). The orientation interviews were not recorded, but notes were taken in the notebook of the researcher and quotes were written down during the conversations. In Appendix A findings from these orientation interviews are described.

Desk research internal and external documents

Internal documents are explored to be able to understand the ship development process of Damen, based on Power Points, blueprints and word documents. Findings extracted from the documents are evaluated with Damen employees to be able to validate the reality of the documents. Besides this, books about shipbuilding are scanned to be able to understand the general process of shipbuilding. Besides this, theories about errors in operational processes are analysed based on the keywords; human errors, operational processes, industry as sensitizing concepts.

Observations

During the research, behavior of people at the engineering department and production department is observed. During the project, production meetings are attended to understand what problems are encountered during the ship production phase. Besides this visits of the engineers to the ship are attended to record the interactions between the engineers and production foremen. The observations caused implicit knowledge and understanding by the researcher of the dynamics in project teams, and the broader culture of the organization. Findings from these observations are written down in the note books of the researcher. Observations are not the main source of data, these are interviews but the observations play an important role in understanding the situation. Some findings from the observations are shown in Appendix B.

2.2 Define phase

In the Define phase an analysis report was written to be able to share gained knowledge about the situation. Based on this analysis, it was possible to dive deeper into the problems experienced by the employees of Damen. Literature is reviewed and empirical data will illustrate challenges of the transition from engineering to production in the current situation. This phase will end with the description of points for improvement. The methods used in this section are described on page 22.

2.3 Develop phase

In the develop phase, different methods are used to come up with ideas about a communication process and tool to improve the collaboration between the engineering and production department. The researcher has looked for inspiration in other industries and at trends in the industry. Methods used in this phase are described on page 49.

2.4 Deliver phase

In this phase the proposed communication process and tool is evaluated. Besides this the overall research is discussed, conclusions are defined and recommendation are given.
3. The Damen case

This research is executed on behalf of Damen Shipyards Group with the head quarter located in Gorinchem, The Netherlands (DSGo). Damen wants to know more about error detection and communication in the ship production phase, when engineering and production are geographically separated. First the company will be introduced (section 3.1). Secondly, Damen’s ship development process will be described (section 3.2). In section 3.3 the different project stakeholders involved in the process are described. Section 3.4 describes problems that occur in the current situation. Section 3.6 describes how to move on from here. This chapter addresses the sub research questions: (1) What does the ship development process look like? (2) Which key actors are involved in the ship production process? (3) What manifestations of errors occur during the ship production phase?

3.1 Damen Shipyards Group

Damen Shipyards Group (DSG) is a shipbuilding group with an annual turnover of €2 billion. They deliver between 120 - 160 ships annually, produced on one of the 32 shipyards worldwide. Damen is a client-focused, international and family-owned shipbuilder with Dutch roots. Damen designs and builds innovative quality ships, supported by a worldwide network of sales and services including maintenance and repair & conversion facilities. Damen is a company with a global workforce numbering more than 9,000 employees. Damen is a family owned company with an executive board who decides on the direction of the company. The executive boards consist of four key figures; René Berkvens (Chief Executive Officer), Arnout Damen (Chief Commercial Officer), Frank Eggink (Chief Financial Officer) and Jan-Wim Dekker (Chief Products Officer).

Damen is a matrix organization divided into vertical business units (High Speed Crafts (HSC), Yacht Support (YS) Workboats, Offshore & Cruise, Damen Technical Cooperation (DTC) and more). At the top of a Business Unit (BU) there is a Product Group (PG) with a managing director which can be seen as an internal client who decides which ships will be build. The functional disciplines (project management, engineering, productions, purchase and material coordination) are located on the horizontal axis. Project Management, Engineering and logistics flow is organized from its head quarters in Gorinchem.

Mission and vision

Damen Shipyards group has formulated their vision as:
“Become a global market leader in niche markets of shipbuilding, ship repair & conversion and related services”.

To reach their vision their mission is formulated as:
“Design and build innovative ships of excellent quality, supported by a worldwide network of sales and services including maintenance and repair & conversion facilities (Damen, 2017).”

Damen Shipyard Group has defined three main business goals to reach their vision, concerning the production of standard ships (Source: Damen ECM strategy PowerPoint), increase product quality, reduce cost price of a ship to become a cost...
leader and reduce production lead time of a ship, to be able to compete with other shipbuilders in the market.

Core values
Damen has defined core values that guide the employees in doing business as shown in figure 6. Core values like teamwork, one family, commitment and professionalism, trust and openness, integrity and responsibility, safety, respect and fun are key when performing activities.

The Damen Standard - building hulls on stock
The Damen Standard, a concept of standardization generates clear advantages: fast delivery times, reduced costs and proven designs. By producing ships in small series, economy of scales can be achieved. These days, small series of 15 till 80 ships of the same type are being build, but also semi-custom ships and one-off ships. To be able to deliver the “Damen Standard”, collaboration between actors from the different departments which are geographically separated is essential. There are about 200 hulls in stock, which leads to very short delivery times. Damen guarantees the “Damen Standard” wherever the ships are built in the world. Damen has developed a standard range of ships in its portfolio, ranging from luxury yachts to tugs, defence and security ships to public transport and work boats. The level of standardization of ships depends per business unit.

Global project teams
Projects are coordinated from the head quarter, Damen Shipyards Gorinchem. Project management, planning, logistics and a part of the engineering department is located in Gorinchem. Roughly 80% of the Basic Engineering (BE) in performed in the Netherlands and 95% of the Detailed Engineering (DE) is outsourced to partner engineering companies in the Ukraine or Poland. The hull production can be performed at one yard, while outfitting is done at another yard. During the production of a ship different errors can occur as the process is complex, labour intensive and globally distributed.

3.2 Ship development process
Section 3.1 gives a general introduction about Damen. In this section the development process of a ship is described and the problems encountered in the process. The sub research questions will be answered: (1) what does the ship development process look like?

The development of a ship is based on the Basic Design Cycle for naval engineers of Evans (1959). Ships are complex systems with highly interdependent variables. It quickly becomes impossible to calculate factors simultaneously (as shown in figure 7). Instead, the design spiral describes a process of iterative refinement, each iteration is referred to as a ‘spin’ of the spiral. Phases or cycles are considered once a given level of technical refinement has been achieved.

Figure 7: Basic Ship Design Spiral with dependencies between the domains (Evans, 1959)
The engineering work is often described as making choices among alternatives and has an iterative character. Starting with a General Arrangement (GA), the design of blocks, zones and in the end the systems. When engineering the blocks, the building strategy of the yard is considered for building.

The ship development is divided into different phases with stage gates in between towards the following phase. The overall process is guided by the building strategy of the yard. The development process of a ship is shown in figure 8, a yard/production is highly dependent on the input from (production information) delivered by engineering and the equipment and material delivered by the supply chain. In the Design Check (DC) phase, the design of a ship is checked for feasibility. In the Basic Engineering (BE) phase information (like schemes in AutoCAD and the Bill Of Material) is developed for the supply chain and in the detailed engineering (DE) phase production information (developing the 3D model with the shipbuilding parts and mechanical parts in Nupas/Cadmatic) is generated. Job preparation is the shift from engineering to production in which shop orders are released, and CAD drawings are prepared for sending to the cutting machines at the yard.

**Development process of a ship**

![Diagram of ship development process](image)

*Figure 8: Processes and departments in the ship development process (D&P excluded)*

**Standard, semi-custom and custom build ships**

Damen is capable of building different types of ships, ranging from fully customized ships (one-off), semi-customized ships like super yachts, to standard built small series of ships like tugs. The difference between the project types is the amount of information that is available and the level of uncertainty during the project, the difference in relation with the client is shown in figure 9.
In the research three projects are followed. One project is a standard series, and the two other projects are semi customized ships based on a series of ships. The starting point of a “standard” ship is a template. In this template pre-defined modifications (variants and options) are defined. The product definition is covered in a template, which means that there is not much engineering required after the first ship. When building a ship, there is a focus on an efficient building processes instead of the single project result. One of the larger series Damen has produced is the Damen ASD Tug 2810s, which has been built around 80 times since 2002. A project is performed by project team members with different backgrounds. The team is constrained by limited resources (such as time and money) and is organized, planned and controlled by a Project Manager (PM). To be able to scope the shipbuilding project, it is divided into a Product Breakdown Structure (PBS) and a Work Breakdown Structure (WBS).

Product Breakdown Structure
A Product Breakdown Structure (PBS) is used to divide a ship into blocks like the aft part, forepart, and the superstructure. These blocks are divided into zones such as the engine propulsion room, and wheel house. In the different zones, different systems are located. The sequence in which the blocks, zones and systems are produced and constructed at a yard is called the Building Strategy and depends on the yards where the ship is build.

Hull construction and outfitting
The hull is the steel (or aluminium) structural cohesion of the ship. The hull production phase consists of different parts. First the steel should be gutted by machines. Then the steel plates are welded to each other leading to building blocks. These building block are assembled and in the mean time some equipment are already added to the blocks. Afterwards, the blocks are welded to each other and the super structure (Wheel house of the ship) is installed.

Outfit is split up into hot outfitting and cold outfitting. Hot outfitting consists of outfit materials that have to be welded to the hull. Hot outfitting can only be done on unpainted steel and consist of foundations, little tacks, cable trays, insulation pins, man holes, steel doors, steel window frames, stairs, handrails and the small steel parts and piping with pipe clamps, spools, and HVAC (Heat Ventilation Air Conditioning) ducts. Cold outfitting consists of outfit materials or components that can be mounted to the hull without welding like insulation of the accommodations, engine room, cables wall, floor and ceiling insulation, joinery in floors, wall panels, ceiling panels and furniture. Besides this prefabricated spools and big equipment like engines, generator sets, switchboards, propellers and big pumps. Finally, small equipment like lights and coffee machines will be installed. To prevent corrosion, cold outfit materials can only be fitted on sufficiently painted steel. Painting can only be done when all other workers are gone because of health and material reasons. Painting is required when all hot structural works and outfitting is done for the specific surface.

Work Breakdown structure
For the WBS, milestones are formulated based on the building strategy, for example the finalizing of the design check, the arrival of the main engine at the yards, the keel laying, and launching. To be able to realize these milestones, the project is divided into three main operational sub-processes, including engineering, supply chain (procurement, logistics) and production. The sub-processes again are divided into activities that are connected with departments which causes interdependencies between operational processes. The planning of these processes depends on the delivery time and the building strategy of the yard.

The activities in the WBS are connected to the PBS and are performed by different project team members. The sub-
process engineering consists of activities such as the Design Check (DC), Basic Engineering (BE), Detailed Engineering (manufacturing engineering), Job Preparation (JP) and Production Support (PS). The supply chain process consists of the procurement, logistics and storage of the resources. In the production process, tangible inputs (raw materials, semi-finished goods, sub-assemblies) and intangible inputs (ideas, information, knowledge) are transformed into goods or services. The production process is divided into steel cutting, the hull construction outfitting, launching and commissioning and trials.

3.3 Project team members

The previous section describes the ship production process. This section describes which actors are involved and answers the sub research question: (2) Which key actors are involved in the ship production phase?

Damen is a matrix structured organization (as shown in figure 10), with vertically the different business units and projects, and on the horizontal axis the different departments which are involved in a project (Project Management Institute, 2004, p.16). For a project, the project team consists of a Project Manager (PM), Project Managers Engineering (PME), Engineers (ENG), Planning (PLAN), Procurement (PUR), Material Coordination (MC) and Logistics (LOG) and a Yard/Production Foreman (PF) is involved. Besides the project team, a client is involved in the project (an internal client or external client), Contracting Yard Support (CYS, decides which yard will be used) and a classification society (to check if a ship follows the regulations) and co-engineers and sub-contractors.

Dynamic project team

Project teams are dynamic, depending on the project, the Project Manager (PM) and Project Manager engineering (PME) with a focus on Ship, Mechanical, Electric (and depending on type of ship Interior) roles are full time or part time. A PME can have multiple engineers working underneath him/her. These supporting engineers are not full-time involved in a project. An engineer can work on multiple ships at the same time, consequently a project team expands and shrinks depending on the amount of work available during the project. Roles like procurement and material coordination are

![Figure 11: Overview development process with dependencies between team-members over time (based on interviews)](image-url)
General Project Manager (PM)
The general Project Manager is responsible for the budget of a project and making sure the ship is delivered on time. Besides the project manager has contact with the client and makes decisions with the client. The Project manager initiates a project and becomes more involved again when closing a project. When working with a yard abroad, communication between the engineering department and yard is facilitated by the project manager.

Internal or external client
A client can be internal (the Product Group) when the ship has not been sold yet. The Product Group (PG) is the head of a business unit (for example High Speed Crafts or Yacht Support) decides which modifications should be made to a design, based on the demands from the market. When a ship is sold, the external client comes into the picture, based on the demand of the external client, adjustment can be made to the current design.

PME Mechanical
Project Manager Engineering Mechanical is responsible for the engineers that focus on the mechanical systems in a ship, like the heating system, air-conditioning and ventilation systems, piping, pumps and equipment. The mechanical, electric and interior engineer are more involved during the outfitting of a ship. They make sure that all pipes and equipment are routed in the 3D model, and reserve space for equipment. In the BE phase he develops schemes and Bill Of Materials for equipment.

PME Electrical
Project Manager Engineering Electric is responsible for the engineers who focus on the electrical systems in a ship such as cables for navigation, alarm systems and television. In the BE phase he develops schemes and Bill Of Materials for the electric systems of a ship.

PME Ship
Project Manager Engineering Ship (PME Ship) is responsible for the engineers that focus on the construction of a ship. The PME ship makes sure the construction of the ship is correct and that equipment can be placed on foundations.

PME Detailed Engineering (DE)
Design Check, Basic Engineering and Production Support are performed in the Netherlands, while the Detailed Engineering is performed by an engineering team in the Ukraine, Vietnam, Romania or Poland. Parts of the Basic Engineering is also performed by the DE team

Production Foreman (PF)
Coordinates the operational work and planning on the ship with shop floor employees and communicates with co-makers. The production foreman makes sure that the engineered ship is being realized. Depending on the size and complexity of a ship, there are multiple foremen responsible for the shipbuilding process. During the production of a ship multiple co-makers are involved for painting, electrical parts, piping etcetera. The production foremen manages the planning of the ship and guides the shop floor employees.
Project teams are hierarchically structured, decisions are made by the client/internal or external and influence the basic engineering phase. Output from the basic engineering (BE) phase and detailed engineering (DE) phase influence the production (Hull, outfitting and commissioning and trails) phase. Production can ask questions about drawings to the engineers that are involved in the project (called production support, PS). In this research there is a focus on the critical nodes the Project Managers Engineering ship, mechanical and electrical who are located in Gorinchem, The Netherlands, and the production foremen (PF) located abroad. Decisions made by the project manager (PM), client and classification society (Class, is an external organization which checks if a ship is built by the prescribed rules) influence in the process but will be considered less. The influence of the different actors is visualized in Figure 11.

In Figure 12 an overview is shown of the involvement of different types of engineers and production during the ship development process. It should be noted that production is minimally involved during the engineering phases, while engineering is minimally involved during the production phase. In the figure only one production foreman is displayed, but
for different tasks like painting, piping and interior separate production foremen are responsible, but there is one (or two depending on the complexity of the project) foreman or ship coordinator responsible for the ship. The different actors are described; in the next section the problems will be discussed that occur during the production phase of a ship.

3.4 Manifestations of errors during production

The production process and involved actors are described in section 3.2 and 3.3. This section described problems that occur during the ship production phase. The sub research question will be answered: (3) What manifestations of errors occur during the ship production phase?

During the ship production phase, manifestations of errors occur that obstruct the progress of the shipbuilding process. These manifestations are called “aanlopers” in Dutch by Damen production and engineering and are caused by errors earlier in the process. In Appendix D a long list is shown of manifestations of errors during the ship production phase. In this research there is a focus on problems in series of ships.

“Yes an “aanloper”, it is something that production encounters and then they cannot continue. So if it is really a problem, you cannot move on, then you have to discuss it.” - Project Manager (P2) 4.

Figure 13 gives four examples of problems that occur during production. On the left, the cutting files of sea chests are not updated, this leads to misfit between components. The second pair of pictures show that manholes are not added in the 3D model, which means that it was impossible to weld inside the structure. In picture three, equipment in the technical space does not fit on the foundation. The last pictures indicate that air filters could not be installed since drawings were missing for the foundations. A few more examples of problems that occur during production will be described below:

“Construction defects; engineering may have engineered a pump where it actually cannot be placed, those kinds of examples. Knees of trusses are wrong; a motor mounting can be a little too small.” - Production Foreman (P8) 5.

Another example is described below which discusses that the hull has wrong dimensions, this can depend on the quality delivered by the yard:

Figure 13: Overview manifestations of errors during the ship production phase.
"We have a hull from Turkey, but the hull has bad quality. The main deck is 2 centimetres lower than it should be and now everything gets stuck, piping should be rooted 2 cm lower, the ceiling should be two cm lower. – Engineer mechanical (p4) 6.

Engines or pumps of a ship that do not fit anymore because of a change in supplier, but the question is if drawings are not updated for the new engines or the 3D model is incorrect.

"On a ship a 1505 it was mainly about the engines. The ship always had a certain type of engines and these engines fit perfectly, but then we had Caterpillar engines which were much bigger so the cooling water pipes did not fit anymore. That was really a thing, in the end it was okay but it took a lot of time to find out how it was possible. It took me two days to look for the right person who could tell me why we had different engines now...” - Project Manager (P2) 7.

The example below described how tolerances can cause problems in production, here engineering is blamed for not considering tolerances for production.

"The gap was smaller than tolerance, had to cut off to make it fit in there. It does not happen a lot, 1-2-3 time on a big section. This is the thing, engineers should think, how is this mounted in? Because they should keep in mind the tolerances a bit inside and outside, but as an engineer you do not have tolerances. AutoCAD does not have tolerances, 0000 something. But in real life, it can be 10 mm inside or outside. 10 mm from inside, to big for the hole. This is something to keep in mind when designing." - Hull Coordinator (P21) 8.

The last example of a manifestation of error has to deal with the interpretation of production information delivered engineering to production, causing problems with the stabilizers of a ship.

"stabilizer, it is quite a heavy thing, with a lot of forces on it, they should reach to a certain depth in the ship, so we have made a nice drawing with a comment that the welding should be strong, but we did not include in the drawings what the maximum distance till the bearing was. So they welded a really thick line, the distance was not defined correctly so we had to smoothing the welding point, and let it check again by class". - Project Manager Engineering Ship (P7) 9.

Some technical manifestations or errors are described above, the cause of these manifestations will be described explored in the define phase.

3.5 Conclusion

This chapter gives an overview of the shipbuilding context of Damen in which processes and actors depend on each other, causing problems in the ship production phase. Below the sub research questions will be answered.

SRQ1. What does the ship development process look like?
The ship development process consists of sequential dependent processes and phases. Operational processes are project management, engineering, supply chain and production. Only the engineering and production processes are considered in this research. The engineering process consists of four phases, the Design Check (D.C.) Basic Engineering (B.E.), Detailed Engineering (D.E.), and Production Support (P.S.). The production process consists of three main phases, the hull production, the outfitting of the ship and commissioning and sea trials. During the production process engineering is involved with Production Support to answer questions and to solve problems. Both processes are based on the Work Breakdown Structure and Product Breakdown Structure. From an engineering perspective only the production support phase will be considered, from a production perspective only the hull and outfitting phase are considered. Production is highly dependent on the information delivered by engineering but engineering also depends on production with the amount of questions and feedback received. Both processes lead to the shared goal, developing a ship. In this research project there is a focus on the interaction between engineering and production the production phase of a ship.

SRQ2. Which key actors are involved in the ship production process?
From the engineering department there is always an engineering team consisting of an actor that focuses on the
mechanical part, electrical part and hull part. Depending on the size of the project there are multiple levels within a project team, so you will have a Project Manager Engineering (PME) for all categories Mechanical, Electrical and Ship (MES). The PME coordinates multiple engineers (MES). At the production department there are also multiple levels, on top there is the Production Foreman who coordinates shop floor employees. On one ship there are different PF with their own focus on piping, electric, painting and so on. The PF coordinates and collects questions from the shop floor employees and subcontractors, and will pass on the questions to the engineering department, to the PME or to the general Project Manager (PM). The different actors from the engineering and production department exchange information and knowledge and collaborate in a highly interdependent environment. In this research project there is a focus on the key nodes PME Mechanical, Electrical and Ship and Production Foremen.

SRQ3. What manifestations of errors occur during the production of a ship?
During the production of a ship multiple problems occur, some are small and are fixed by production on the job, but some are big and they need to be discussed with engineering. Many structural problems occur at the level of pumps that do not fit on foundations, at components like pumps, all disciplines come together, the electrical cables, the mechanical pipes and the ship engineers foundations which makes it a complex component. The engine room and technical space are the most complex rooms in the ship as all disciplines come together there. Besides having problems, production also has questions about drawings. Examples of problems encountered during production are described above. Multiple causes can be identified that influences problems in production. For example, the practical knowledge of engineers, insufficient communication between team members, production that does not follow the drawings, mistakes in drawings that are not being updated. Many different actors are involved in the shipbuilding process that have to work together.

The next phase will dive deeper into barriers between the engineering and production department to be able to define the root cause of problems that occur during production.

Room for thought

“With no exceptions, Michael Schrage said (CIO MIT’s technology review), the key element of all successful collaborations is a shared space. We all had the experience of sketching on a napkin together. The collaboration depends on the napkin.”
- Schrage

This is also what happens at Damen where engineering and production are co-located. If a problem occurs a production foreman visits the office with a question, or an engineer visits the ship. Sketches are made by the engineer to explicate his ideas and to share it with the foreman. Together they create a shared understanding of the proposed solution (as shown in figure 14). A sketch can be seen as a boundary object to share knowledge and information.

Figure 14: Engineers explicate their ideas about the solution of a problem by means of a sketch with shop floor employee.
PART II. Define

In the previous part, the research context is described in which manifestation of errors that occur during the ship production phase. Multiple actors are involved during the process, the context of Damen will be used to explore the collaboration between the engineering and production department.

In the “Define” part starts with the methods used in this phase. Afterwards there will be a focus on the cause of these problems based on literature and empirical research. Boundaries are defined between engineering and production on an actor level and on a department level. These boundaries will be translated into requirements for improvement for the situation within Damen.
This chapter gives an overview of the methods used in the define phase, in this phase multiple methods are used to collect data for defining the root cause of problems for the case of Damen. Literature is used to be able to understand the situation, and ethnographic research has been performed to be able to answer the main research question.

4.1 Literature review

In this phase, literature is referred to as a sensitizing concept which means that existing theories and concepts are used as ‘a general sense of reference and guidance in approaching empirical instances’ as defined by Blumer (1954). This means that existing theories and concepts are used as a lens to look at and understand the phenomenon of collaboration in the shipbuilding industry. The literature review focusses on concepts and theories that focus on the phenomenon of collaboration between experts and is applied to collaboration between the engineering and production department. The research for literature was guided by the research questions and by the knowledge of the supervisors of the researcher. Based on these books an articles, notes were kept and keywords from literature are used to explore more about the topics. The literature review is an ongoing research process during the project, a combination of deductive and inductive reasoning has been used in this project, the difference are shown in figure 15. Another option was not to look at literature at all, in this way the researcher is less influenced but maybe double work would appear. Literature is searched in electronic databases Google Scholar and Web of Science, and are reviewed based on peer reviewed journals. Besides this doctoral theses were used as an input for this project. In Appendix E an overview is shown of the used keywords and literature found.

4.2 Semi-structured interviews

After the unstructured orientation interviews, semi-structure interviews are conducted during this thesis project to be able to discuss observations and to learn more about problematic events and the shipbuilding process in general. 19 semi structured interviews are performed with different actors. Another alternative would have been to do a questionnaire or to use internal documents to define problematic events, but in a questionnaire the answers would steer the participants already into a direction. On the other hand, internal documents are available called Product Feedback Loop lists with obstructing events. These could have been discussed with different stakeholders, but not all actors fill in these lists. Semi-structured interviews are chosen as a method to gain deep and rich insights in problems and motivations of people.

Sample

The interviewees are purposefully sampled, based on ‘of context’ and ‘sampling of participants’. Interviewees do not only cover participants of the interface between engineers and production department but also broader (like planners, project managers), to be able to understand the problems in production and the interface between engineering and production in the broader social context of the organization. These interviews caused a snowball sampling approach, which means that participant suggested others to interview. During the research project, information is gathered based on the sources available. In figure 16, an overview is shown of the interviewees and their position in the context (P# stands for participant number). Appendix F gives an overview of all formal interviews.
Interview procedure

During the project actors have been interviewed based on a semi-structured interview guide with topics to discuss like problems during production, in communication and collaboration (Appendix G). Based on these topics, introduction questions were asked to be able to put the answers in perspective like follow up questions, probing questions, specifying questions and structuring questions. It was interesting to observe that interviewees tend to open up when the interview has ended, that is why the recordings are not swished of immediately after the interview. Interviews are performed face-to-face in conference rooms, to create a safe environment in which the interviewee can speak freely.

Data processing

During the project, the interviews are recorded and afterwards partly transcribed. This formed large number of unstructured textual material. To be able to structure the material, grounded theory is used as a framework for analyzing the qualitative data (Glaser & Strauss, 1967). The transcripts are coded based on theoretical sampling. According to Glaser and Strauss, theoretical sampling 'is the process of data collection for generating theory whereby the analyst jointly collects, codes, and analyzes his data and decides what data to collect next and where to find them, in order to develop his theory as it emerges. The process of data collection is controlled by the emerging theory, whether substantive or formal.' Strauss and Corbin (1990) distinguish three types of coding practices.

1. Open coding – sentences that are interesting are coded
2. Axial coding - making connections between codes and leading to some insights in barriers between engineering and production.
3. Selective coding - results in categories as shown in figure 17 in which different barriers are defined.

Codes and categories developed over time during the project. All data from the interviews, experts session, focus group and tests are collected in the qualitative data analysis software Nvivo (overview as shown in figure 19). Findings from this source of data are discussed in chapter 6 and will answer the sub research question: What collaboration barriers can be defined between engineering department and production department?

4.3 Midstream Modulation sessions

Next to the semi-structure interviews with the different stakeholders, 4 key actors from both sides of the engineering and production interface are interviewed repetitively. This collaborative method is used as an addition to the semi structured interviews with other stakeholders to gain a deeper understanding of behavior and feelings (frustrations and needs) of engineers and production foremen. The sessions are also used to discuss and evaluate the proposed design. The method is used to explore deeper underlying needs. Other methods to explore these deeper underlying needs could have been context mapping (Visser et al., 2005) but the researcher did not know much about the context, by repetitive dialogues with the four key actors knowledge was gained about this too.

Sample

Four Damen employees participated in the study as shown in figure 18. Two participants have an engineering background, Participant 3 (P3) and Participant 4 (P4) focussing on the mechanical part of a ship. On the other side, two participants Participant 8 (P8) and Participant 18 (P18) have a production background, focussing on the management
of the ship production. These participants are selected based on probability sampling (Bryman, 2012), to understand perspectives from both sides of the interface, two were chosen based on availability in Gorinchem, and they should be working on series of ship or semi custom built ships.

**Interview procedure**

These interviews are structured based on Responsible Innovation methodologies (Flipse, 2013). During and after every interview notes are made with interesting insights from that interview, written down in the researcher’s notebook. Insights from one interview were used to strengthen the questions for the following interviews. A semi-structured approach is used based on the decision protocol to consider social, technical and economical aspects during the research project. By interviewing the same participants 6 times, insights are gained about social structured and interactions within the project team besides this, observation findings could be validated. The sessions are used to explore the situation on the one hand and on the other hand to evaluate findings and discuss directions with the four employees. In figure 20 an overview is shown of the times the MM session took place during the design process. In appendix H an overview is shown of the protocol which is used as a guidance during the meetings.
Data processing
The six interviews with four participants resulted in roughly 20 hours of recorded interviews. These interviews were recorded and partly transcribed. Quotes were used for social, economical and technical opportunities, considerations, alternatives, outcomes. Outcomes of the midstream modulation sessions are also added to Nvivo but are coded based on themes, design criteria and on opportunities, alternative, considerations and outcomes. The findings of these sessions can be find throughout the whole report in chapter 6 till 10 leading to the final design.

4.4 Expert session

During the project, an expert session was organized to evaluate the findings of the discovery and define phase and to discuss the direction for the define phase. The session is organized to reduce investigator bias into a direction by involving external experts on communication, design and the Damen organization. The three experts are consulted in a 2 hour session on the potential direction of the research based on the findings of that time.

Sample
Representative of the company (Project Manager Engineering Mechanical), a representative of design perspective (Industrial Design Engineering graduate student TU Twente) and a communication expert (Assistant professor, Science Communication) together to discuss the interaction between engineers and production.

Procedure
In the session, findings are discussed besides this discuss the direction of the project with them and ideate on possible actions and instruments to detect, indicate and correct errors. The six categories defined for the root cause analysis are discussed during the expert session. Besides this there was a brainstorm about activities and tools to detect, indicate and correct errors.

Data processing
The session is transcribed and analyzed in Nvivo. Based on the data, during the session it becomes clear that there should be a focus on problems caused by deficiencies in information and deficiencies in the communication process between the engineering and production department. Findings of the session are incorporated in chapter 6 and contribute to the research question about barriers for collaboration between engineers and production. Findings of the expert session can be found in Appendix I.
5. Literature review

In the discover part manifestations of errors are described that occur during the ship production phase. This chapter gives a theoretical review of existing knowledge about problems that occur in project teams from a social perspective. Theories described in this chapter will be used as lens to look at the boundaries for interdisciplinary collaborations in the New Product Development process of Damen, to be able to understand why manifestations of errors occur. The sub research question that will be answered with this literature review is: (4) What is already known about barriers for collaboration between the engineering and production department? The review starts with section 5.1 with literature about errors and how they can be recovered. Section 5.2 describes how knowledge differs between engineering and production, and section 5.3 explains the influence of awareness on collaboration. Section 5.4 describes how boundary objects can be used to exchange knowledge and section 5.5 focusses on the interaction between actors. Section 5.6 concludes on what has been found in literature.

5.1 Error recovering process

This research focusses on the detection of errors more than prevention. In labour intensive industries errors occur as humans make mistakes and this cannot be prevented. On of the theories that have been used to explain why errors occur is by Sasou and Reason (1999). They distinguished three types of failures in recovering an error. The failure to detect occurrence of an error, failure to indicate and bring attention to the error and at last the failure to correct the error. In their study they determinate how team errors are made based on Performance Shaping Factors (PSFs), which are factors that cause errors in a team context. PSF can be internal (high arousal, deficiency in knowledge/experience and low situational awareness), external (seriousness, deficiency in human machine interface and high workload) or team PSFs (deficiency in communication and excessive belief like ideas, opinions, decision and actions). In figure 21 an overview is shown of factors that influence the detection, indication and correction of errors. If a team fails to indicate and correct individual and shared errors, there has been influence of human relationships (Sasou and Reason, 1999). They found that the most common team PSF is the deficiency in communication as if team member does not have enough information through communication, they will not be able to detect errors. The study concluded that responsibility and non-fulfilment of responsibility seems to be crucial for the prevention of team errors.

![Error detection model with factors that cause errors by Sasou and Reason (1999)](image_url)

Figure 21: Error detection model with factors that cause errors by Sasou and Reason (1999)
Looking at individual actors within a team differences in the awareness and knowledge of an actor are influenced by the level of information exchange and communication between team members. That is why on an actor level knowledge, awareness are described more into details to explain how errors can be detected.

5.2 Knowledge of actors

When collaborating in an interdisciplinary project team, every person has a certain amount of knowledge which can be described as a mental model. Peter Senge (1990, p 8) describes “Mental models are deeply ingrained assumptions, generalizations, or even pictures or images that influence how we understand the world and how we take action. Very often, we are not consciously aware of our mental models or the effects they have on our behavior.” Mental models are “mechanisms whereby humans are able to generate descriptions of system functioning and observed system states, and prediction of future states” Rouse & Morris (1986, p.7). Mental models are built up out of over many years of education, training, experience and work, they become ingrained with a very deep understanding of work performed and enable a person to carry out work effectively and efficiently (building routines). Apparently a mental model consists of explicit knowledge which can be shared easily and implicit knowledge which is harder to share with others. Routines are described as implicit, tacit technical knowledge (know how) and is a personal quality which is harder to formalize (Nonaka, 1994). Besides the tacit technical knowledge, a person also carries cognitive knowledge. Cognitive knowledge consists of personal beliefs, values and perceptions and assumptions like commitment and involvement of individuals as shown in figure 22.

When two actors with similar cultural beliefs and the same field of expertise work together, they will have a similar mental model. They understand the way they are thinking and what the other means. While working with people from different cultures, transferring knowledge can be harder as different interpretations can lead to misinterpretation of information (Carlile, 2004). It is easier to transfer knowledge and information between two people with similar backgrounds as the interpretation of information will somehow be the same. International project teams backgrounds of actors are different influencing the possibility to collaborate, dimensions defined by Geert Hofstede that influence are “individualism”, “power distance”, “masculinity”, “uncertainty avoidance”, “long term orientation” and “indulgence” (Hofstede, 1980). When a Dutch actor has to work with a Vietnamese actor, the dimensions differ from each other, influencing the common ground between actors.

When working in interdisciplinary project teams, actors have different background and expertise leading to so called incongruent mental models (Smulders, 2006) which makes collaboration more difficult. In a project team working towards a shared goal like the shipbuilding process, actors should be able to understand the other person. In literature, multiple studies describe how errors occur and different activities are described to create more effective communication between actors to create shared mental models. This is needed as “being able to supply information when a user or team of users needs it depends on having enough of a shared mental model of a problem to anticipate when the next step differs from context to context in a way that cannot be entirely predicted by a set of rules.” (Gorman, 2010, p. 90).

Synchronizing mental models can be done by the job training, observations, practice, continuous dialogue between experts (Nonaka, 1994). Sharing a mental model is needed to be able to consider the viewpoint of the other actor. By dialogues, joint actions actors can make sense of another’s knowledge and routines, creating a context in which decisions can be made, mental models can be shared and leads to better understanding of the other actor.
5.3 Situation awareness

Social interaction between actors appears to be the key for collaboration, if collaboration is there between actors then social interaction can be found in it, and vice versa, “if there is no social interaction then there is also no real collaboration” (Kreijns et al., 2003). To be able to reach a common goal in teams, situation awareness is needed and is described as “an understanding of the activities of others, which provides a context for your own activities” (Dourish & Bellotti, 1992, p.107). Awareness is facilitated by team processes and behaviour that allow sharing, developing and maintaining knowledge. Awareness can be supported by information systems and is needed to connect information to the already existing mental model of an actor (Endsley, 1995). Information is the basis of all communication and is needed to create this awareness. In project teams not only task related information is exchanged between actors but also social emotional information for creating a bond between team members. In collaborations it is essential not only to share task related information but also social and context related information to create a picture of the other actor. Information and knowledge can be shared just by face to face interactions but often objects are involved to exchange information and knowledge between team members, called boundary objects. Boundary objects are described in section 5.4.

5.4 Boundary objects

Star and Griesemer define “Boundary objects are objects that are both plastic enough to adapt to local needs and constraints of the several parties employing them, yet robust enough to maintain a common identity across sites” (Star and Griesemer, 1989, P 393). In shipbuilding an example of a boundary object is the General Arrangement or a 3D model which consist of already exciting knowledge. Boundary objects enable actors to create a shared understanding and to synchronize the mental models (Smulders & Bakker, 2012). Boundary objects are used as temporary anchors or bridges to a shared understanding between team members. Carlile (2002) describes boundary objects as object to transfer knowledge and information. Boundary objects play and important role in the new product development to synchronize mental models of different actors (Bruinessen, 2016; Smulders, 2006). The different levels of a boundary object are described in figure 23. Syntactic description focusses on the processing of information, the shared perception of information between actors (like shared repositories, CAD). Semantic description describes that a common language needs to be created between actors (like standard drawing forms). And the pragmatic level is more about a common interest and making negotiation about knowledge possible. A boundary object itself like a drawing can also be a cause of problems, mistakes in production information makes it harder for engineering and production to create a shared understanding.

5.5 Interaction between actors

Literature describes the incongruent mental models of actors from two different departments, boundary objects are used to share knowledge and synchronize mental models. Besides this awareness is needed of an actor of their task in the bigger picture. Another factor that influences the collaboration of a project team is the quality of the interaction between actors, which depends on the experience and social relationship between actors (Smulders & Bakker, 2012).
The collaboration between two departments like engineering and production is essential to be able to build a new ship. Engineering has a more exploration character, by looking for possible solutions, while production performs more routine work. Actors in production transform information like drawings developed by engineering into a tangible product. They do this based on previous experiences and knowledge of practical activities. In the production phase, organization routines are key to efficient and effective working.

Collaboration is about sharing knowledge and skills to be able to achieve a common goals and to solve problems. Looking at ship production as a social process in which ‘synchronizing incongruent mental models’ of engineering and production actors is needed to be able to communicate and exchange information in an effective way and to make sure problems do not occur or are fixed as soon as possible. Synchronizing incongruent mental models means understand what other need from the other perspective. How actors perceive the interaction influence the amount of information and knowledge shared with the other actor. Smulders (2006) defined the following tentative categories of incidents that influence a project. The categories are: incomplete information, learning, prototyping, organizational setting, disturbance of ongoing processes, late, poor or no communication, definition of targets or project goals, planning and control, New Product Development deliverables and the inherent difference of actors. These categories are used as an input to be able to understand the situation at Damen.

5.6 Conclusion literature review
In this review the research question is answered:

SRQ 4. What is already known about barriers for collaboration between the engineering and production department?

In literature different barriers are described in general, causing errors in project teams like deficiencies in communication, low task awareness or difference in knowledge between actors. Mental models of actors represent a mental picture of the situation of actors and consist of knowledge and experience and influence routines of actors. Knowledge and awareness influence the formation of a mental model. When two actors from different backgrounds work together, time is needed to be able to understand the other way of thinking. Theories as described in this review are used to understand the actors and the situation in Damen. Barriers in the interactions between engineering and production will be analysed based on the boundary objects used, knowledge that is shared and the awareness of the actors. Figure 24 gives an overview of the literature described above and is used as a guidance for the researcher to be able to make sense out of the situation in Damen.
Chapter 5 describes existing concepts about barriers between the engineering and production department. The framework will be used as a lens to look at collaboration during the production phase of a ship at Damen. Data is collected based on midstream modulation sessions to explore frustrations at the two engineers and two production foremen concerning the interaction on an actor level. Findings from the semi structured interviews give a more general impression of barriers between engineering and production department and also support the actor level. The barriers are divided on three levels, inter-actor level and project or inter-department level and company level (Kleinsmann & Valkenburg, 2008). This research focusses mainly on the inter-actor and inter-department level as shown in figure 25. This chapter addresses the research questions: (5) What barriers can be define in the collaboration between actors during the ship production phase? And the sub research question: (6) What barriers can be defined between engineering department and production department during the ship production phase?

Five main themes of barriers occurred during the analysis of the data (partly influenced by literature) that influence the collaboration between engineers and production and influence if manifestations of errors during the ship production phase. These five interconnected themes are; knowledge barriers, awareness barriers, information barriers, communication barriers and technology barriers. This chapter results with an explanation how communication process between the engineering and production department can be improved.

6.1 Barriers on an inter-actor level
On an inter-actor level the thoughts, ideas and frustrations are described about the communication process between individuals, communication is about details. Below some quotes are written down illustrate the barriers, multiple quotes are there describing the same problem in the data. Connections are also made in the intra-actor level, where knowledge is located.

Technical knowledge barriers
Knowledge can divided in technical implicit knowledge that is based on the skills, abilities and know how of an actor, and in cognitive implicit knowledge which is based on beliefs, cultural norms and values. Production employees highly dependent on the production information delivered by engineering, which is developed with knowledge from the engineers. One of the main barriers that mentioned that influences problems during the production phase of a ship and influences
the collaboration between engineers and production employees, is the lack of practical knowledge of young engineers. Back in the days, engineers worked in production for many years and then started to work as an engineer, these days’ engineers come from school without having set one foot in production. This causes that the mental models of production foremen and engineers are not shared. A senior engineer describes the difference between having practical experience or not:

(...) it depends on what's on the engineering person and what kind of people you are dealing in production. Look, I myself have walked in production for years, I know exactly know what those guys need and I will make just a sketch and then they can work further and keep them going. (...) Back in the days, if I had de draw a general arrangement, I was trying to put the engines in there and create space for the outlets and the dampers and the generator, that is how you should build a general arrangement. I have a general arrangement already in my head. That does not happen today anymore, engineers do not have the knowledge and experience. - EN1 (10)

The lack of practical knowledge on the one hand causes production information that does not suit the routines of production employees. Working together with an engineer with experience and practical knowledge is perceived more easy:

(...) Because he has the experience of how to build a ship and he knows what we need, he delivers the package completely and he delivers the rest of the information. And that's the same with the [mech. eng.] now, he knows what we need and what potential "aanlopers" can be.- Production foreman (P8) 11.

Having practical knowledge means that an engineer can emphasise with production and is able to understand what is needed by production. An engineer with practical knowledge is aware of how the ship will look like in the future, how it will be build and what potential problems can occur during production. Another point that frustrates production is when there is a standard or when they have done a job multiple times already, but engineers “reinvent the wheel again”. This is not only influenced by the practical knowledge but also reusing and sharing knowledge between engineers and production. Knowledge is already there from previous projects, but also using the knowledge of production. Now individual engineers and foremen have tacit knowledge and experience about a project, what did not go very well, what problematic areas in a ship. This knowledge is located in the head of the involved engineers and production foremen. There is a gap between the learning curve from one ship to the next one in a series of ships. Production has a lot of knowledge about a previous ship and is able to predict the problems will occur on the next ship. This implicit knowledge that is gained during previous ships is hard to communicate abroad.

Cognitive knowledge barrier
On a cognitive level, the personal believes, values and culture influences the interaction and relationship between engineers and production foremen. The level of involvement of an engineer with the work of a foreman influences how he experiences the collaboration. Engineers that visit the ship on a regular basis are valued by production, but in general production believes that engineers do not visit the ship enough. These moments are often used by production to ask some small questions. This is also acknowledged by the engineers that were involved in the research, the two engineers who were followed closely (in the midstream modulation session) visit the ship on a regular basis. They do this deliberately, on the one hand to show their face so that production can ask questions and to be able to solve problems together, and on the other hand the engineers use this moment to see the ship instead of the 3D model. But in general many engineers stay behind their computer and do not visit the ship even though engineering and production are co-located. This is also observed by the researcher, the young engineers need to be pushed to visit the ship at least once a week.

There is some discussion about the role of decision making in production. Production foremen believe that in production decisions should be made, while others believe that if there is a question, the project manager or engineer should be called.

To sum up, the level of involvement and interest of the engineers with the foremen influences the relationship between the two, some engineers are highly motivated to visit the ship but in many cases engineers do not visit the ship, which is
not understand by production. Young engineers describe that they should have a clear purpose to visit the ship.

Awareness barriers
The previous section elaborates on the difference in knowledge between engineers and production foremen influence their relationship. A known difference between engineers and production is that engineers work at the office behind their desk with 2D drawings and the 3D model as their reality. Engineers are responsible for need to work to their deadlines within the hours they receive for developing production information.

Engineers are more theoretical oriented and production practical oriented, production knows how a ship is build and an engineer is aware of the why behind decisions and which alternatives are being evaluated. This can cause a barrier between engineering and production as production is not always aware of the options that have been evaluated. Designing a ship is about making consensus. Foremen are only aware of the options they know and how they always have done it.

Awareness of the tasks of others influences the decision making process and the performance of employees. If the awareness of an actor in the bigger picture is low, decisions will be made that negatively influence the project team performance (Endsley, 1995). An example what happens within Damen is the lack of awareness of engineers how their work will be used by production (this is also connected to the practical knowledge).

"Engineers should be aware of the impact of their work, they are part of building a ship. Help them become aware of the one who builds the ship. That requires something of their empathy and willingness, but also knowledge and skills. If they do not know what is encountered by production"- Production manager (P14) 12.

While production is working on the shop floor, producing the real ship. Some engineers are not aware that production need answers fast. This causes waste of time, efficiency and productivity by waiting on answers from engineering. Besides this a visual is needed from the ship to be able to answer a question. In Gorinchem the foremen are able to visit the engineers directly on their desk, which means that they have to help them. These visits to the office are also used by the foremen to hear what is going on at the engineering department.

Production is sequential dependent on engineering, during the production phase engineers are often working on multiple projects. When production asks a question over the phone engineers compare the 3D model with reality. Engineers do not real understand situation at yard, in Gorinchem visiting the yard is the best way to get a clear impression of the problem.

Information barriers
As explained in the awareness part, engineers develop the production drawings and 3D model. The construction drawings and 3D model are boundary objects, transferring knowledge from engineering to production. Unfortunately, this information is not always complete and correct. In the current situation 2D schemes are developed in the basic engineering phase. Later these will be used by detailed engineering to develop the 3D model. This translation from 2D and 3D is separated from each other. Besides this, the 3D production information is translated into 2D production information again. This means that when there is a mistake in a drawing, it is time consuming to adjust it and it is possible that connected drawings are not adjusted, leading to inconsistent information. For engineers this is a point of frustration but also for production, there is no single source of truth. In Appendix J an overview is shown of information that is shared during the ship development process.

The 3D model has become an important tool (or boundary object) for production to be able to understand the 2D drawings. The 3D model it is easier to understand and gives a better impression of the future state of the ship. Information on 2D drawings is harder to interpret than the visuals in the 3D model, as described by two production foremen below.

"Then I get a very good idea of how it should look like in 3D, which can be done in 2D but in 3D really walk of the ship. And then you’ll see a closet here, a closet there, on a drawing you feel less. If I work in the 3D model and I see that there’s an electrical box in a corner, I can click on it and see what it is, if I have missed it on the drawing, because it is less easy to read. Now I walk through a ship, then I can look around, and then I’ll look for the drawing. Like, I have to do something about it and about that. It’s just a useful
During the production phase, detailed engineering is still ongoing which means that information still can change. This is a point of frustration for production, when information is adjusted without informing production about it.

When engineers and production interact with each they become more aware of the situation of the other, a push and pull of information arises while sending a email is only informative.

**Communication barriers**

During a project multiple communication moments are there between actors in which engineering and production interact with each other. In figure 27 an overview is shown of the different communication means used during a project, in Appendix K a more extensive explanation is given per communication mean.

When engineers and production interact with each they become more aware of the situation of the other, and a push and pull of information arises between engineers and production, but still most communication happens via email. This is a big point of frustration of many interviewees.

The use of email is also perceived as giving the responsibility away. When the sender send an email, the receiver becomes responsible for answering the email. Not getting an answer on an email is a big frustration point, not knowing if a message has been received creates uncertainty at the sender side.

"yes and then an answer like, I am working on it, is really useful, or boys I’m busy can someone pick it up. Then you know that someone is working on it" - Production foreman (P18) 14.

Hierarchy in the organization causes that there is not a closed feedback loop between engineers and production, there is also not a clear standard for giving feedback. Sometimes feedback from production is send to the project manager and sometimes to engineering. Engineers cannot learn from their mistakes as described by the engineer mechanical (P4, 15) below:

"(...) There is a lack of feedback on drawings, because there are many layers, engineer, lead engineer, pm engineer, pm. The whole tower, engineering draws a drawing and it is discussed in a meeting, but it does not always come back to the engineer if something else needs to be done. (...) It is not good for your development if you get exactly tasks like you need to pull line from left to right. (...) Production often says: yes, we are reporting to the project manager, for example, but that is not always communicated to engineering. That is of course the question, you never know." - Mechanical Engineer (P4) 15.

During the production support, different communication means are use in different situations. Below the communication means are described with positive and negative aspects and examples are given how the tools are used during a project and how they are perceived by the actors. When engineering and production are located abroad, less one-on-one, direct communication is there between actors which leads to less collaboration between the actors.

![Figure 27: Overview communication means used in a project between engineers and production foremen](image)
When a problem occurs in production, engineering has problems in understanding the situation at the ship. Visual images are needed. Pictures are made by production to share problems and to give updates to engineering, these pictures are shared via email once a week or every two weeks, depending on the project.

For production employees it is important that they feel valued for giving feedback. If feedback is not processed and the same mistakes occur in the next ship, motivation will decrease to share feedback. On an individual level the person characteristics like attitude, knowledge, skills influence the collaboration between team members. Some engineers are proactive in asking for feedback from production which is valued, some engineers prefer to stay behind their desk and do not show often in production.

Social relationships between team members is important for good communication and the other way around, it lowers boundaries to discuss errors with each other. For project team members who work close together, building these relationships is much easier.

“Twice, the first time when I took over the project I had after a month, we were emailing and Skype all the time. I prefer to go there to show my face. Drink a beer together, communication definitely improves then. (...) Yes, because they dare to ask questions then (...)” – Mechanical Engineer (P3) 16.

Technology barriers
The previous sections describe barriers for information exchange, communication, awareness and knowledge exchange between engineers and production foremen. This section describes the situation from a technology perspective and barriers on technology level will be discussed.

Engineers from the basic engineering phase work in 2D AutoCAD and if an adjustment needs to be made in 3D model, detailed engineers in Romania, Ukraine or Vietnam are informed to make the adjustments in 3D CAD model. This is a time consuming process and it means that the 3D model is not always up-to-date. When the ship is being build, a part of the engineers is already working on another projects and the 3D model is not always adjusted to the as-build situation. Unforeseen errors arise because there are deviation between the production information and the real ship both engineers and production foremen are not aware of this.

Different technologies used to process feedback now done with the PLF (product feedback loop) list, people have their own lists and now a mobile software tool called SnagR is implemented to detect, indicate errors on the ship. But there is no clear standard for giving feedback.

The 3D model is often used by production but not all information is included in the 3D model. It depends on the time and money available for a project to what extend a model is complete. This is discussed in agreement with the yard as described below:

“Small things, the agreement is actually keep it simple, so anything less than 20 mm is not visible in the Ebrowser. 50-50 cm should actually also not be visual in the Ebrowser, but I decided now I want everything in the 3d model” - Mechanical engineer (p3) 17.

But when the 3D model then is used on another yard, these agreements should be the same, which is not always the case.

6.2 Barriers on an inter-department level

On a project level different boundaries are defined between engineering department and production department (or yard) that in the end lead to manifestations of errors during the ship production phase. These boundaries focus more on planning of the project, budgets and organization of the project. This section gives an answer to the question: What barriers can be defined between engineering and production department?
Knowledge barriers
Not only the practical know how of engineers is decreasing, the know how at some yards is also criticized by both production and engineers, there is a difference between the know how of yards.

Engineers develop routines for developing drawings, but production employees also develop their routines which causes that drawings are not always followed in Gorinchem. When working with a yard abroad the drawings are exactly followed by production. Where production in Gorinchem fills in the gaps with their problems solving skills, this does not happen at a yard in Vietnam. This depends on culture but also on the relationship between Damen and the yard. If a problem occurs the question arises who is responsible and who needs to pay for it.

“There is also a lot in the culture, and it is also has to deal with money of course. Nowadays, the question is increasing, who is guilty?” Who did it wrong. - Manager Contracting yard (P24) 18.

Information barriers
The yard depends on the quality of information delivered by the engineering department. When developing production information for a ship, it is impossible to deliver a 100% correct production information package, as this the too time consuming and expensive. It depends on the budget for engineering to which detail the production information will be engineered,. This is in agreement with the yard, but sometimes misinterpretations can occur what is included or not. Below is discussed that sending a complete information package is impossible (quote 19):

[en1, ship engineer] “send a complete package, but that is not possible.”
[pf1, production foreman] “Well, it is possible, you know what we are doing then, we will engineer the whole ship, into every detail. We will build that one here then, if we are going to engineer all the details we become too expensive, so what are we going to do now? We engineer the big lines and the rest is for production.”

Besides this engineers develop their own routines of design for example a foundation, but by the lack of practical knowledge, these designs do not fit the routines of production very well, as illustrated by the quote below.

“Even foundations of for equipment we have the same problem. They make it complicated. But the reason is not so clear not for me but also not for them. They say this is how I used to design foundations, but looking back there is no real reason. You start working in one style, you always design foundations in the same way, the point is that one situation is not the best solutions. It is hard to quantify that.” - Hull Coordinator (P21) 20.

Besides this actors make mistakes which is inevitable, but this means that there are some “gaps” in the production information. This incorrect, incomplete, unclear and inconsistent production information cause problems during the production of a ship, besides this production information does not always fit the routines in production. These “gaps” in the delivered production information needs to be filled during the ship production phase by the production employees and engineers involved during the production support (as shown in figure 28). By asking questions to the engineering department these “gaps” can be filled, but when questions are not being answered, the yard will find its way to fill in the gaps themselves. An example of a quote about this can be read below (quote 21):

“That should come back to engineering, like listen we’ve always done it like this, please change for the next ship. But these are not
huge things that they change independently. Little foundations of closets or something, they should use 50-50 cm but they say never mind we do 30-30 cm, nobody gets better or worse from that.” - Mechanical engineer (P4) 21.

When a ship is being build multiple times at a yard, production employees will develop their own routines and develop implicit knowledge to handle the production information (as shown in figure 29). Besides this the importance of monitoring or checking the ship is stressed. This is illustrated with the following quotes (22):

“Yes, it is on drawing. But if there’s no checking, then something becomes normal, then you get it like, we’ll always do it like that. (...) Yes, that works like this. If he does something always year after year, you’ll get like; We always do that, that does not always mean that it is good. That’s why it’s good if someone with a fresh eye looks at it. Therefore, if you are inspecting a boat, you look at the ship differently than when you’ve been working on it all day long. Sometimes you’re blind to things, you just do not see it anymore.” - Production foreman (P18) 22.

But when the same production information then will be used on a different yard, or when new production employees are involved in the project, the same mistakes will occur again as they do not have the knowledge yet to solve the problem. This is also a point discussed during the focus group, the discussion about this topic can be read below (23):

[Production foreman 1] “Here you often have a problem and a foreman and those guys on board often already have a solution. Then talk to [engineer ship, en1] or [engineer mechanical, eng2] or someone else, if you agree”.
[Production foreman 2] “Whatever it is, if it has not changed in the standard, we often remember it, then with the next ship then I think, right this is how we should do it. Then it’s not really a problem anymore”.
[Mechanical engineer 2] “then we are lucky that you are responsible for the ship again, if we get another foreman...”
[Interviewer] “imagine there is another foreman?”
[Production foreman 2] “Yes, then you have a problem.”
[Ship Engineer 1] “I’ve experienced the same in Cuba, with 42 meters there’s a steel package to build the hull and it is not correct at all, all sheet plates. I just miss out on things. That was still in one of the previous versions. These problems have not been eliminated, I mean hulls are being made here at [Company Name], they have their own cutting package now in which these problems have been solved for a long time. That problem is a few years old, and then we are going to build a hull somewhere in Cuba, then all childhood diseases come up again.”

In production engineering activities are performed and in production problems with the delivered information by the engineering departments are being solved on the job (as shown in figure 30 on the next page). These problem solving activities cause that new knowledge is created during the production phase of a ship. These small problem solving loops normally occur during the engineering phase but in the ship production phase there is room for these small iteration or incremental innovations on a ship, which are not captured in the production information.

**Development of implicit knowledge by production and engineering when serie of ship is build:**

![Diagram showing the development of implicit knowledge over time.](image)

Figure 29: Experience being build over time by engineers and production (based on interviews)
In Gorinchem, these solutions are shared with the engineering department, but because of a lack of time/money, these adjustments are not processed. Depending on the budget and motivation of the product group/project manager it is decided whether the solution is processed in the production information for the next ship. It happens that this “as build” information is not processed and tacit knowledge is at the individuals that are involved in the project. Factor that causes that information is not adjusted are: the ship is there, we do not have budget to adjust information “as build”. This means that a problem occurs again and again is series of ships. When experienced employees are involved there is not really a problem, as they developed routines for filling in the “gaps”. But when this information is used to build a series of a ship on a new yard, the same problems will be encountered by that yard, causing many questions.

At some yards like Vietnam, production information is strictly followed by the production employees, then the problems also arise again, an example is described below. The quote also described that not at all yards the employees have the ability to do the engineering activities. The level of know how or implicit knowledge differs per yard, the amount of problems and questions also depends on the skills and problem solving abilities of the yard as described by the following quote about Vietnam.

“(...)And sometimes I ask the question. Please did you think about it to do it like that? No because the drawings shows this. Or there is nothing on the drawing, so we do what we think is best”. - Mechanical engineer (P3) 24.

When a ship is being build on a yard for many times, problems are solved easily, but when a ship is being build on a new yard or on a yard that has never build a ship before, these problem solving skills are not developed yet or they do not dare to not follow the drawings.

“Secondly is that for many clients it is the first time they build a ship, and in Galati or here in production they have build a ship already ten times, they can solve problems much easier, they have more knowledge” - Production manager (P14) 25.

Communication barriers
In a hierarchical structured organization like Damen, formal communication is facilitated by the project manager (PM) of the project. This means that the engineering department and production department only have indirect communication
lines, which is time consuming and feedback and questions can get stuck in this process. This means that there is no closed feedback loop between engineering and production department, causing that engineers are not aware of their mistakes and that the yard does not rely on Damen as questions are not being answered. When questions are not being answered or when feedback is not considered, trust between the two departments decrease as shown in the quote below:

“And without communication or feedback to engineering. In the past they have given feedback, but nothing was been done with it, engineering did not process the feedback. And then they said, the document package we will throw it away, if we know where it should comes then we can fix it ourselves, and then they build something. Without engineering knowing what production was doing.” - Mechanical engineer (P3) 26.

Formal communication route is not always followed, during a project engineers and production employees can decide to switch from formal, indirect communication to informal direct communication (an overview is shown in figure 31) as shown by the example below:

“So you send the answer to the project manger and they pass it on to the yard?” - Interviewer
“Yes, but in my experience the communication line becomes directly and that is also what I prefer” - Mechanical engineer (P4) 27.

Difficulties with processing feedback at the start of a project, the lists of the previous ship are not considered anymore as these points of improvements from the previous ship are indirect costs as described in the quote below. Project managers wants to keep their budget for their project as low as possible, which means that nobody takes responsibility for the points of improvement unless money can be spend on it. This happens more over by series of ships by the product portfolio manager who is responsible for these points of improvement. When the points of improvement are not processed, problems will occur over and over again when a ship is being build on a different yard.

“How come they do not see the need?” - Interviewer
“Because for the current ship it has been fixed, for the next ship the attitude is like, yeah then we will see. We’ll see that again, but if you want to do it right then you change it immediately. Now we start with an action list, everyone is running around, and we’re moving on. Suppose there’s an 09, I’d like to take the time to get things right for the next project. But the project manger engineering already said that will not work. But these are more or less indirect hours, you do not earn anything with it immediately. That is just very difficult.” - Mechanical engineer (P4) 28.

Technology barriers
Yard and engineering department use different systems, in Gorinchem for example IFS is being used, but not at all yards this system is also implemented. Production information therefore needs to be exported and printed for the yard which causes that information. This means that information is easily outdated when a revision needs to be made it takes time before the yard receives the revision.

At many yards the 3D model is not assessable for all production employees, only the ship coordinator or a production foremen has access to the model in his office. Having the 3D model is described as a irreplaceable tool for understanding the 2D drawings.
6.3 Problem space

In the previous section different barriers are described, on inter-actor and inter-department level. These barriers are summarized in figure 32 and 33. Below the sub research questions will be answered and the problem space on which there will be a focus is discussed.

**SRQ 5. What collaboration barriers can be defined between actors during the ship production phase?**

The root cause of problems in production is the inherent difference engineers and production employees. Their have a different perception of the world (their mental models), based on their knowledge and experience. Both engineers and production work on their own activities and are not aware of the activities of the other actors or their part in the bigger system. On an inter-actor level feedback loops are not always closed between engineers and production foremen. For example questions are not being answered or feedback is not processed. When communication via email, there is no real interaction between engineers and production which is needed to create a shared understanding, of the situation.

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**Information barriers**
- Lack of practical knowledge of young engineers
- Engineers develop routines for developing drawings
- Engineers reinvent the wheel (knowledge exchange between projects)
- Production engineers on small scale on the ship
- Technical know how depends per yard
- Knowledge about problems previous ship on person
- Production employees choose routine over drawing in NL
- Abroad drawings are followed exactly
- Routines are developed to handle drawings

**Knowledge barriers**
- As build information not updated
- Information copied wrong from previous project
- Not share all information or knowledge to keep power

**Communication barriers**
- No proactive communication about adjustments
- No confirmative communication (Questions not being answered)
- Technology mediated communication and level of interaction
- Indirect communication lines
- Emailing is putting responsibility in someone else his/her hands
- Lack of informal communication moments

**Technology barriers**
- Multiple ways to process feedback
- No wifi at the yard or bad internet connection
- No one single source of truth
- Don’t know all options, why something is done in a certain way
- Not all actors have access to 3D model

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**Figure 32: Overview barriers on inter-actor level**
SRQ 6. What collaboration barriers can be defined between engineering department and production department during the ship production phase?

Errors occur during the production of a ship because two parties who have to work together are decoupled from each other. The engineering is less involved in production phase and production department (or yard) is not involved with engineering phase. If a problem occurs based on information that is incorrect, some yards have developed routines for solving problems on the job. When an information package is send to a yard that builds the ship for the first time again or to a yard that follows the drawing exactly, multiple problems will occur. These problem solving activities also can be seen as engineering activities in the production phase causing small scale innovations in the ship design which are not captured in the information package. In the current situation production is sequential dependent on engineering, but engineering also depends on production as they have practical experience if information can be produced or not. Production an engineering solves problems during the production phase which is not always captured, so if a information package is send to another yard, same problems will occur again.

Figure 33: Overview barriers on inter-department level

Information barriers
Yard depends on quality of production information and routines of the engineering department. Incorrect, incomplete, unclear and inconsistent production information cause problems during the ship production phase. As build information not being processed same problems keep occurring.

Communication barriers
Hierarchical structure of organization causes that all formal communication is facilitated by project managers causing indirect communication lines which are time consuming, and information is interpreted different. There is no closed feedback loop between engineering and production department and question not being answered.

Technology barriers
Yard and engineering department use different information systems, production information is therefore soon outdated.

2D and 3D information needs to be adjusted separately from each other, which means 3D model not always up to date and differences between 2D and 3D information occurs.
Direction of problem space.

Engineers and production employees are different by definition, being aware of these differences and the activities that the other performs is needed, to anticipate to what is needed by the other party. Accepting the other and knowing the other what is needed by the other is essential for collaboration. Information exchange, communication and collaboration are interconnected and can facilitate the synchronization of the different mental models. When actors communicate with each other, relationships are build, a shared understanding is created and empathy is developed for each other, which is needed to build the ship together.

Improving the whole engineering and production interaction during the production phase is to big for a thesis project, that is why there is a focus on a small interactions during the production phase of a ship, the problem solving activities between engineering and production. During midstream modulation sessions frustrations and positive points are discussed concerning the collaboration with the other actors, some examples of themes are discussed below:

**Mechanical engineer (P3)**
- No proactive communication if deadlines not held
- Feedback can be processed but afterwards not picked up for the next project
- Visits the yard to ask production how they would do something. The engineer learns from this and production feels valued and listen to.
- Explaining not knowing the answer on a question is also an reaction to production
- Explain the why behind an idea to production for awareness
- React to questions from yard quickly, to build trust

**Mechanical engineer (P4)**
- Information package other product group mistakes in there, engineering and production build own routines to be able to send information that is incorrect. When using it by another product group, takes a lot of time to find out the problem
- Reaction to production within a day to keep the production going
- Autonomy of an engineer is essential for commitment, if everything is pre-defined

**Production foreman (P8)**
- If a revision is made, engineering already knows about it for 3 weeks, they should communicate about it proactive
- Engineers with understanding and awareness of what production needs is easier to collaborate with
- 3D model essential to understand 2D drawings
- Engineers pro actively visiting the ship

**Production foreman (P18)**
- Sending an email but not knowing if an email has been received, not receiving an answer leads to uncertainty
- Earlier in the supply chain should feel responsible for what happens in production
- Reinventing the wheel for projects because problems and solutions are not captured, managed and reused for new projects.
Room for thought

Internal discussion at Damen about feedback from yard, level of knowledge of engineers and work pressure. During the work council meeting of 28-09 a question was asked about feedback from production:

What happens to the feedback given by the foremen from production given to existing drawings? Are they handled now it is more quiet?

The foremen are getting frustrated because feedback for adjustments is not implemented. The Executive Board has approached Engineering very concretely about this. It turns out that it does happen, but this is not always communicated back to the foremen. The Works Council has also heard that it does not happen, because there are no engineering hours. This is nonsense, according to the Board and this should not happen. It may be that improvements are “saved” and will be implemented when there is a new ship. However, the Board believes it is a concern. Many engineers have never seen a yard from the inside, and the distance from their office to the site yard where ship is actually built is often very large. This is a reason why things happen that are not practical or logical. The Board thinks about measurements to solve this problem. Some departments show that engineering is too busy, for example Tugs. This is known to the Board and we have to be careful with this.

Box 1. Question during Work Council meeting at Damen (Source: OV-Verslag 28-09-2016.pdf report, p.10)

From this text it becomes clear that the executive board of Damen, believes that feedback is being processed. Some reactions from the work floor describe that actually there are no hours for adjusting drawings as build and causing frustrations amongst engineers and production. Below some examples illustrate the lack of hours and money for updating the production information. This leads to shadow information packages at yards. When a ship is being build on a new yard with the same information package, the same problems will occur over and over again.

“Project management wants to spend as few hours and money as possible. If there is a feedback list with 100 points, then maybe 60 are dismissed, that’s what happens in practice. That results in problems for engineering and production, you want to improve things, but you do not have a budget. (...) This is nonsense according to the board, but this is what happens. So that an action list is released on a boat, and hours and budget. Then you will have to go through the whole process. Things you need to improve but there are no hours because the hours are tight, then the improvements will remain untouched.” - Mechanical engineer (P4) 29.

At one of the projects that has been followed, hours were approved but in the end not, which means that the standard will not be updated. This topic was a point of frustration discussed during the different midstream modulation sessions:

“But how come at other projects, it is not being processed?” - Interviewer

“Well, it’s all about the money. Now we get hours to process feedback. We requested budget for processing feedback. And we also get that budget form higher up because they notice, in the past on another type of ship, if the budget is not given, you just get such a mess of documents and ships, and they really want to avoid that.” - Mechanical engineer (P3) 30.

“What are those 2000 hours for? - Interviewer

“ To pick up the points form production, and put everything correctly in the model, so if a new ship is being build, that everything is correct. So you can use those hours just to put all points on a list and that one time we start on a new ship you have to cover all feedback points first, before starting with the ship.” - Mechanical engineer (P3) 31.

“I thought that is was okay to process all feedback?” - Interviewer

“yes, no, production was really happy but that was for a short time. From now on we have to say to production, yes I will put it on the list and that is it.” - Mechanical engineer (P3) 32.

During the focus group the topic is also discussed from the engineering perspective:

“Change of people and having time to make modification to the ship, A it becomes more beautiful and B it becomes cheaper. But is has to be engineered, and we do not receive time for that. If you look at my colleague he as made a whole list of things that can be improved, but we cannot spend hours on it, there are a lot of things which could be better and cheaper.” - Ship engineer (eng1) 33.
Chapter 6 describes barriers for collaboration between the engineering and production department, leading to problems during the production phase of a ship. The barriers are described on an inter-actor level and inter-department level based on the information, communication, knowledge, awareness and technology perspective. The problem space that will be further explored for improvement are collaborative problem solving activities between engineers and production. This chapter described the design vision, guiding principles and criteria to improve the current situation. The sub research question will be answered: (7) How can the current situation between engineering and production be improved?

7.1 Design vision

Barriers as described in the previous sections are part of a much bigger system than that a communication process in the ship production phase can solve. There will be a focus on a communication process and tool between engineering and production to detect and correct manifestations of errors during the ship production phase.

By improved collaborative problem solving between engineering and remote production department, the amount of problems also can be fixed. The shipbuilding process is seen as a social process in which information and knowledge is exchanged. Figure 34 gives an overview of the design vision and in figure 35 a scenario is shown that will be improved. Two guiding principles are used for improvement of the current situation these will be discussed in section 7.2.

![Diagram: Vision on the interaction between engineers and production foremen]

Figure 34: Vision on the interaction between engineers and production foremen
Figure 35: Problems in the interaction between engineers and production foremen.

Current formal interaction when problem occurs:

1. Problem occurs on ship → Make pictures → Save pictures on pc → Sends email to PM → Receives email → Define solution → Adjust drawing?
   - Check IFS
   - Check 3D model

2. Feedback and questions are not always received by engineering → Sends email to EN → Receives email → Solve problem
   - Takes two weeks before solution on question is there
   - Discuss solution
   - Sends email to PROD
   - Production comes up with own solution

3. Informal communication lines occur direct between engineering and production → Make email with solution → Sends email to PM → Update 3D model
   - As build not always updated, same problem in next ship
   - Update IFS

4. Feedback and questions are not always received by engineering → Sends email to EN → Receives email

5. Production does not know if question and feedback is being handled → Sends email to PM

6. Hard to explain problems over the phone, so send email but is time consuming → Receives email

7. Informal communication lines occur direct between engineering and production → Make email with solution

8. Production comes up with own solution → Receives email

9. Feedback and questions are not always received by engineering → Sends email to EN → Receives email

10. Production does not know if question and feedback is being handled → Sends email to PM

11. Hard to explain problems over the phone, so send email but is time consuming → Receives email

Define | Chapter 7. Improving the current situation

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7.2 Guiding principles

A communication process and tool will be proposed for engineering and remote production during the ship production phase, to solve problems collaborative. Two guiding principles for the communication process and tool are formulated.

Closed loop communication between engineering and production
- If a question is asked by sender, receiver is obligated to send an answer (reciprocity).
- Production information is shared by engineering with production, feedback needs to come back as an exchange.
- Knowledge sharing and feedback is needed between actors and departments.
- Symmetric interaction between engineering and production is needed.
- Direct communication is needed for a shared understanding between engineering and production.

Mutual responsibility of engineering and production
- Engineers and production should feel mutual responsible for problems that occur during the ship production phase.
- Commitment of an engineer is needed to be involved with the work of production.
- Higher team awareness is needed by engineers to be willing to support production.
- A shared vision is needed between engineers and production towards end result.
- Acceptance of differences and understanding the need of the other person.

7.3 Criteria for the communication and collaboration process

Based on the needs of Damen employees design criteria are defined to improve collaboration between the engineering and production department, these design criteria are discussed during the Midstream Modulation sessions and in semi-structured interviews. Besides this literature has been reviewed. Literature about collaboration is divergent as it is a phenomenon that depends strongly on the environment. On the following page factors about collaboration from literature has been summarized. Besides this findings from this the empirical data are presented next to it. These criteria are used as a guide for the communication tool and process.
Requirements for collaboration based on empirical findings:

- **Direct, one-on-one interaction.** This is needed for developing relationships, become aware of the other person. Direct interactions are needed to lower boundaries between actors and makes it easier to ask questions and give feedback.

- **Understanding practice and need of other.** Awareness is needed about the problems encountered by the other actor to be able to proactive communicate and understand situation and the role of the actor in the bigger system.

- **Acceptance and respect that other is different.** Every actor is different and this is what adds value, but respect and acceptance of the other is key for collaboration.

- **Shared responsibility and common goal.** We have to do it together, in a trusting relationship collaboration is better, if you know what you can expect from the other person.

- **Flexibility and commitment of actors.** Anticipation to the situation of the other and willingness to help the other is a requirement for improving collaboration

Negative factors on collaboration:

- Hierarchy in organization
- Anxiety
- Dynamic project teams
- Lack of commitment
- Time pressure
- Cultural diversity
- Mainly indirect communication

Requirements for collaboration based on literature:

- **Trust, norms and values**
  Trust is at the core of collaboration it creates the willingness to be vulnerable. Trust can be gained when norms and values between actors are comparable. Reciprocity can encourage motivation and decreases uncertainties, when actors are increasingly exposed to each other it is more likely that beliefs, assumptions and attitudes become more similar (Von Krogh et al., 2000).

- **Common perspective or shared understanding**
  Actors have different mental models and different knowledge, awareness of these difference is needed. Becoming aware of the other perspective is essential for effective interaction (Smulders & Bakker, 2010) and collaboration. Evaluating the situation from the other perspective can create alignment and the creation of a common perspective and synchronization of mental models (Gorman, 2010; Senge, 1990).

- **Common ground**
  Common ground is the set of knowledge, awareness and beliefs, if these are comparable between two actors collaboration is easier (Von Krogh et al., 2000).

- **Continuous dialogue and shared experience**
  Nonaka (1994) describes that a continuous dialogue is needed to keep relationship between team members in cross-functional teams, tacit knowledge can be shared in conversations. An understanding between actors is created which encourage mutual trust and improved collaboration.

- **Social interactions**
  If there is collaboration then social interaction can be found in it, and vice versa, if there is no social interaction then there is also no real collaboration (Kreijns et al., 2003). Interdepartmental integration on the one hand formally coordinated interaction routine meetings like production meetings. Other more collaborative and unstructured meetings are also needed to build relationships (Kahn, 1996).

**SRQ 7. How can the current situation between engineering and production be improved?**

Two guiding principles will be used to improve the current situation, close communication loops and create mutual responsibility between engineering and production to improve the collaboration. Interaction between engineers and production foremen is needed in the ship production phase to build a common understanding of the situation, share knowledge and become aware of the situation of the other to be able to collaborate in a more effective way. By improving the feedback and questions are answered which also positively influence collaboration, a common ground and perspective can be created between actors.
Room for though

Client is king

From the interviews barriers are extracted on a department level. Main decisions are made by the internal client, the Product Group or the external client. When an external client comes in the picture, a standard ship is adjusted to the needs and wishes of the client, which makes standards ships semi-custom build. Standards ship are only standard when they have the same client. The hull is often standard but all the systems in a ship are different, customized to the client wishes.

Damen Gorinchem and the yard

The head quarter of Damen in Gorinchem outsources the shipbuilding process to damen yards world wide. A yard is hired to build the hull and to perform the outfitting of the ship based on the production information delivered by Damen Gorinchem. When a problem occurs in production, the question is who to blame, is it the problem of the yard or was there a problem with the information delivered by Damen Gorinchem. That is why some yards follow drawings exactly like in Vietnam, but at other yards like Galati (Romania) or in Gorinchem (The Netherlands), production foremen more freedom to fix problems on their own.

Completeness of production information

The product group (internal client) or the project manager decides if information is updated at the end of a project or not. Time and money spend on the engineering phase is a point of discussion for every project and influences how in-depth information will be delivered at the yard, this is captured in the Standard Engineering Production Information (SEPI) document. Back in the days, the yards developed their own production information, it is decides that Damen Gorinchem develop all production information to keep it standard and to be able to send it to multiple yards. Now completeness of production information depends per project which makes reusing information for project such as DTC projects difficult.

Departments have their own budgets

The shipbuilding industry is a cost price driven industry. Competitive advantage can be gained by a low cost price and short delivery time. At Damen, every department in the shipbuilding process has their own budget. If one can save money in their part of the project it feels like a good thing for them but, this can influence the process of another department. Sometimes a short term investment in updating information should be made to save money on the long term (34). This is also discussed in the focus group by the engineers and production foremen, when a hull is produced abroad and is outfitted in Gorinchem, The Netherlands:

“Does the hull quality influence your job?” - Interviewer
“Fore sure, it makes your work much easier if it all goes right, less hours spend here [in The Netherlands]. Now we first have to fix the hull before we can start.” - Production foreman 2
“Do you believe the costs ..”- Interviewer
“On the long term, definitely” - Production foreman 1
“People there [a yard abroad] are a cheaper, but we have to fix things and we are more expensive.” - Production foreman 2
“That is just not so efficient” - Mechanical engineer 2
“But those kinds of decisions are being taken, why it is outsourced to Poland, because it is much cheaper. They [the decision makers] say then the painter will be a few tones more expensive, but then you will not see anything of it. The ones who decide does not know what kind of problems it causes for us, the management of the product groups or Contracting Yard Support.” - Ship engineer 1
PART III. Develop

In the previous part, the current situation of Damen is described with barriers between the engineering and production department. Points for improvement are described with a design vision and criteria for the communication process for improving the collaboration.

In this part the improved situation is explored by looking at other industries and trends in the industry. First methods used will be described. Chapters 9, concepts will be presented to detect, indicate and correct manifestations of errors in the ship production phase. Chapter 10 describes the proposed solution in the process of Damen and the testing of it.
8. Methodology develop phase

In this chapter, the methods will be discussed that are used in the develop phase. Until now there was a focus on the internal organization. In this part there will be a focus on external trends and other industries as an inspiration for the situation in Damen.

8.1 Technology trends
Desk research has been performed to explore what technologies trends can be observed in the industry to facilitate real time collaboration between the engineering and production department and to facilitate the detection, indication and correction of errors. Inspiration and insights what is possible at this moment and what will be possible within a few years. An overview of technologies to compare reality to 3D are shown in Appendix L. The findings are described in chapter 9.

8.2 Case studies other industries
Three cases studies are performed to explore how communication and collaboration between the engineering and production department is structured in other industries. Case studies are used to get an understanding of best practices for collaboration between engineering and production in comparable industries.

Method, case selection and data analysis
The selected industries for the case studies should be comparable with the shipbuilding industry. The case studies were selected on the complexity of the products which should be relatively high, the size of series should be small or medium. The products should be complex and multiple stakeholders should be involved in the development process. Best practices from different industries are described like European Space Agency (ESA), BAM for the construction industry, Fokker for the airplane industry. All three organization were visited by the researcher, and representatives of the companies were interviewed.

Outcomes
Inspiration from other industries, it gives the researcher some broad view of the shipbuilding industry compared to other industries. Fokker has a real first model to test and simulate the building process to detect potential problems during production. Having one place with most up to date information gives certainty to the different actors, that they use the most up to date information. The findings are described in chapter 9.

8.3 Morphological chart
A brainstorm is held during the expert session with a communication expert, a design expert and a Damen expert. Besides this the researcher herself did a brainstorm on possible solution, besides this the morphological chart is discussed and enriched during the focus group based on the experience and creativity of the engineers and foremen. The focus group will be discussed in the following section.

Outcomes
The morphological chart is created based on experience, intuition and creativity. On the one hand, to explore different types of activities to interact between engineering and production and on the other hand to come up with and instruments to explore what instruments can be used to detect, indicate and correct deviations between the real ship and the 3D model. On the other hand functions are defined, detect errors, report errors and correct errors. The findings are described in chapter 9. The morphological charts are shown in Appendix M.

8.4 Focus group
The aim of the focus group is to get an understanding of important aspects communication and collaboration between engineers and production foremen. An alternative would have been to interview all participant individually but then the interviewee only has his own point of view. In a focus group, a participant can bring fore issues in relation to the topic of communication and collaboration. A focus group is interesting to explore how the two interfaces think about topics
discussed. A focus group offers the opportunity to study the way individuals make sense of a phenomenon and in this sense reflect on the every day life.

Sample and procedure
In total six participant attended the focus group, which is a typical group size (Morgan, 1998a). Three engineers and three production foremen, working on the same project as shown in figure 36. The session is transcribed and in a focus group with three engineers and three production foremen, the differences between interaction in Gorinchem and abroad were discussed. Findings for the session are divided in characteristic of interaction between engineering and production, characteristics of the environment and characteristics of the individuals. Criteria for the interaction between engineers and production foremen are discussed and solutions based on their experience and creativity to improve the communication and collaboration between engineers and production abroad. These ideas are filled in a morphological chart with the three functions, detect, indicate and correct errors, based on theory, experience and creativity. The researcher was the moderator and facilitated the focus group.

Data processing
Quotes give a description of the aspects; the quotes are freely translated into English. Real time visual interaction/dialogue between engineers and production foremen who are geographically separated is suggested. Limitation of the focus group is that one engineer is the boss of another engineer which might have influence the ability the engineer to speak freely within the group. The findings are described in chapter 9. Main findings of the focus group are described in Appendix N. The transcript of the focus group is saved in Nvivo.

8.5 Usability test
After the focus group, a prototype was used, the Alpha Eye from Alphatron to test the real time interaction between engineering and production. From this initial test, point of improvements are formulated for the final design. The final design again is evaluated and recommendations are given for further research.

Sample
Purposefully sampling based on availability and criteria they should work on a series of ships. Test one was with two engineers and test two with an engineer and a foreman (n=4). The test is performed at the yard in Gorinchem.

Procedure and data processing
In the first test the prototype is used as the engineer wanted to see something on the ship The second time, the production foreman was wearing the device on the ship and was discussing problems on the ship. The sessions were recorded and evaluated with the participants. Based on these tests and evaluations a different tool is proposed. Findings from the interactive prototyping are described in chapter 10 and main findings are described in Appendix O. The transcripts, pictures and videos and quotes from the session and evaluation are captured in the Nvivo software.

8.6 Evaluation final design
In the Midstream Modulation sessions, ideas and the is discussed. The sessions of the usability test are recorded and during the midstream modulation sessions and with the two engineers and two production foremen. The findings are described in chapter 10. Besides the MM sessions the final design is evaluated with four engineers (technical manager engineering, two production support engineers and a Electrical engineer), three production foremen and a Business unit director as shown in figure 38.
9. Ideate

In the previous part boundaries for collaboration between the engineering and production department and on an actor level are described. The direction has been chosen to focus on collaborative problem solving. This chapter will have a look outside the organization at technology trends. It will be explored how other organizations facilitate collaboration between the engineering and production department. This chapter describes some interesting trends which enable collaboration between geographically separated actors. These trends as described in section 9.1. Best practices for collaboration between the engineering and production department in other industries in section 9.2. Section 9.3 discusses the outcomes of the morphological chart. In section 9.4 idea directions are proposed. The sub research equations will be answered: (8) What communication methods can be used to improve the collaboration between engineering and production?

9.1 Technology trends

Gartner is a leading information and technology research and advisory company who defines on a yearly basis the top 10 of technology trends that strategically can be applied by industry in 2016 till 2020 (Gartner, 2017). These technological trends are opportunities for Damen to differentiate from competitors. The most interesting themes which are interesting for Damen concerning error detection and correction are described below.

**Virtual Reality and Augmented Reality**

As second trend is the ambient user experience with immersive environments like Virtual Reality (VR) and Augmented Reality (AR). These developments will have significant potential for the user experience. An example of VR is shown in figure 39 and is mostly used during the early stages of the new product development to explore problems before the product has been built. Figure 40 shows how AR is used to check systems. Gartner predicts that the tipping points for these technologies are being reached in terms of prices and capabilities in 2020. There are many different types of AR and VR, in Appendix L an overview is shown of the scope of possible technologies.

**Digital twins can be used to analyse and simulate the real world.**

A digital twin is a modelled representation of the reality one-on-one, as shown in figure 41. The aim is to detect, indicate and correct errors or deviations between the 3D model and the real ship. As the design of a ship becomes a more digitalized process with a 3D model, opportunities arise from Damen to check the physical ship with the 3D model.

A digital platform can facilitate the collaboration between production employees and development engineers who are geographically separated from each other.

**Conclusion**

These technology trends can be used to observe or detect deviations between the real ship and the virtual 3D model during the development of a ship. Collaborative platforms enable engineers and production employees to solve problems together. Augmented Reality (AR) could be interesting for finding deviations between the real world and 3D model.
9.2 Collaboration between engineering and production in other industries

The shipbuilding industry is seen as a conservative industry compared to other. Three case studies are performed to explore how engineering and production collaborate in other industries where small till medium size series of products are developed. The five domains Information, communication, awareness, knowledge and technology are used to describe how collaboration is supported at companies like BAM, Fokker and ESA. The case study methodology is described in chapter 8.

European Space Agency
In the space industry, multidisciplinary project teams work on the development of a product, for example a satellite. Compared to the shipbuilding process, projects at ESA are long-term. The same iterative process is applied as for shipbuilding (the spiral model). ESA uses the concurrent design approach to develop their products, with an integral model in which all stakeholders can work. As described by Gorman (2010), these concurrent design facilities can be seen as trading zones for interdisciplinary collaboration. Instead of a sequential or a centralized approach, a concurrent approach has been applied as shown in figure 42, which means direction interactions between different disciplines.

Construction industry - BAM
To manage the collaboration between stakeholders in the construction industry, a management process is used, called BIM. BIM which has multiple definitions, Building Information Model which is the digital representation of the building. Building Information Modelling focusses on the process and collaborations based on integral design, concurrent engineering, lean planning and sharing of digital information. 3D Building Information Model to encourage collaboration between different actors in the design and construction of a building. At a BIM centre, all information is connected in a database to the 3D model which is assessable for all stakeholders. BIM can be seen as a trustworthy source with the most up to date information about the project. It can be used as a foundation for making decisions through the whole building process, from the initial design, during the construction and when the building is demolished. Different actors in the operational process have access to the BIM like architects, structural engineers, HVAC and plumbing engineers, electrical engineers, and others to ensure short lines and see problems is early stages.

Aerospace industry - Fokker
Fokker develops and manufactures lightweight structures, modules and landing gear for the aerospace and defence industry. Medium size series are build from 100 till 600 pieces. More time and money can be spend on prototyping and testing the production process compared to the shipbuilding process. Fokker has defined all separate steps in the production process and the amount of time required to perform each step. The engineering phase only can take about two years, the whole production process is simulated before production starts.

On the following page findings are discussed based on the five categories, knowledge awareness, information, communication and technology.
Knowledge
ESA brings all relevant knowledge perspectives (client, engineering, production etc.) together in one room during the design phase to discuss potential problems in the production phase. One small mistake in the development of a satellite can be disastrous and can lead to potential mission failure.

BAM has an open standard for their 3D model, problems can be detected and corrected with involvement of multiple stakeholders during the whole project, all knowledge is captured in the BIM model.

At Fokker, manufacturing engineers (that have experience in production) work at the office together with the other engineers to guarantee that the design is possible to produce. It is their job to check all the drawings for mistakes. These manufacturing engineers are the bridge between engineering and production.

Awareness
At ESA errors are prevented, detect and correct early in the process by evaluating the design from different disciplines at the same time. Besides this, actors from the production phase have a better understanding why decisions are made earlier in the process.

At some projects, the contractor has a tablet with the 3D model on it. Co workers ask to have a look at the model with BIM 360TM Field.

At Fokker engineers and production are co-located in Papendrecht which makes it easy for engineers to visit the production facility, there is a dedicated production support team next to the manufacturing facility.

Information
ESA, BAM and Fokker all work from an integrated 3D model, at BAM and ESA different stakeholders have also access to the 3D model.

BAM experienced a changing need for information on site, having right information at right time. To do so you need to know what information is needed for which activity/task. The main challenge is to build the 3D model in such a way that an IKEA manual can be created. The building strategy should be considered.

At Fokker TV screens are present at the manufacturing place, displaying which drawings are updated by engineering. Besides this, employees use tablets with information per job they have to perform. Information for a task is placed in a Power Point for them which can be seen on the tablet.

Communication
ESA involves production in the engineering phase with bi-weekly sessions to create shared understanding of future status of design and problems that may occur, these face-to-face meetings also create a bond between project team members.

At Fokker there is a dedicated production support team available who help with problems in production, next to the production facility, but the facility is co-located with the engineers, if a problem occurs a Root Cause Analysis is performed to find the root cause of the problem to be able to fix and avoid it.

Technology
Fokker has a 0-serie to test and simulate the building process of a airplane tail to detect potential problems during production.

BAM uses Virtual Reality to walk through the building before it is build and model the building process and steps and information that is needed, they are testing now with task oriented information for example for augmented reality. The production foreman has an tablet will all information about the project.

At ESA an integrated design model is used accessible for the multidisciplinary team members, besides this an offline facility (Concurrent Design Facilities) is used with a suitable IT infrastructure. Video conferencing with remote team members is possible in these facilities but face-to-face contact is preferred during these sessions.
Conclusion

Comparing the situation of the three organization and the situation of Damen, other industries are a step ahead with an integrated 3D model, besides this all three companies actively involve the perspective production in the engineering phase. The application of new technologies like tablets, VR and AR in the production phase of products is in development. Tablets are already used at BAM and at Fokker in production, to work paperless and to have access to the most up to date information. BAM uses VR in the engineering phase to show the building to the client. AR is a technology that has not been used extensively in the industry. BAM is experimenting with AR to be able to deliver task related information, but challenges are still there as the model easily becomes to big for the Hololens. At Fokker engineers and production are co-located which makes collaboration easy for them. ESA is more focussed on the collaboration between different parties, early in the new product development process. From the case studies it becomes clear that having a 3D model, a single source of truth is needed with all information about specification and deliveries connected to it. This is currently not the case at Damen, one single source of information (one model with all information) is needed first.

9.3 Morphological chart

Based on the input from the expert session, focus group and search on the internet, a morphological chart is developed as shown in appendix M. The three main functions which are described in the chart are, error detection, indication and correction. Based on the three functions clusters are made, resulting in two main directions for problem solving between engineering and production. Based on the different options in the morphological chart, different clusters of solutions can be made as shown in appendix M. Two main directions are chosen based on input from different stakeholders, the two directions will be discussed in section 9.4.

Detect errors or deviations between the real ship and the 3D model.
Indicate the problem at engineering.
Correct the problem or define follow up action.

9.4 Production support concepts

In the previous section the research has been inspired with possible technologies that can be used to detect errors during the ship production phase. The two main directions are explained for detecting and correcting errors during the ship production phase and to support the communication between engineers and production foremen with the aim to improve the collaboration between actors. The function, what it solves, positive sides and negative sides of the solutions are described.
Synchronous communication between engineers and foreman is needed to be able to discuss deviations in the ship from drawings and revisions. Besides this the impact of these revisions should become clear for the engineer by seeing the consequences on the ship. Engineers should become aware of the information need of production, by closer involvement real time communication.

Real time communication between engineers (mechanical/ship/electric) and the foreman is proposed in engineering-production meetings. Structural communication could be applied preferably in a combination of audio, visual and video information. By doing so, not only task and process oriented information is shared but also context information and social-emotional information (as shown in figure 43). Engineers and production foremen are encouraged to discuss problems more regularly and solve problems earlier by visualizing and communicating issues. Together they can create a shared understand of the problems and share implicit knowledge. Standard behaviours like pointing and gesturing are communicated easier, no matter where the team is located or what languages are shared. The combination of body language and speech together can dramatically improve understanding between two actors. These meetings can be ad hoc or structural organized. By means of these meetings a closed feedback loop is created between engineering and production.

**Figure 43: Solution area 1. Real time interaction**

Real time communication between engineers, during commissioning, real time problem solving, progress meetings, compare reality and 3D and surveying. Tools could include augmented reality.

**Pros**
- Direct interaction between engineers and production, makes asking questions easier
- Questions can be answered immediately and engineering gets feedback on information
- Discuss potential problems with pumps, foundations and immediately solve problems together

**Cons**
- Production foremen can feel like they are checked upon (big brother is watching you), therefore it would be good to also involve them in the engineering phase.
- Engineer and foremen need to be available at the same time
Solution area 2.
Asynchronous error detection and then communication

The second solution area is to first scan the real ship, afterwards the engineer and production foreman can discuss the deviations from the 3D models and the real ship. Differences between real ship and 3D model should be captured, such that it can be used for following projects and enrich the information for the next project. The 3D scanning of can be done multiple times during the production of a ship to capture the progress, to see where the 3D model and the real ship differ from each other as shown in figure 44.

The process will be as followed: A foreman get the scanner and place it in the ship. The scanner will develop point clouds of current situation or a 360 degree picture. When a problem occurs, a scan needs to be made. The scanning can be used multiple times during production to capture the progress of the ship or one room. After the scan, the engineer and foreman should discuss the outcomes of the scan to problematic area. This can be done in a video conferencing session or the scan and 3D model can be imported in for example VR glasses. Together the engineer and foremen then can walk through the ship virtually to get a shared understanding of the situation. To be able to look behind objects, at least 3 scan should be made per room as shown in figure 45. Depending on the level of detail needed the amount of points can be defined, this will influence how long it will take before the scan is ready. This can deviate from a few minutes for a rough scan to hours for a very detailed scan.

Functions

- Detect problems in ship by scanning the ship and afterwards compare it to the 3D model. Engineers can become aware of the problems that occur on the ship.
- Indicate errors by comparing the scan and the 3D model by the engineer and discuss what went wrong between engineering and production.
- Engineer and foreman discuss how to correct errors by discussing outcomes between engineers and production and project manager.

Pros

- Information about as build situation is captured and can be used for next ship.
- Scan of ship can easily be compared with 3D model for deviations
- After a scan engineering and production virtually can walk through the ship when they are remote located. Video conferencing

Cons

- No direct communication between engineers and production, a meeting should be planned to discuss scan
- Problems arise in details of the ship, if you want to capture the details, scan should make many point-clouds
- There are many objects in the ship that you do not want in the scanner
- Information is quickly outdated as a lot can happen in one day
- A detailed scan of the ship is needed to find small deviations, which means that much time needs to be spend on the scans.
- Why walk through a 3D model if the real ship is there, many actions should be taken before a problem is seen
9.5 Focus group

In the focus group the communication between engineers and production is discussed. Conclusions from the focus group are described in Appendix N. The interaction between engineers and production appeared to be very important for the three foremen and engineers.

From the focus group it becomes clear that there should be a focus on real time, visual and one-on-one interaction between engineers and production foremen on the one hand when a problem occurs but also structural to be able to prevent errors before they become real problems and to just be aware of the status of the ship. The support from the engineers and production foremen is essential in a later stage to be able to implement the solution.

9.6 Conclusion

SRQ 8. What communication methods can be used to improve the collaboration between engineering and production?

In the ideation phase different alternatives are explored to be able to detect, indicate and correct errors in for example the engine room, technical space and construction of the hull. Emerging technologies make it possible to communicate over distance and to share visual information. In other industries a tablet is mostly used in production to facilitate the communication between engineers and production employees.

Two solution directions are discussed to improve the collaboration between engineering and production: The first direction is real time video communication between the production foreman and engineer to solve problems on the job and propose solutions collaboratively. The second direction focusses on scanning the ship during the entire production phase to check for deviations and discussing the outcomes between engineering and production.

Based on the feedback from different parties and the rating on criteria it is decided to focus on the real time interaction by means of real time video communication. 3D scanning of the ship and afterwards discussing the results between engineering and production is too time consuming and too many steps should be taken by production. Scanning the ship is interesting for capturing the as build situation at the end of a project, but is it a lot of work to do this during the project multiple times and then discuss the outcomes this between engineers and production. For real time interaction between engineering and production, multiple scenarios are possible. From the analysis it became clear that when engineers visit production, questions can be asked and progress of the ship can be discussed. On the other hand when a problem occurs, engineers visit the yard ad hoc in Gorinchem to get an impression of the problem.

In literature, real-time communication between engineering and production enables the creation of a common perspective between engineers and production can be created and makes it possible to develop shared mental models (Endsley, 1995. P 53). By sharing an experience together and solving problems together engineers and foremen develop empathy for each other and change from reactive to proactive interactions, change monologues into dialogues and breaking the routine of both the engineer and the production foreman. Interactivity between an engineer and a foreman increase the degree of psychological closeness between communicators (Littlejohn, 2010 p. 158). Immediacy and relational closeness can cause communicators to feel more engaged with one another. From a social psychological perspective. Real time and face to face communication gives more context and social information, creates a bond and increase collaboration, leads to better understanding of different worlds and increase the shared situational awareness and collaborative problem solving.

“Scanning the ship is more interesting at the end of a project, in between there are many people walking on the ship and there are a lot of things there like stairs that you do not want on the ship or in your scan”

-Production Support

“you can not have it all in your head” - Ship engineer

“you know what the advantage is, you have an image of the ship when seeing it. Sometimes someone can explain really clearly, but the other just can’t, seeing it then is useful.” - Production foreman 2
10. Proposed process and tool

In chapter 9, two idea directions are discussed, the real time video communication direction has been chosen. This chapter describes the chosen direction for the testing and the testing process is discussed. The research question will be answered: (9) How do engineering and production evaluate the proposed process and tool?

10.1 Real time video communication between engineering and production

The proposed solution consist of a communication process between the engineer and foreman, supported by technology. For the communication process, three scenarios are possible. Based on the interviews, real-time communication between engineering and production should be enabled both structurally and ad hoc.

User scenario A. Structural interaction between engineering and production

Structural interaction between engineering and production is needed on the one hand to monitor the progress of the ship, and on the other hand to give the foreman the chance to ask questions directly to the project manager engineer (ship/mechanical/electrical). Potential problems can be discussed one-on-one, during hull construction, casco check and during outfitting and commissioning. Depending on the complexity of the project and the moment during the shipbuilding process, the engineer and production foreman should have contact once a week or once in every two weeks.

User scenario B. Ad Hoc interaction when question from production to engineering

Ad hoc communication is required when questions arise in production about the delivered production information. In Gorinchem engineers are able to visit the ship with the drawing to see the problem for themselves. If a ship is produced on a remote yard, emails are send with pictures, the drawing number and the question from the production foreman. Production also solves problem on the job, then engineering needs to be informed about the way they have solved the problem and capture it. Agreements should be made between engineering and production when ad hoc questions can be asked. At the end of a project more problems can occur, because all disciplines come together during outfitting, then more regular contact is needed compared to the start of a project.

User scenario C. Ad Hoc interaction when question from engineering to production

A third scenario is when an engineer has a question for production or when an engineer needs a visual image of the ship. In the current situation now the foreman is asked to make pictures and send it to the engineer.

As described above, different scenarios are possible in for real time communication between engineering and production. When a standard ship is being build on a new yard it is most likely that scenario B will occur, that is why this scenario will be worked out in section 10.2 but scenario A and C are also s also important to consider.

10.2 User scenario Ad hoc questions from yard

The scenario that will be worked out is the Ad Hoc questions from production (the Production Foreman, PF) to engineering (project manager mechanical engineer, PME mech.). The process is two folded, from a production perspective and from an engineering perspective. In figure 46 a general overview is shown of the communication process. In the scenario, a pipe cannot be connected to a pump.

1. The Production Foreman (PF) finds out that a pump does not fit on its foundation the drawing might be incorrect, but a solution needs to be found.

2. The PF gets his device out of his pocket and opens the menu to contact the PME mech. who is responsible for the systems in the ship. Based on the information from Outlook the foreman sees that the PME mech. is
Define follow up

Problem occurs on ship

Interaction between production and engineering

Ad hoc

User action

Production

foreman

Line of interaction

Engineer

User action

Line of interaction

Use Ipad / skype buss

Make pictures

Discuss problem

Make email with question

Send sketch

Make sketch

Adjust drawing

Receive sketch

Make email with question

Receives call

Receive sketch

Make email with question

Solve problem

Receive email with question

Capture solution

Update drawings

Share solution

Make sketch

Receive sketch

Make email with question

Update drawings

Figure 46: Proposed interaction between engineering and production

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currently available. In this scenario PME mech. is available. If PME mech. is not available the foreman has two options, send a notification to PME mech. that a problem has occurred in production and that he needs help or try again later.

ENG accepts session and sees the PF. PF describes that the pump does not fit and the question is how come and how to solve it. Together PME mech. and PF have a look at the problematic situation at the ship. PF moves the device to show the problem from different sides.

ENG checks the 3D model on his computer and the drawings. PME mech. asks the PF to make some pictures of the situation. ENG shares print screen of 3D model, drawing, sketch and preferably draw on screen that will be seen by PF. Information, ideas and problems are exchanged between PME mech. and PF.

Can the problem be solved? Discuss if and how problem can be solved. If a problem can be solved, the data should be saved at the central database. The question needs to be answered, should the problem only be solved on this ship or also following ships. If it is applicable for following ship, as build drawing should be made for then next ship. If problem can not be solved: Define next step like ENG should look for solution come back later by PF. The engineer and foreman should discuss the follow up of the session, should a drawing be adjusted, or the 3D model. It should be discussed who should do what and the action should be confirmed.

10.3 User scenario Structural interaction between engineering and yard

The second scenario that should be considered is the structural interaction between engineering and the production. Structural meetings make sure that engineers and production build up a relationship, by discussing potential problems, one-on-one a shared understanding can be created, the PME engineer becomes aware of that is going on the ship.

Depending on the phase of the shipbuilding, the PME (mech/ship/electrical) and the production foreman should have regular meetings, once a week or once in every two weeks. The PME and PF agree on a time. In these meetings specific parts of the ship should be discussed, for example the engine room if that has a main focus in that week.

To support the interaction, tools should be there both on the engineering side and production side. The solution of real time communication consists of three parts. The engineering side, the production side and the connection between the engineering and production side as shown in Figure 47. The proposed communication process has been tested with engineers and foremen. Test are conducted with a tool at the production side for real time video communication, the test setup is discussed in section 10.4.
10.4 Testing real time video communication

An usability test is performed by means of the Alpha Eye from Alphatron as shown in Figure 48, to explore how engineers and production foremen experience the real time interaction and collaborative problem solving. The Alpha Eye has been used as a prototype as it already facilitates sharing files and making pictures which are functions that are described by the different actors as needed when a problem occurs. The system and functions that were available during the test are shown in Figure 49.

In appendix O an overview is shown of the findings from the usability test. Below conclusions are described based on the tests with the Alpha Eye. In Figure 50 and 51 pictures are shown of the tests.
SRQ 9. How do engineering and production evaluate the proposed process and tool?

The process
At the start engineers were sceptical about the tool but during the sessions engineers mentioned that it is actually useful for getting a visual image of the ship. The file sharing did not go that well during the sessions but this is something which is essential for the interaction between engineers and production. The video function was switched on contentiously so the engineer could follow the engineer, but this is not perceived as functional. It is preferred to just have a video overview on the spot. With this tool a session should be planned up front, but this is not useful. Problem occur ad hoc so the production foreman should be able to initiate a session.

When ending a topic on the ship, the engineer asked if it would be possible to make a picture of the situation. This idea of capturing the problem is needed for the engineers if a problem is to complex to solve at hand. The picture could be saved in the software, but it would be preferred to have it immediately saved in a central database. During the tests it was not possible to share the 3D model between engineering and production, this is a function that should be possible.

Sketches are often use to share ideas, based on the input of the testing phase, an iteration will be made on the concept. From the observations during the session the engineers were ticking on the screen to point at something, unfortunately this could not be seen by the production foreman. This real interaction is something to consider for the next iteration step. A way should be found to let the engineer pinpoint at something in such a way, production can also see it.

The tool used by the production foreman
The Alpha eye device is considered as expensive for the functions it has, the real time video communication, the foremen do not see themselves walking on the ship with such glasses, as they gain a lot of attention with it. Besides this the device should be picked up at the office and then the engineer has to walk back to the ship which is time consuming. Based on the Technology Acceptance Model (TAM) as shown in figure 52 (Davis, 1989) it can be concluded that the perceived ease of use and usefulness of the tool is too low to let the foreman used the Alpha eye for real time communication. Having a tablet of phone is proposed by the production foremen as a cheaper and more useful device, using Skype for Business has the same functions.

For the next iteration step there will be a focus on a hand held device like a tablet or phone and the interaction between engineering and production will be explored more into depth.
PART VI. Deliver

In the previous part the development towards a proposed solution is described for improving the collaboration between engineering and production. In this part, the final design is described into detail. Afterwards implications and the implementation is described for Damen (chapter 11).

In chapter 12 the findings from this research project will be discussed and compared to existing literature. Chapter 13 reflects on the main research question and conclusions are defined based on the empirical data, besides this suggestions for further research are defined.
11. Final design

In the previous chapter the real time communication process and a tool are tested, based on the input from the test an iteration has been made on the communication process and tool for collaborative problem solving. This chapter presents the final design and how it can be implemented at Damen. (10) How does the communication process and tool improve the collaboration during the ship production phase?

11.1 Real time video communication

A real time video communication process and tool is proposed during the production support, when a standard ship is being build on a remote yard, for the first time which can be compare to a first of series. When a series of ships is being build on a other yard, problems will occur that are normally solved by production and engineers involved in that project. When building a ship multiple times, the team builds up experience and they know the bottlenecks of a particular ship. This experience is tacit knowledge from engineers and production foremen about where problems occur and how they can be solved (or are solved on the previous ship) it knowledge should be used to support the yard who has less experience in solving problems.

In figure 53 an overview is shown of the process at the production side. The production foreman at the remote yard, or one of his shop floor employees experiences difficulties, as the real ship is different from the drawings. Problems occur when there is a misalignment between the real ship and the 3D model or drawings or when drawings are unclear. Normally the foreman would have called the engineer and tries to explain the problem over the phone. Another option is...
to take pictures, walk back to the office and send an email.

In the proposed solution, the production foreman got his device with him, which enables him to contact the engineer directly and share the problems on the ship immediately in a visual way with engineering. If there is a problem in the construction of the ship, the foreman can contact the ship engineer. If problems during outfitting of the ship for example a pipe that does not connect to another pipe, the foreman can contact the mechanical engineer and for problems with electrical components, the electrical engineer which is involved in the project is consulted.

In figure 54 a mechanical engineer is working at the office, receiving a incoming call from production. Together they can have a look at the problematic space. The the problems solving conversation starts, the problem space is compared with the 3D model to see what is different. Information is exchanged about the problem, possibilities how it can be solved and what the best option might be. The engineer shares his theoretical knowledge and production explains how he would solve it in a practical way. If needed drawings and sketches can be shared and the engineer can make a sketch on his screen with his mouse and production receives how it can be solved as shown in figure 55 and 57.

In this equation the engineer can also be replaced with a foreman who has build the ship before, to share his knowledge about how they solved the problem the last time as shown in figure 56. On page 68 and 69 the communication process is explained more into detail.

**Why is real time communication needed?**

When engineering and production are remotely located, collaboration becomes hard. Engineers work behind their desks while production is working on the ship and there is less interaction between the two compared to co-located project teams. Engineering is fully aware of the 3D model but has less knowledge about the status or problems that occur on the real ship. The foreman is working on the ship and is less aware of the work of the engineer. In Gorinchem where engineers and production are co-located they see each other on a regular basis in real life. This interaction is missing when a ship is being produced abroad. The face-to-face meetings occur sporadically when building a ship abroad, but interaction is essential to build and maintain a relationship between engineers and production and to create mutual responsibility and created closed feedback loops between engineering and production.

Real time video communication enables the closed feedback loops by detection, indication and correcting/following up problems for first of series. The communication process and tool enables information and knowledge exchange which

*Figure 55: Production foreman with his device*
leads to a shares awareness between engineering and production. The process is a shared experience, which leads to a common understanding and maintain the relationship between engineers and production. Looking back at the cause of errors described in chapter 6, incorrect/incomplete and inconsistent information causes problems in production. A lack of a closed feedback loop between engineering and production causes that problems occur over and over again. Feedback on drawings should be collected at one central point and stimulate continuous improvement of produces and learning within Damen.

The structured and ad hoc meetings should be considered next to the existing communication moments like production meetings, email contact and calling. The sessions can replace some of the many emails send and calls between engineering and production.

**When standard ship is build on new yard:**

When standard ship is being build on a new yard, same problems will occur which are normally solved in production but not on drawing. Knowledge of these engineers and foremen about potential problems can be used to prevent and solve them at new yard.

Previous experience of engineers and production employees involved in previous ship can be used to solve problems that occur at the new yard.

*Figure 56: Knowledge and previous experiences can be used to help solving problems at a remote yard*

*Figure 57: Engineer with his laptop behind his desk*
The conversation between engineering and production

By exchanging information and knowledge a shared understanding and a shared vision is created between the engineer and production foreman which is needed to improve the collaboration between the two parties.

Production perspective

Foreman do not always have time to take pictures, walk to the office to give feedback or to ask questions. They solve problem themselves and need to inform engineering. With real time communication both engineers and foreman can inform each other better.

Pictures can be exchanged between engineering and production and remarks can be made on the pictures.

Engineering perspective

Figure 58: Detailed interaction between engineering and production
Added value
- With structural meetings problems can be prevented.
- With ad hoc meetings direct feedback and questions are received, quick problem solving.
- Shared understanding and awareness created between engineering and production
- Interaction for mutual responsibility and closed feedback loop between engineering and production.

Close session: Define follow up of session, who should do what? Is the problem only for this ship, or should it be considered for the following ships?

An important point for finalizing the conversation is capturing the solution on a drawing, in the template or in a central database.
On the job problem solving
Besides this problems are solved on the job between engineers and production foremen. Frustrations are there when engineers do not receive any feedback, besides this a yard get frustrated if the same problems occur in information over and over again. Solving problems collaborative encourage to understand the perspective of the other person.

Shared awareness and understanding
Sassou and Reason (1999) describe low tasks and situational awareness as one of the reasons errors occur in project teams. Real time interaction between engineering and production is proposed to get a shared understanding, documents can sketches can be exchanged. Production gets frustrated when questions are not being answered, foreman can ask questions to engineer directly (fast loop reaction). This solution will not fix all of these problems but it is a step forwards to closing the feedback loop between the engineering and production. Engineers become aware of the status of the ship and the person at the yard.

Share information and knowledge to create common ground
By direct exchange of information and knowledge a relationship is being build on reciprocity between engineering and production which results in more commitment and the creation of a shared vision. Both structural and ad hoc interactions are proposed by the engineers and foremen in this research. Regular meetings are there to maintain the relationship between engineer and foreman. The engineers becomes more aware of the current status of the ship and with the real time interaction also other information is shared like social emotional information (like frustrations and excitement) which helps in creating common ground and understanding between two actors. Not only explicit knowledge is exchanged but also tacit knowledge which can lead to shared mental models between engineers and production

Detect problems before they become real problems
With regular meetings potential problems can be detected earlier before they become real problems. Depending on the moment in the project and the complexity of the project, once a week or once in every two weeks, real time contact between engineering and production is proposed by the involved actors of this research. This in addition to the production meetings, email contact and sharing of progress reports. The one-on-one contact between engineers and production encourage the creation of a common ground where the mental models of the engineer and foreman can be synchronized.

Capture data about how problems are solved
Essential for Damen is to learn over time, by capturing problematic areas and make sure drawings and the 3D model are improved for the next ship. Damen should learn from the mistakes that occurred in the previous ship.

11.2 Evaluation of final design with production and engineering
In the previous section, the final design is explained. The final design is evaluated during the midstream modulation session and with different engineers and production employees. A video is shown of the proposed interaction process. The research question will be answered:

SRQ 10. What is the added value of the proposed communication process and tool improve the collaboration during the ship production phase?

The final design is evaluated with the two engineers and two production foremen, it is discussed how the communication process and tool can improve the collaboration.
Figure 59: Schematic overview of the conversation
Production perspective
The main consideration for production is that it should be easy to use, fit into their daily routines, it should work. In
the pictures a tablet is shown but for real time communication itself a mobile phone should be enough. Most Damen
employees still have an old fashioned phone. If the 3D model can be visible on the tablet, this is preferred over a phone.
Having the 3D model on a tablet makes it possible to compare the real ship and the model on potential problems.
Consideration is the language spoken, engineer and foreman should be able to speak English with each other. On a
remote yard the foreman should be able to speak English to be able to communicate and interact with the engineer.
Time differences between a remote yard and Gorinchem can cause problems in overlapping time frames. This should be
discussed between the involved engineer and foreman. The know how of production foremen differs per yard and how a
yard is structured, at some yards there is a site team, or the detailed engineering team is located at the yard, influencing
the communication flow, this should be considered as it influences if for the final design sill be used.

Engineering perspective
The engineers see the added value of real time communication. In Gorinchem visiting the ship is part of the work, but
when a ship is being build on a remote yard, a visual image of the situation is also needed. On series of ships that have
been build multiple time already there are not that many questions anymore, so in that case it is not needed. For first of
series or even semi custom-built ships, the added value of real time communication is acknowledged. Processing the
outcomes is key, for the added value of the communication process and tool.

"with a tablet, I believe it would help. I make a screen shot very often of the 3D model and then I put arrows in there with Snagit,
but then you have to be careful, this can be misinterpreted really easily. With live images you can say, no not like that but.."-
Mechanical engineer (P3) 35.

Besides the midstream modulation sessions, the final design is discussed with a technical manager engineering, three
engineers and three production foremen. The discussion are based on a visual movie that displays the interaction and
based on the schematic overview of the conversation as shown in on page 68 and 69. Questions that have been asked
to production and engineering are: Would you be willing to use the proposed communication tool and process? What is
the added value of the tool?

For engineering it is important to have a visual image of the ship and direct interaction with production:

"I believe it is really useful, It is something I really miss. (...) most value moments are there when they ask you, have a look at this, it
is not going so well". - technical manager engineering . 38 .

It is agreed that it depends on the involvement of the engineer with the project if the tool and process will be used. For
production having a phone by the hand is easy, when collaboration with production abroad there are some challenges like
time zones, engineering should be available for ad hoc questions. It depends per production foremen if the added value is
seen, it is acknowledged that direct interaction is needed but agreements should be made when working over time zones.

Besides this time and money at the side of engineering to adjust information is essential to make this solution successful. A closed feedback loop is needed
between engineering and production, and information should be captured as build.

In the following section implications for Damen are described.
11.3 Implications for Damen

The proposed intervention has consequences for the current way of working of engineers and production within Damen. In table 1 the main challenges are described and suggestions are given how to handle the challenges. The challenges are discussed during the MM sessions with different actors.

**Organizational challenges**

The communication process and tool means an intervention in current communication process during the production support phase. Direct interaction between the yard and engineering is needed, short communication lines

Engineers should have time to support production, and to adjust information as build. If engineers are under a lot of time pressure and priorities are on other projects, production cannot be supported.

**Principles of change management literature should be applied to change the behaviour of people. This is described in section 11.4. The yard should be involved in being willing to have direct contact between basic engineering department in Gorinchem and the yard.**

**How to handle organizational challenges**

Engineers should be available to answer questions. Hours are needed to adjust information. Time is needed for engineers to be able to interact with production and to be able to adjust the perceived feedback. The managing directors of business units and project managers should be approached for this.

**Technological challenges**

To be able to have a live video communication between engineering and production, a network connection is needed at the yard.

The current IT infrastructure is not yet ready for the solution of video communication in which documents can be shared easily. IFS, Outlook, Skype for business, SnagR and the 3D model are decoupled systems, these should be integrated in a collaborative platform.

Current tools used by production are not suitable for real time video communication.

**Damen should invest in 3G or Wifi facilities on new building ships during the production phase. Not only for this solution but also for the paperless yard initiative and to be future proof. This will be discussed in section 11.4. IT infrastructure should be adjusted to facilitate the direct communication. Money should be invested in exploring deeper how a connection can be made between the different systems. Within 5 years the PLM system (CATIA) will be implemented at Damen which includes such a collaborative (3D experience platform) the 3D model will be integrated with a feedback loop. But until that time agreements should be made of how to capture feedback. Damen should invest in tablet for production, which also can be used for paperless working, displaying the 3D model.**

**How to handle technological challenges**

**Human challenges**

Change in way of working of foremen and engineers

Technology acceptance of production foremen to use the tablet.

**Involvement of people in creating the new collaborative working environment, do a pilot test to show the added value. It will depend per person of the technology will be accepted or not based on the perceived ease of use and usefulness of the tool (Davison, 1989, 2000). The added value should be big enough, if the 3D model is available on the tablet it has much added value for production, this should be validated. For just real time video communication a phone is preferred.**

**How to handle human challenges**

Table 1: Organizational, technological and human challenges
Both engineer and production foreman should be willing to collaborate. That is the main issue of the proposed process, engineers and production foremen should be willing to collaborate, this depends on the intrinsic motivation, commitment and involvement of people, this is hard to influence. A relationship between engineering and production is needed, this can be supported by informal interactions between engineering and production at the start of a project.

When with a yard abroad, there is a language barrier, culture and time zone barrier. Hierarchical structures within the organization should be considered, in most case formal communication goes via the project manager but informal communication is directly. Language can be an issue, but when you have to work together, when having seen each other in real life, understanding of the other person will be bigger. Working over time zones means that agreements should be made about when to approach each other.

11.4 Implementation
In the previous section implications are described from an organizational, technological and social perspective and suggestions for handling these challenges are given. The proposed solution will have an impact on the current way of working during the production phase of a ship. Intentions from both engineering and production are there to used the system if it would be available. In this section a proposition is described on how to the implement the real time video communication between engineering and production, starting with change management theory, a roadmap and business case.

Change management
The proposed communication process and tool depends to a change the current way of working for production foremen and engineers. But changing peoples behaviour is difficult. Based on the ADKAR method (Hiatt, 2006) five elements are described and explained as a follow up for this project to be able to implement the proposed solution.

1. Awareness of the need of change
First make project managers, managing directors aware of the need and added value of processing feedback from production and improving the quality of ships. To do so time and money is needed for engineering to adjust production information during the production support or capture the information at one central place. Secondly, engineers and production should be aware of the importance of real time collaborative problem solving and capturing the solution in a central database. Engineers should be aware that asking for feedback builds a relationship. If production gives feedback but they do not see or hear what is done with it they will stop giving feedback.

2. Desire to make the change happen
Do a pilot in Gorinchem and use the best practices to shown to others, how easy it is and how quick problems can be solved. The positive and negative consequences should be evaluated. There are production foremen within Damen who would be willing to do the pilot test. If its validated that it really improves collaboration, a coalition can be formed for change.

3. Knowledge about how to change
Knowledge is needed to, explaining the procedure and to work out the procedure more into detail. The part for capturing the solution is essential to be able to reuse it for the next projects.

4. Ability to implement new skills and behaviours
Enable production foremen and engineers to fit it in their daily routines, this is also connected to the TAM model, the perceived ease of use and usefulness high enough.

5. Reinforcement to retain the change
Make sure that the process can keep going, feedback can be collected but if nothing is done with it, the motivation will decrease to give feedback and the proposed communication process and tool will not work.

Roadmap
To be able to improve the information or data exchange between engineering and production, three levels are defined (as shown in figure 6). The system of records should be consistent to support processes within the organization. A system of records focusses on consistent data usage, coded in a consistent way, for example dimensions in the 3D model, or the numbering of drawings, this will be facilitated by the new Product Lifecycle Management (PLM) system that will be implemented within 5 years in Damen. This is the ERP system and the product life cycle management system which will be changed from Nupas/Cadmatic into Catia. The second layer is the systems of differentiation which are applications that are unique for a company processes. An example is working in the cloud so that a yard and engineering can collaborate and have access to all information at any time, anywhere. On the highest level there is the system of innovation with new applications. The proposed solution is located at the system of system of innovation. To be able to implement the proposed solution in a meaningful way, it is recommended to Damen to first implement the system of records (to be able to have one single source of information, and an integrated 3D model). New applications can be implemented but when the system of records does not function well, this system will also have a big chance to fail.

In Figure 61 an overview is shown of a roadmap on the one hand validate if engineers and production employees really would use the proposed communication tool and process. Afterwards a pilot project at a yard where a first of series is being build or where a series of ship is being build for the first time to evaluate the added value of the proposed solution. In appendix P business case is described for a pilot project.

Figure 61: Follow up roadmap for after this project.
Practical limitations and broader applications
Evaluation of the final design with different actors (engineers, production foremen and Project Managers Engineering) gave insights in the limitations. These limitation can be translated in practical recommendations for Damen.

1. Added value for first of series
The communication process and tool is expected to have an added value for standard ship that are being build on a remote yard or first of series, and engineers and production indicate to be willing to use the system, this is based on the pictures and video shown during the evaluation sessions.

2. From peer to peer problem solving to a database
Now there is a focus on the peer to peer interaction. Tools are discussed with the foremen and engineers to detect deviations between the 3D model and real ship. Comparing the 3D model and real ship is essential for problem solving. During the midstream modulation sessions the added value of having a the 3D model is stressed.

3. Time and money is needed for engineering
Money and time is needed to capture the problems and solutions and a central space should be created to store them, time should be invested to process feedback. Sassou and Reason (1999) on error detection are also discovered in their research that deficiencies in resources are one of the main causes that errors are not corrected.

4. Every yard is different
Every yard has a different organization structure, it depends per yard if there is a site team to support production or not. At some yards there are different hierarchical layers. This causes that there is not always direct communication between the production foreman and engineering. But this is something that should be encouraged.

11.5 Practical recommendations for Damen
In this section some practical recommendations are proposed to Damen.

1. Avoid errors in stead of detecting them
The current solution focusses on the detection, indication and correction of errors. For Damen real added value lies in preventing errors form occurring by ensuring the right information for production. For example to perform design reviews and to check for potential problems during the production phase. It would be an interesting means to involve production during the design & proposal phase to already explore potential bottlenecks there.

2. Create central database with problems and solution from production
One of the most important recommendations is when the new PLM/PDM system will be implemented that feedback, problems and solution that occur during production should be captured in a consistent way. One standard procedure should be developed to do so. This makes it possible to learn from previous mistakes on ships. When starting a new project feedback should be evaluated for implementation in a template to improve the quality of products. Every team member involved in a project should be aware of the database, not to reinvent the wheel again.

3. Validate tool ease of use and usability
The involved interviewees define that they would use the tool, based on the Technology Acceptance Model (TAM) of Davis (1989) the intentions and behaviour can be predicted, but because of time constrains it was not possible to validate the design. It is recommended to used the proved questionnaire of Davis (2000) as shown in appendix S if the production will be used. Further research should be performed on what information should be displayed exactly.

4. Further research AR in production for error detection
Damen should further explore the added value of Augmented Reality technologies in the shipbuilding process as a method to detect errors. There is some potential for Augmented Reality in the production phase which should be researched more
into depth as a step before the real time video communication. Like delivering just in time information through Augmented Reality. For detecting errors a virtual layer over on the reality can have added value for production (As shown in figure 62). To be able to use AR effectively, the 3D model should be complete and correct.

5. Who was involved in which project?
It should be clear who worked on which project, so if questions are there by the new yard and the involved engineer does not know the answer, knowledge of engineers from the previous project can be reused. This can be done on Damen Plaza or any other platform on which profiles of Damen employees are visible.

6. Build first of series in Gorinchem
It is recommended to Damen to build first of series in Gorinchem, where engineering and production are co-located. This makes processing feedback from production easier compared to building a first of series on a remote yard.

7. This is just one solution out of many options
In this research project, only one solution direction is explored more into depth. There are multiple other options that could have been tested to improve the communication and collaboration between engineering and production.

“.. Those 3D layovers, yes maybe in 10-20 years from now, who knows how it will look like then.” - Production foreman (P8) 40.

“That is really useful, but I think it is also really expensive, but for use it would be useful to compare the 3D model with really in this way” - Production Foreman (P18) 39.
12. Discussion

To be able to give answer to the main research question, first the results are interpreted. This chapter will critically reflect on the research project and put the results into context. In section 12.1 the overall project is discussed. Section 12.2 describes the application of a quite a new method in the design process and in section 12.3 findings from this research are shortly compared to existing literature.

12.1 Overall project
This research focusses on the interaction between engineering and production during the ship production phase of series of ships. The proposed tool focusses on real time video communication between engineers and production which is remotely located. It should be mentioned that the problem as described in this report is much more complex and more “wicked” than can be captured in a graduation project. Many different, interdependent actors (engineering, supply chain and production and subcontractors) are involved in the ship development process influencing the manifestations of errors that occur during the ship production phase. Because of the narrowed down scope of the project, the complex situation could be handled, but is also limits the research.

The direction of the research is influenced by the decisions made by the researcher. During the project there has been a strong focus on mechanical engineers, (more than on ship engineer, electrical engineers and interior engineers) which may shown only one perspective on the problems. The researcher could have adjusted the criteria for selecting samples more spread over different disciplines like mechanical, electrical and ship. The researcher should have focussed on one yard abroad and find that out, now know how the interaction between engineering and production happens in Gorinchem, but at every yard it is different. Looking back the researcher should have focussed on one yard and export the interactions into depth, not multiple and more superficial.

The research is performed at Damen Gorinchem. Interactions between engineering and production are discussed and observed in a context in which people collaborate in the same culture. Later the solution focusses on engineering in Gorinchem and a remote yard. At different yards the same type of problems occur but the relationships with Damen are different. In the report quotes from participants have been used, these quotes have not been checked with the interviewees as it would have been better for the reliability of the quotes. But the proposed solution has been checked by engineers and foremen for validation.

During the project data, the process and interpretations has been shared during the expert session, during midstream modulation sessions and during consultations with the supervisory team to reduce researcher bias. In the next section the application of quite a new method (Midstream Modulation) in the design process of the researcher is discussed.

12.2 MM method applied in design process
This section shortly reflects on the application of MM during the design process, an more extended personal reflection can be found in Appendix Q. Normally the MM method is used as a collaborative methods in a context in which an embedded humanist (social scientists) discusses decision made by an technical expert (for example from the R&D department) to let the expert reflect on social, ethical considerations and let the innovator make deliberate decisions.

In this case, the graduate student was the embedded humanist/innovator, and used the six Midstream Modulation sessions as an input to design a communication process and tool the engineering and production department in the shipbuilding industry. The sessions facilitated a dialogue in which the four participants (with two engineers and two production foremen) could think along and reflect on the project. Frustrations were shared, the sessions helped in defining or what goes well, share design criteria and to evaluate the final design. In these sessions the four participants reflected on the decisions made by the graduate student and the sessions were used to explore the shipbuilding context more into depth. The sessions made sure that the four participants were engaged in the project for a longer time than just one interview, social,economical and technical considerations are taken into account based on the sessions.

The graduate student who applied the Midstream Modulation sessions was new in the shipbuilding context and the session were also used to explore procedures and social structures, without the sessions this would have been more
difficult. In that sense the sessions were very useful for the researcher to be able to understand the situation and how a project develops over time. During the MM sessions it becomes clear that the solution that is proposed will not prevent errors, but is more a fire fighting solution when errors occur. When consulting with the client, a fire-fighting solution is preferred, in contrast to the outcomes of the MM session.

After a session, the results of that session were not explicitly presented to the participants, which is recommended to let participants actively see their input in the process. There has not been a pilot test with decision making protocol, in the design process. This would have been better to understand the process of such sessions. It is necessary after an interview immediately take a moment to work out the session and send the results to the participants. The way the researcher has applied the method influences the added value for the design process. Because of the sessions, the opinions of the four participant have influenced the researcher a lot. Working out the sessions was time consuming and this caused that less other actors could be interviewed which have led to a more narrowed down perspective. The researcher did not have much reference points on how to apply the sessions during the design process, but if someone decides to apply this method in the design process again, some recommendations can be given where to focus on.

Because of the Midstream Modulation sessions, the researcher was focussed on the current situation, which made it hard to think out of the box and come up with radical innovations as costs are the key drivers, for every project first a ship needs to be sold.

12.3 Findings of research compared to existing literature

In literature the barriers between engineering and production has been discussed already, but these researches focus more on mass production process. Findings by Sassou and Reason (1999) on error detection are also discovered in this research, mostly the deficiencies in resources to correct errors. Existing literature about the distinct mental models of engineering and production (Smulders, 2006; Senge, 1990; Rouse & Morris, 1986) became very clear in this research too, there always will be an interface between the two departments and sticky tacit knowledge (about problems and experience) of individuals is hard to share (Nonaka, 1994). The prosed tool can bee seen and a pragmatic boundary object to change realities by means of conversations (Carlile, 2002). When working over distance this only becomes more challenging. Having shared awareness makes collaboration easier between engineers and production (Endsley, 1995). From the data it becomes clear that at some yards, production solves problems as there is room for interpretation in the production information. These problem solving activities normally happens during the engineering phase.

Existing literature about collaboration is divergent, as it is a phenomenon that highly depends on its context. In this research the connection has been made between errors in shipbuilding, communication (or interaction) and collaboration. The importance of face-to-face interactions has been found in literature but also in this research to build relationships. Findings from this research are consistent with existing literature about collaboration. When working with a yard abroad the dimensions of Hofstede (1980) also appeared to influence the collaboration between engineering and production.

Scientific relevance

In this research two field of studies have been combined, Strategic Product Design which focusses on the innovations in the New Product Development process. Research has been performed on the barriers between the engineering an production department in mass production companies, while this research focusses on the barriers between engineering and production in small series of complex products. This research presents empirical evidence that in the ship production phase the ship, small improvements are made on the ship design which improves the design and can make it cheaper to produces. These innovation loops should be acknowledge by the company and knowledge should be reused over projects.

Science communication focusses on the communication process in innovation practices. Midstream Modulation has been used as repetitive method to collaborate with four stakeholders in the design process. It is hard to described to what extend the method contributes to the design process but some results and experiences are shared in Appendix Q and R. Opportunities, considerations, alternatives defined by the participants are actively used in the design of the communication tool and process.
13. Conclusion

In the previous chapter the validity of the research is described, this chapter will use the results from this research to answer the main research question. This explorative research presents a case study at Damen Shipyard in Gorinchem. The time domain covered in this research is from July 2016 until May 2017. Three projects performed in Gorinchem are closely followed and information is gathered about project performed abroad. Interaction between the engineering department and production department are analysed during the ship production phase. Email, calling, meetings and face-to-face contact facilitates the information and knowledge exchange between engineers and production foremen. When a series of ships is being build on a new yard, problems occur that are normally fixed during production.

Main research question:

In what ways might the communication and collaboration between the engineering and remote production department be improved by the introduction of a new tool?

13.1 The main research question

In the report the sub research questions are already answered. In this section the main research question will be discussed. In the shipbuilding industry small series of ships are developed. In contrast to other industries the production information delivered by engineering to production is incomplete, contain mistakes and there is room for interpretation by production. Compared to other industries more interaction is needed between the engineering and production department during the production phase.

When a ship is being built multiple times at the same yard production develops routines to handle the information delivered by engineering, if information is incorrect or incomplete, production fills in the gaps with their practical experience. After the first time, the production foreman has implicit knowledge about how a problem on the ship is solved the last time, and there is not a real problem anymore. This implicit knowledge is not consistently captured in the production information, is not always send back to engineering or it is not captured by engineering because of time and money constrains.

When a standard ship is being build by a new production team or on a new yard the same problems occur again. Depending on the yard the production employees have these problems solving capabilities or they ask questions to engineering. As engineering has implicit knowledge about the theoretical solution, what alternatives have been considered and why a option has been chosen.

Questions form production are asked over the phone, via email or when engineering and production are co-located the foreman visits the office or the engineer visits the yard. In these face-to-face interactions the problem is discussed, the foreman often already has an idea about the most suitable practical solution and the engineer thinks along about the most suitable theoretical solution. In these interactions the foreman and engineer create a shared understanding of the problems and the solution. These problems solving activities are now captured in the heads of the involved engineer and foreman but when engineering and production are geographically separated and problems occur contact is often indirect via email. There is less interaction between engineering and remote production department, while these direction interactions are important to build and maintain the relationship, shared understanding and shares awareness between engineering and production.

One-on-one, real time communication between engineers and production foremen is proposed when a problem occur during production. Collaborative problems solving is encouraged as this process encourages the creating of a common
understanding of the situation between engineers and production and the engineer becomes quickly aware of the problem. This one-on-one communication process is facilitated by a tool that enables video communication between engineer and production. The added value of the Alpha eye was not acknowledged as useful as it is big, a tablet or mobile phone would be more useful.

Engineers see the added value of real time interaction between engineering and production to created a shared understanding of the situation. By weekly or bi-weekly meetings the engineer stays up-to-date about the current state of the ship and problems that occur. When the engineer and foremen structural intact with real time video it is expected to detected problems before they become real problems. Besides these structural meetings, ad hoc meetings are proposed when a foreman has a question. This communication process and tool ensures interaction between engineering and production which is needed to build trust, a shared understanding and awareness of the other situation. By these real time interactions information and implicit knowledge is shared, besides this these dialogues ensure that a shared picture is created a relationship between the engineer and foreman. Quick answers and reciprocity between engineering and production improves the collaboration between engineering and production.

Production foremen involved in this research agree that direct communication is essential but they are more aware of the practical implications of real time video communication, the engineer should be available, when working in another time zone can be a challenge. For both the engineers and production employees it is essential that the feedback from production is processes in the template to improve the ship and that “the wheel does not have to be reinvented again for the next ship”. With the communication process and tool, feedback loops can be closed.

13.2 Limitations and suggestions for further research

In this research project only problem solving situations are discussed, there are many more options to facilitate interaction between engineering and production to improve the collaboration. The phenomenon of collaboration is much more complex than could be captured in this research project. The complex situation within Damen is simplified in this thesis project, the questions as described above is also much more complex and it is impossible to find “the answer” to the question. As the type of research suggests, this is an “explorative” research, to be able to answer the research question only the tip of the iceberg has been shown in this research project.

Further research should be done on the interactions between engineering and production earlier in the process. As shipbuilding process can take years it was not feasible to do that in this research project. The perspectives of electrical engineers, ship engineers and interior engineers should have a stronger focus to create balance in the engineering perspectives. The application of Midstream Modulation in the design process should be researched further.
Bibliography

References


Flipse, S.M. (2013). Enhancing Socially Responsible Innovation in Industry: Practical Use for Considerations of Social and


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Dutch quotes

Below a list has been composed of all the Dutch quotes used in this report.

1. “Op een van de boten hadden een we zwembad, de engineers hadden een afvoerpijp bedacht die eerst omhoog moet en daarna omlaag, maar ze hebben niet nagedacht over een pomp. Een pomp is nodig om het water weg te voeren door de pijpen.” - Production employee 1.
2. Blijkbaar gebruikt productie niet de meest up to date tekeningen, wij gebruikten revisie 5, zij gebruiken revisie nummer 3” - Engineer ship (ENG) 2.
3. Als ze niet snel reageren, dan gaat de werf zelf een oplossing zoeken met hun eigen interpretatie. Je wilt dat productie vragen stelt, en dat engineering snel antwoord geeft. - Project Manager (PM) 3.
4. “Ja een aanloper, dat je ergens tegenlaanoopt waardoor de productie niet meer veder kan. Dus dat is echt een probleem, dan kan je echt niet meer verder, dan moet je echt even bespreken.” - Project Manager (P2) 4.
5. “Constructie fouten, engineering kan een pomp hebben verzonnen waar die eigenlijk niet kan, al dat soort dingen. Knieën van spanten zitten verkeerd, een motorfundatie kan iets te smal zijn.” –Production Foreman (P8) 5.
6. “ja, maar ze hebben het casco gebouwd in Turkije volgens mij, maar het is echt een klote casco, het maindeck is 2 centimeter lager dan die moet zijn, dus nu loopt alles klem, de pijpen komen 2 cm lager, het plafond komt 2 cm lager. - Engineer mechanical (p4) 6.
7. “The gap was smaller than tolerance, had to cut off to make it fit in there. It does not happen a lot, 1-2-3 time on a big section. This is the thing, engineers should think, how is this mounted in? Because they should keep in mind the tolerances a bit inside and outside, but as an engineer you do not have tolerances. AutoCAD does not have tolerances, 0000 something. But in real life, it can be 10 mm inside or outside. 10 mm from inside, to big for the hole. This is something to keep in mind when designing.” - Hull Coordinator (P21) 8.
8. “Een stabilizer, dit is een vrij pittig ding, komen veel krachten op te staan, en die moet tot een bepaalde diepte dat schip in dit we hadden mooie tekeningen en het aangegeven van joh die lassen moeten heel sterk zijn, maar we hadden niet aangegeven van

88 Bibliography | Dutch quotes
wat de max afstand was in de lager. Dus ze hebben die lassen extra dik gemaakt. En die afstand niet goed gedefinieerd dus wat is er gebeurd, de las was te dik, we stopte dat ding erin en dat lager buis gaat in de las, dus het past niet. Dus ding weer terug, lassen laten bijslijpen, laten keuren en weer terug. – Engineer ship (P7) 9.

10. (...)Het hangt er vanaf wat voor persoon er bij engineering zit en met wat voor mensen heb je in productie te maken. Kijk ik heb zelf jarenlang in de productie gelopen, ik weet precies wat die jongens nodig hebben en dan maak ik even een schetsje en dan plop en dan gebeurd dat, want ze zijn er mee bezig. (...)Als ik vroeger een algemeen plan maakte dan was ik al bezig om de motoren erin zetten en ruimte voor de uitlaten te creëren en de dempers en de generator set en zo bouw je een algemeen plan op en zo heb je een algemeen plan al helemaal in je hoofd zitten. Dat gebeurd tegenwoordig niet meer, die mensen hebben die kennis niet, die hebben die ervaring niet. En daar begin je al mee van hoe ga je dingen opbouwen om ruimte te creëren zodat iemand anders nergens tegenaan loopt... - EN1

11. [...] Hoe komt het dat je met hem zo goed kan samenwerken?
[P8] omdat hij de ervaring heeft van hoe bouw ik een boot en hij weet wat wij nodig hebben, hij levert het pakket compleet aan en hij levert de rest van de informatie aan. En dat is met de mech eng nu ook, die weet ook wat wij nodig hebben en wat de aanlopers kunnen zijn. (11)


13. Dan krijg ik een heel goed beeld van hoe het eruit moet komen te zien in 3D, dat kan in 2D ook maar in 3D loop ik er echt door een boot heen. En dan zie je ook kastje hier, kastje daar op een tekening heb je dat veel minder gevoel dan ik dat gemist heb op de tekening omdat dat minder makkelijk te lezen is. Nu wandel ik door een boot, dan kan ik rondkijken en dan zie ik wat van he, even tekening erbij zoeken. Van hee daar moet ik ook nog wat mee doen. Het is gewoon een handige en onmisbare tool. - Production foreman (P8) 13.

14. ja en dan is een antwoord van ik ben er mee bezig wel echt nuttig, of jongens ik heb het druk kan iemand anders het oppakken. Dan weet je dat er iets mee gedaan wordt. - Production foreman (P18) 14.

15. (...) groot gebrek geen feedback op tekeningen, omdat er veel lagen zijn, engineer, lead engineer, pm engineer, pm. Hele toren, engineering maakt een tekening en dat wordt een keer bij vergadering besproken maar dat komt niet altijd terug bij de engineer als er iets anders moet. (...) Het is niet goed voor ontwikkeling als je precies taken krijgt van je moet lijnje van links naar rechts trekken. (...) Productie zegt vaak, ja dat melden wel bij de project manager bijvoorbeeld maar dat wordt misschien niet altijd door gecommuniceerd. Dat is natuurlijk de vraag, dat weet je nooit. – Mechanical Engineer (P4) 15.

16. P-TM Twee keer, de eerste keer toen ik het project overnam had ik na een maand, zaten we de hele tijd te mailen en te skypen. Ik wil liever daar heen gaan om ons gezicht te laten zien. Een biertje samen drinken, de communicatie verbeterd daardoor wel hoor. [I-DW] door dat biertje?
[P-TM] Ja want dan durven ze dingen te vragen, en dan laten zien van kijk wij zijn ook maar mensen die fouten kunnen maken in een email. Vaak schrijven we een email, ze voeren dat dan door zonder erbij na te denken. Dat probeer ik ze ook af te leren, van denk daar nu eerst bij na van wat je leest. Normaal gat het oh ja hij zegt dat dus dan ga ik dat gewoon zo doen. En als ik het dan zie wat ze uitgewerkt hebben dan ik dan denk; ah shit, dat had beter anders gedaan. Maar dan denken zij; ooh hij heeft een opmerking over zijn eigen vraag. Dus dat probeer ik erin te krijgen, dat we gelijk zijn en dat we samen iets moeten ontwikkelen. Maar ik wil ook graag zo bij productie dingen vragen, dat doe ik heel graag.

17. kleine dingen, afspraak is eigenlijk keep it simple dus alles lager dan 20 cm is niet zichtbaar in de ebrowser 50-50 cm moet eigenlijk ook niet visueel in de ebrowser zijn, maar ik heb nu beslist, ik wil alles in het 3d model hebben als. - Mechcnial engineer (p3) 17.

18. [...] ja dat zit ook heel veel in de cultuur en het heeft met geld te maken natuurlijk. Tegenwoordig is de vraag steeds meer, wie heeft de schuld? Wie heeft het fout gedaan. - Manager Contracting yard (P24) 18.

19. [en1, ship engineer] een volledig pakket sturen, maar dat kan niet. [pf1, production foreman] naja kan wel, weet je wat we gaan doen we gaan de hele boot uit-engineeren, tot in de puntjes uit-engineeren. Die gaan we bouwen hier, als we het helemaal gaan uit-genineeren dan wordt het te duur, dus wat gaan we nu doen? Grote lijnen uit-genineerd, de rest is voor productie.

20. “Even foundations of for equipment we have the same problem. They make it complicated. But the reason is not so clear not for me but also not for them. They say this is how I used to design foundations, but looking back there is no real reason. You start working in one style, you always design foundations in the same way, the point is that one situation is not the best solutions. It is hard to quantify that.” - Hull Coordinator (F21)

50-50 cm, amahoela we doen 30-30 cm daar wordt niemand beter of slechter van. - Mechanical engineer (P3)  21.

22. [I] maar komt dat het wel op tekening staat maar niet gedaan wordt?
 [P18] Ja het staat wel op tekening. Maar als er geen controle op is, dan sluipt iets erin, dan krijg je zo iets van dat doen we altijd zo.
 [I] geen soort van eigen routine?
 [P18] ja dat werkt zo, dat is hier ook zo. Als ie iets altijd jaar in jaar uit doet, dan krijg je van; dat doen we altijd zo, en dat wilt niet altijd zeggen dat het goed is. Daarom is het wel goed als iemand daar fris eens tegenaan kijkt. Daarom als jij inspectie doet op een boot, dan kijk je daar anders naar dan dat jij daar de hele dag mee bezig bent geweest. Soms ben je ook blind voor dingen, je ziet het gewoon niet meer.

23. [P1] hier heb je vaak een probleem en als voorman zijnde en die jongens aan boord hebben vaak al een oplossing. Dan is het even met en1 of en2 of wie ook overleggen, en als je het erover eens bent.
 [Pf2] wat het ook is mocht het nog niet in de standard veranderd zijn, wij onthouden het vaak, met de volgende boot dan denk ik oja zo maken we dat. Dan is het niet echt meer een probleem.
 [en2] dan hebben we mazzel dat jullie daarop zitten als we een andere voorman krijgen.
 [g] stel je voor er komt een andere voorman op?
 [P2f] jaa dan heb je wel een probleem.
 [en1] ik heb zelf ook in Cuba meegemaakt, met 42 meters er ligt daar een staalpakket om een romp te maken en dat klopt van geen kant, die hele vaak beplating. Ik mis gewoon dingen, die nog van een van de eerdere versies in het snijpaket zaten. Dat is er niet uitgetekend, ik bedoel schepen worden hier bij [Naam bedrijf] gemaakt, die hebben hun eigen snijpaket, dat is allang opgelost. Dat probleem is van een jaar jaar, en dan gaan we opeens ergens in Cuba bouwen, dan komen alle kinderziektes weer naar boven.

24. Verschrikkelijk veel, want ik krijg dan af en toe wel eens updates van die boten daar foto’s. hier kan ik alles makkelijk oplossen, maar daar lopen ze net voor op ons, dus niet alles kan je dichtknaipen op voorhand. En dan als ik soms de vraag stel. Alsjeblieft hebt je daar over na gedacht? Om het zo en zo te doen? Nee dat doen ze niet want het staat zo op tekening. Of er staat niets op tekening, dus we gaan het zo doen wat we denken dat goed is. Die nadenslag wordt niet gedaan. - Mechanical engineer (P3)

25. [P14] Twee is dat voor veel klanten het eerste keer is dat ze een boot bouwen, en Galati of hier in productie die hebben het al tientallen keren gedaan, die kunnen veel makkelijker problemen oplossen. Dus die hebben meer kennis. - XX  25

26. [P3] en zonder te communiceren of feedback naar engineering. Ze hebben in het verleden wel feedback gegeven maar daar werd niets mee gedaan, engineering nam die feedback niet op. En dan zouden ze van ah hier het documenten pakket gooien we over boord, als we weten waar dat moet komen dan lossen we het wel zelf op. en dan bouwen ze zelf iets, zonder dat engineering wist waar productie mee bezig was. - Mechanical engineer (P3)  26.

27. [I] dus jullie sturen het antwoord naar de project manager en die speelt het door naar de yard?
 [P4] ja. Maar mijn ervaring is wel dat het uiteindelijk wel direct wordt en dat vind ik ook wel het fijnst, al zeg ik het zelf. - Mechanical engineer (P4)  27.

28. [I-DW] hoe komt het dat ze de noodzaak niet in zien?
 [P4] omdat het voor het moment de huidige boot is het opgelost, voor een volgende boot is dan de instelling, ja dat komt dan wel weer. Dat zien we dan wel weer, maar als je het goed wilt doen dan verander je het meteen op tekening. En we beginnen met een actielijst, dan gaat iedereen rond rennen, en we gaan door. Stel dat er een 09 komt dan zou ik graag even de tijd nemen om full time dingen recht te trekken voor het volgende project. Maar de project manager engineering zei al, dat gaat niet lukken. Maar dat zijn min of meer indirecte uren, je verdient er niet mee direct. Dat is gewoon heel lastig. - Mechanical engineer (P4)  28.

29. [P4] het project management wilt zo min mogelijk uren insteken en geld eraan besteden, als er op een bouwnummer een feedback lijst is met 100 punten dan zegt die misschien, dan streept die er 60 weg dat scheelt al weer, dat is wel wat er gebeurd in de praktijk. Dat levert dat bij engineering en productie ellende op, je wilt dingen verbeteren, je hebt er geen budget voor. [P4] Dit is onzijn volgens de directie, dit is wel wat er gebeurd. Zodat er een actielijst wordt vrijgegeven op een boot, en uren en budget potje. Dan zal je het hele proces moeten doorlopen. Dingen die je moet verbeteren maar er zijn geen uren omdat dat krap is, dan blijven de verbeteringen liggen.

30. [I] maar hoe komt het dat het bij andere bouwprojecten niet verwerkt wordt?
 [P3] Ja het gaat ook allemaal om het geld ook. We krijgen nu uren ook om die feedback te kunnen verwerken. We hebben daar expres uren voor aangevraagd budget voor aangevraagd om dat te kunnen verwerken. En we krijgen ook dat budget van hoger op omdat ze merken, in het verleden van een ander type schip dat ja, als het budget niet wordt gegeven, dan krijg je gewoon zo een wildwar van documenten en van schepen, en dat willen ze eigenlijk vermijden.

31. [I] maar die uren, die 2000 waar was dat dan precies voor?
 [P3] om de punten uit productie op te pakken, en alles goed in het model te zetten, dat als er een nieuwe wordt gebouwd, dat het eigenlijk allemaal goed staat. Dus nu kan je enkel uren gebruiken om punten op een lijst te zetten en dan de ene keer dat we aan een nieuwe boot beginnen moet je eerst al die punten aanpakken en dan ga je verder met de boot.
[I] ik dacht van de week nog dat het goed was dat jullie al die feedback mogen verwerken

(P3) ja née productie was er ook super blij mee maar dat was maar voor even. Vanaf nu moeten we weer zeggen tegen productie, ja ik zal het opschrijven en dat is het.

32.

33. [en1] wisseling van de wacht en tijd krijgen om modificaties te doen aan een schip, van a het wordt mooier en b het wordt goedkoper. Dat moet dan wel ge-engineerd worden, en daar krijgen we de tijd niet voor. Als je kijkt een collega heeft een heel lijst gemaakt van dingen die verbeterd kunnen worden, er mogen geen uren gespendeerd worden, terwijl er een heleboel dingen bij zijn waar je eigenlijk uren in moet stoppen wat het wordt er beter van goedkoper, maar dat mag niet want je mag als engineer er geen uren instoppen.

[pf2] maar het moet wel goedkoper en beter

34. [g] heeft de casco kwaliteit veel invloed op jullie werk?


[g] denk je dat die kosten tegen elkaar opwegen?

[pf1,2] op de lange termijn zeker, tuurlijk

[pf2] die mensen daar zijn zijn wel een paar euro goedkoper, maar wij moeten het weer opknappen, wij zijn veel duurder.

[en2] dat ben je eigenlijk niet zo handig bezig

[en1] maar dat sort of beslissingen worden wel genomen, waarom het uitbesteed aan Polen omdat het veel goedkoper is, natuurlijk zeggen ze van dan zal de schilder wel een paar ton duurder zijn van al dat plamuren, dan zie je dat toch niet. Degene die dat beslissen weten niet wat voor problemen het oplevert, de directie of de productgroep of CYS.

35. [P3] ja met tablet vind ik dat wel, dat zou wel helpen. Vaak maak je een screenshot van het 3d model met pijltjes en dat zit je met snagit te werken van dat en dat en dat moet je opletten, vaak wordt dat mis geïnterpreteerd. Dis snagit pijltjes. Met live beelden kan je je echt zeggen van nee niet dat maar...

36. [P4] omdat anders die response tijd veel te lang is wat je net zegt met Galati, een mailtje sturen een print screen, daar gaat gewoon een week of twee over heen dat kan niet. Als er een fundatie aangepast moet worden en die moet geschilderd worden, snap je dat eindelijk door dus je ziet zo snel mogelijk in zo kort mogelijke tijd problemen afhandelen. We kunnen niet heen en weer vliegen om continu van de laf los dat maar op. ik denk dat je dat real time mee kunt kijken, dus in plaats van dat de voorman zegt van he kom eens aan boord. hoe gaan we dat doen. Dat zo een man in Galati weet ik veel kypt of de helm opzet op kijken eens even mee, dit gaat er mis hoe gaan we dat doen? Dat heeft 100% zeker toegvoegde waarde.

37. “ik zou het willen gebruiken. Dat ik heel snel kan schakelen. Vaak is het probleem dat ik het niet uit kan leggen. Ik heb zo vaak al van die dingen.” - PF 3

38. (06:25) “Ja ik denk het wel, sterker nog ik denk dat het heel zinvol is. Het is iest wat ik gewoon echt mis, ik ben hier opgegroeid in dit bedrijf in de tijd dat wij hier bouwde, het dat doen we nu voor YS de FYSsen maar daarmee zijn we heel lang geleden. Ik heb dat 15 jaar niet meer gemaakt. Maar een van de meest leerzame moementen is natuurlijk van kom eens even kijken, het gaat niet goed. Dan sta je daar om 8 uur in de ochtend met .. op e kaken van eh oh ja dat moeten we de volgende keer toch even beter doen. Je moet het ervaren. (...) Die wereld is zo ontzettend abstract voor ons dat bijna niet te doen” - Technical manager engineering

39. “.. zulke 3d dingen over elkaar heen ja dan zal je misschien 10- 20 jaar verder zijn, hoe zal het er dan uit zien.” - Production foreman (P8)

40. “Dat is wel echt handig, het kost waarschijnlijk veel geld maar voor ons is het nuttig om het 3D model te vergelijken met de werkelijkheid op deze manier” - Production Foreman (P18)

41. En1] Nou dat ligt aan de verhoudingen tussen engineering en productie voorman. Hoe zijn die? Kijk ik kan me best voorstellen dat er mensen zijn bij productie denken van oh we hebben die manager engineering erop zitten, die ga ik niet alles vertellen want die wordt toch wel vaak aan de kant geschoven en engineering hem helemaal niet ziet zitten. Dus het is ook acceptatie.

[pf2] hoe makkelijker je bij elkaar kan binnenlopen, hoe meer feedback je krijgt

42. [P19] En als het bij de werf blijft dan krijgen zij ook meer verantwoording van dan kost het ons geld. Ze hebben het verkeerd gedaan, ze moeten met een oplossing komen en dat is ook wel wat ook gerooid is. Een voorman krijgt hier een tekening pakket, staat er een keer iets niet op dan denk de voorman van, hey daar moet iets op tekening en die gaat bellen. In Hardinxveld of ergens anders als een voorman hoofdlijnen krijgt en er mist iets dan denken die van oh dat moet ik zelf verzinnen. Dat creëer je zelf als je een heel gedetailleerd pakket opstuurt dan verwachten ze ook dat het klopt, mis je een keer iets dan gaan ze bellen. Wat logisch is hier is iets vergeten. Als je een kleiner pakket oplevert, dan regelen ze het zelf.
Appendices

Appendix A. Insights from 9 orientation interviews
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Appendix A. Findings orientation phase

During the orientation phase, interviews were conducted to get a better understanding of the shipbuilding process. Findings from the orientation phase are described below.

Insights from orientation interviews

Causes of errors in the production of Damen shipyards (interviews and observations)

When interviewing different stakeholders about errors that occur in the production of a vessel, it became clear that technical errors are caused mostly because of different social factors. Below I summed up factors that were mentioned multiple times by the interviewees as causes for errors in the production of a vessel (in Appendix B Overall findings orientation phase, main findings are summarized per interview):

- Errors in drawings/3D model (input production)
  - Examples of errors in drawings are: missing dimensions, what is shown in a drawing is just not possible to produce, BOM incomplete, incorrect information in drawings.
- Lack of practical experience of engineers (production mentions often that engineers should visit production more often)
- Differences in basic engineering drawings (2D) performed in the Netherlands and detailed engineering in 3D model which is constructed in Poland, Vietnam or Romania.
- Lack of checking of drawings (it is boring, drawing blindness, lots of experience is needed to find errors in drawings)
- Not understanding the bigger picture (both engineering and production)
  - Both engineers and production employees needs to understand the bigger picture they are working on, “know what you are building” and feel responsibility for their part in the bigger picture (in production Gorinchem, 3D model is now used in which dimensions can be measured)
- Back in the days, production meetings on board so issues could be discussed immediately and the engineers had a better understanding of what they have designed.
- No feedback processing (during production)
- Production stops giving feedback if they know nothing is done with it, see same mistakes in ship 1 as in ship 9, then production does not feel appreciated.
- Engineering should explain why not adjusted (depends on time, costs and human capacity)
- Production in Gorinchem own interpretation is something wrong in drawing, production aboard follow drawings exactly, so drawings should be correct, ‘drawings as build’.
- Poor engineering vs production communication (during production)
- Theoretical versus practical perspective, engineering can learn from production and the other way around
- Face-to-face contact lowers barrier for production to come by engineers, explaining issues much easier than via email or by phone.
- Revisions in drawings, everybody should work with the same information
- DTC dependents on quality of the 3D model and drawings from other business units
  - The 3D models, drawings and production information is used from other business units. For DTC projects it is essential that the information delivered to client yard is correct and complete. For DTC it is more important that information is complete and correct as these client yards follow this information blindly.
- DTC build vessels from other business units, at client yards.

Notes from orientation interviews

1. Engineer D&P HSC
   - Product feedback loops, in my experience DTC has most questions about information that is not clear on the drawings
   - There are standards for drawings and check lists but often engineers think “this is clear enough for production”, it is all about knowledge and experience of the engineer, is everything in the drawing? And what is shown in the drawing, can they produce it? Experience is important and learning from each other, engineers should also advice
each other.
- In practice every drawing set-up is different. Difference in line thickness, different perspectives. This makes checking drawings also harder because experience is needed to check all the drawings on mistakes.
- Mistakes in drawings: Bill Of Materials not correct, weights incorrect, dimensions incorrect and names incorrect. Collecting all the information about errors only useful when having a ship series, if only two ships are build it takes a lot of time (and money) to adjust drawings. There are different way to collect or prevent there errors, feedback from services, the product portfolio manager and handbooks and instructions for engineer. We tried to use a checklist for engineers for drawings, but it takes to much time for engineers to go trough the whole checklist for every drawing.

2. Project Manager Product group HSC
- Both engineer and production should feel responsible and ownership about the work they deliver. Engineers should make sure their drawings are correct and production should give feedback if something is wrong in drawings. If everybody thinks not my problem and mistakes are not indicated, the process will decrease in quality
- The building strategy should be as a guidance for engineering to make them think about how it will be produced, design for production.
- If engineering make mistakes in the drawings, definitely errors will occur in production as engineering delivers input for production, if this is not 100% correct mistakes will happen in production. Start at the beginning of the process, but often capacity of people and money is a restricting factor.
- There are different types of issues, safety and reliability, performance and production obstructing issues and improvement issues. There is no doubt about adjusting safety and reliability issues, changing performance and production obstructing issues depends on time/costs balance. Improvement issues are nice to have.
- It sounds hard but engineers should make sure that production does not have to think about how it is produced, engineering should think about this already, to do so they need practical experience. “Engineering is the first phase of production”

3. Project Manager DTC
- Not all information of drawing that we need when building on client yards, like screws are not in the parts list. Which is okay when producing on a Damen yard, but harder when building on a client yard when you have to send these type of material. This can cause delays.
- In drawings from high speed, railings were not shown, at yards from high speed they know the railing should be there, but the client yards do not know these type of things. All information should be in the drawings for DTC.
- In America they work in Inches instead of mm, all drawings had to be converted.
- Production employees on client yard often not so good with computers and in Mexico we did not have much access to internet.
- There is a diversity in know how, skills, language and culture between DTC yards.
- Know how of hull builders becomes less (older employees with a lot of know how go with retirement).
- Everything should be correct on the drawings
- Revisions in drawings, at the production site they still used the old drawings.
- Practical problems get fixed and ‘As build drawings’ are made
- Planning is made top down, there is a deadline, within that time engineering and production have to operate.

4. Project Manager Offshore and Transport
- Engineers have a certain amount of time that they get from the product group, they have to do the job in that time.
- Detailed engineering done in Romania of Ukraine, basic engineering done here
- Engineers can get stuck on the vendor data, if it comes to late for the batches of information that will be send to production.
- Important to make sure that agreements to prevent disruptions and frustrations (who is delivering what, and when)
- Job preparation – engineering delivers standard engineering production information (SEPI) to production, but they feel like the information that is in this SEPI document is hard to meet.
- During detail engineering often ad hoc questions, they need to know who their contact person is O&T does not have
a production support team, so engineers (here in the Netherlands) take longer time to react on detailed engineering
Practical knowledge and experience, engineering output not always suitable for production input.
Aboard, if it is not in a drawing, it is not made, here if it wrong in a drawing they change it themselves, feedback
should go to engineering and they need to have the capacity to adjust the drawings.

5. Engineering SX (comes from production)
‘What I miss is the easiness of walking around on a ship that is being built and being able to listen to people on the
work flour, to hear what issues they encounter’
Some engineers miss the feeling of; this is what I have engineered. I want to know what I am building’ and
learn how it should be done differently for the next vessel, a disadvantage of building aboard, you do not get this
feedback. Calling is really hard, using skype already better then you can see each other but still the explaining is hard,
Money is an important driver, there is a certain budget for engineering,
Swimming pool example
On the one hand, Sx first ship so process should be good, but on the other hand, the product becomes better and
better after more ships being built.
Production comes with adjustments for the next ship, but is nothing is done with the feedback, and it goes straight
to the trashcan, same mistake will happen in vessel 1 as in vessel 9. This demotivated production employee to
share their comments. Engineer does not explain Why they did not do anything with it.
Everybody makes mistakes, but is time consuming process to email around about mistakes in drawings. “per mail
komt het toch niet over, ik ga liever voor de korste weg”
Engineering here needs to check the 3D model made in Poland, Vietnam or Romania on mistakes.
Putting everything on drawings can take 8 hours, while in Vietnam it takes them 2 hours to put it into the 3D model.

6. Production subcontractor piping
Feedback, “they won’t do anything with it” PM explains it takes to much time so it will not be changed “in takes to
much time to adjust the drawings so we cannot do it”.
Rooting in 3d model strange, made in Poland or Ukraine, collapsing systems in the model
“Engineering often over qualifies dimensions of the pipes, for example we always use pipes of 120 mm, in drawings
the pipes have a 150 dimension, so in Poland they use those dimensions, while we always use 120 mm which is
good enough but it won’t be changed in the template drawings.”
Back in the day’s engineers would stop by at the production site to have a look on board, this is becoming less, they
stay in the office”. We knew everybody at engineering, now the organization is much bigger.
We have been here since 1992, contact with older employees is much easier as they know us, while the new
generation is more focused on the theory. If we know someone personally it is easier for us to step by at the office.
The organization has grown fast, the personal contact with engineers has become less as project teams change.’
Now we have one contact person for the FYS which is great, he stops by often and we can call him if we have
questions. ‘For us it is important to have one contact person within Damen, that we can go to for questions.’

7. Project Manager
Vendor data not up to date or too late, this influences the BOM.
Capacity of time, and people from engineering too small (engineering time) to do all the engineering work
Plan approval from internal/external client takes a lot of time (client has to react in 7 days)
SEPI document with cutting info, piping information, outfitting information steel can cause deficiencies
For example the heli desk of the FYS 07 (and 08), I have to go there every 2 weeks to check what the supplier is doing
there.
Two different worlds are looking at one process, D&P should already think about the production
Damen should stay in control, and manage that people keep their appointment to be able to stick to the planning
Communication between engineers and production managers by production meeting, engineers among each other visual
management and once a week a project meeting with planning
Building on a yard abroad, the building strategy is used to plan the process, a kick-off meeting is planned to make
agreements on which information will be delivered, design check is done by DSGo, Basic engineering on Gorinchem or in
Gdansk, detailed engineering at MEGA, ship was build in Galati

8. PM engineering
The problem is having correct technical info at the right time for engineering
In production engineering support needed because:
- Yard has no information about the engineering package
- Question about drawings on the yard
- Different understanding
- Angry workers
- Angry yard
- Demotivated engineers
- Delivery time of the ship is in danger
- Angry consumers

- Engineering and engineering support:
- Agree SEPI (standard engineering production information)
- Yards and DSGo knows what they must do
- Introduce the drawing package and explaining
- Answer questions of the yard
- Feedback from yard, next ship will be better
- Safety worker/yard
- High engineering involvement
- Boat ready on time
- Happy consumer

9. Planner management projects
- Engineers think in complete drawings but for procurement, logistics and production the drawings does not have to be finished.
- Every departments is working on their own part of the project and then they throw the information over the fence to the other department, for planning it is hard to make these departments fit. The detail level of detail in information need is different between production and purchase.
Appendix B. Findings observations

During the research project, the student was located at the engineering department of the business unit Yacht Support.

- When a revision is made in a drawing many different actors are involved (to adjust scheme, the 3D model, expert it to 2D again and release information)
- In Gorinchem, asking about obstructing events some mention that they cannot think of examples that are really obstructing or delaying the process, the foundation engine example is given by multiple people from different projects
- On drawings multiple details can be shown and these details cause confusion by the production employees
- Senior engineer pushes junior engineers to visit on board weekly, which is appreciated by production also the juniors understand the added value of visiting the ship every week.
- When joining engineers when they go on board, it happens that different situations are found compared to what they have designed
- Production foremen visit the office a few times a week to discuss drawings and problems with the "project manager engineering ship or mechanical" these PME’s have younger engineers working for them to support.
- After a production meeting production and engineering visit the ship to discuss issues from the production meeting and they come up with a solution together on board
- Email is used as a confirmation for agreements made between parties
- Feedback is now collected but the next step is to do something with it, update the reported about if feedback is processed or not “1 FTE should be there to process all adjustments during the process” - eng ship.
- Freeze and release concept of drawings
- At Schelde the use assembly drawings instead of construction drawings
- 3D model collision alert is swished off as multiple option in one model the collide, besides this piping smaller than 25/10 mm not in model
- Gorinchem is the ideal world for collaboration, but production foremen have a different attitude compared to production foremen in countries like Vietnam. In Gorinchem there is no Job preparation, the production foremen have to search for their information on their own.
- Suppliers who do not deliver their product on time (8 weeks later as promised) “that is always the case with them”
- On the spot engineering “it is not like plug and play, it will still be tricky”
- “after the meeting will check it on board” is an often heard idea. After a production meeting, engineers and production foremen visit the ship together.
- Template freeze and release concept Damen – series ship standard. Freeze and release means that when the engineering package is good enough, it will be frozen. Only adjustments can be made if there is a real mistake in there and the classification society. This template is used and modification documents are made if adjustments are there for a ship, adjustments are send via email with sketches. Product group decides if adjustments can be made in the template. Disadvantage, if ship is build on another yard with less experience, the standard template is used while it is not correct and information is missing. Eng Ship 1 had experience with this in Cuba where steel was missing. Engineer ship 2 in Vietnam.
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- For planning project, it is unknown how much time it takes to do a tasks. For engineering it is already more developed in IFS, but for production it is not known how much time a task takes
- Engineers not involved through the whole development process of a ship only part-time, only PME en and PM involved in the whole project
- Lots of contact between Damen employees via email, many employees on the one hand complain about the amount of emails send but on the other hand it is used as confirmation. Email is putting responsibilities to
- Even though ship nearby produced here in Gorinchem, engineers not always visit the yard. The senior engineer pushes the younger engineers to visit the yard on a weekly basis.
The table above describes the different configurations that are possible between the different operational processes of the ship development (Basic Engineering, Detailed Engineering, Hull Production, Outfitting, Production Support). Even more complex configurations are possible than shown in the table above, but these are the main options. These different configurations are relevant as they influence the responsibility of the involved parties.

<table>
<thead>
<tr>
<th>Damen Shipyards Gorinchem, lead partner</th>
<th>Location A</th>
<th>Location B</th>
<th>Location C</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Basic Engineering (PS)</td>
<td>Detailed Engineering</td>
<td>Hull Production</td>
<td>Outfitting</td>
</tr>
<tr>
<td>2. Basic Engineering (PS)</td>
<td>Detailed Engineering</td>
<td>Hull Production</td>
<td>Outfitting</td>
</tr>
<tr>
<td>3. Basic Engineering (PS 2)</td>
<td>Detailed Engineering (PS 1) Hull Production</td>
<td>Outfitting</td>
<td></td>
</tr>
<tr>
<td>4. Basic Engineering (PS 2)</td>
<td>Detailed Engineering (PS 1) Outfitting</td>
<td>Hull Production</td>
<td></td>
</tr>
<tr>
<td>5. Basic Engineering (PS) Outfitting</td>
<td>Detailed Engineering</td>
<td>Hull Production</td>
<td></td>
</tr>
<tr>
<td>6. Basic Engineering (PS 2) Outfitting</td>
<td>Detailed Engineering (PS 1) Hull Production</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Appendix C. Critical nodes

Below the key actors in the development of a ship are explained based on the input information, core activities, output and characteristics. Key actors are; Project manager (PM), Project Manager Engineer (mechanical/ship/electrical), Planner, Purchase, Material Coordination (MC) and the Production Foreman (PF). Information based on observations, interviews and internal documents (Source: MDT Performance on Integral Planning and progress monitoring v3.0 ENG) for producing and outfitting at a Damen Shipyards Gorinchem.

A structural overview of a project team decided in basic engineering, detailed engineering and yard/production.
Project Manager (PM)

**Input (provided by):**
- Building strategy shipyard (YARD)
- Milestone schedule level 1 (PG)
- Restricted Action list /Unrestricted Action list (PG), Specification, general arrangement, “work list/ option list” (D&P).
- Overview lead times from Purchasing (PUR)
- Overview desired delivery times at yard (YARD)
- Batch schedule/milestones (PM/CE)

**Core activities Integral Planning:**
- Collect input from all parties, incl. building yard.
- Drawing delivery schedule
- Equipment delivery schedule & -conditions
- Transit times
- Delivery milestones building yard
- Make/ finalize demarcation (hull)building yard vs Co-Engineer (CE).
- Coordinate between parties: process timing and dependencies.
- Make logistics plan and schedule.
- To be done in close cooperation with building yard.
- Determine logistics schedule in cooperation with MC.
- Discuss Engineering schedule
- Create batch delivery schedule in cooperation with CE.
- Ensure integral schedule & activities are accessible for all parties involved.

**Output (all to provide to team and YARD):**
- Team Agreed Milestone planning level 2 in IFS
- Demarcation yard / subcontractors
- Monthly Project Status Report

**Core Activities Progress Monitoring:**
- Monitor planned vs actuals and provide feedback.
- Judge impact of possible deviations in an objective manner.
- Determine impact, solutions and make decision on action to be taken together with involved party and update schedule.
- Flag any deviations by team members outside of regular reporting.
- Maintain helicopter view over the project.
- If project is severely impacted, inform other involved parties (e.g. PPM, PG, SM, team leader).

Project Manager Engineering (Mechanical/Electrical/Ship)

**Input (provided by):**
- Action list (PG)
- Specification, General arrangement, option list (D&P),
- PFL-monitor (PPM/D&P/ENG)
- Demarcation Yard, MC (PM/CYS)
- Schedule (Logistics, production) (PM/planner)
- Services letters
2e degree input:
- Subcontractor/vendor data schedule (Purchase/PM/ Subcontractor)
- Engineering Shiptype Information (ESI) (ENG/PPM/PM/YARD)
- Checklist engineering (ENG/PM/PPM)

Core activities Integral Planning:
- Determine scope with shipyard, subs, vendors and PM/PPM, including budget and batch delivery schedule based on logistics schedule and shipyard schedule.

Output (provide to):
- Project Start-up Document (PM)
- Delivery milestones: internal, MC, Yard
- Document connection to del. milestones
- Connection successor activities to milestones to chain (input for planner)
- Workbench (Develop docs, Doc. pack., WBS activities, planned hours). (ENG/inform rest)

Core activities Progress Monitoring:
- Checks are made on own progress
- Communicate with team and Engineering

Production Foreman (PF)

Input (provided by):
- Standard Engineering Production Information document (SEPI)
- 3D model by detailed engineering
- Cutting files
- Materials and equipment (suppliers)

2e degree input:
- Vendor data

Core activities Integral Planning:
- Determine scope with engineer, subs, vendors, including budget and batch delivery schedule based on logistics schedule and shipyard schedule

Output (provided to):
- Building strategy shipyard (PM, Eng)
- Shipyard missing item list, container check report and other questions on material flows (MC/proc.)
- Subcontractor/vendor data schedule (Subcontractor)
- Shipyard schedule
- Feedback on drawings

Core activities Progress Monitoring:
- Schedule subcontractors
- Checks are made on progress ship
- Communicate with PM and Engineering
Appendix D. Manifestations errors

What manifestations or errors do occur during the production of a ship? During the production of a ship level multiple issues can be observed in different parts of the ship, for example in the foundations, piping and steel plates. Some of these manifestations have impact on the progress of the ship, the costs of the ship and frustration among team members. Below examples are given, foundations, piping, plates and equipment are all interconnected.

Pumps are critical components as different disciplined come together, mechanical with piping, electrical with cables and ship with the foundations.

**Foundations**
- Equipment delivered does not fit on foundation in ship (new equipment, old foundation used)
- Profiles
- In practice it is hard to weld on the inside of the ship when following drawings
- Different details shown in drawings which causes confusion which detail to use
- Old drawings used in production
- Revisions in drawings when they are already done in ship (revision to late communicated)
- Revision made in drawing for example stairs but not in all the drawings connected to this drawing
- In 2d drawing different information than in 3d model, block was missing in drawing
- Profile same place as previous ship but should be taken out because collision with equipment on deck.

**Piping**
- Piping should be on places where plates are located in ship
- Few centimetres to left or right compared to drawing
- Feedback about adjustments in production not adjusted in 2D drawings and 3D model
- Bending angle of pipe not same as drawing

**Plates**
- Holes in plates are bigger or smaller than shown on drawing (e.g. holes for stairs)
- Doors do not fit in plates
- Plates are too small for the profiles (material of plates was changes, ordering plates with different sizes)
- Windows in plates not on the same level in ship
- Plates are too big to put on ship
- Different packages of cutting files

**Equipment**
- Equipment does not fit on foundation
- Nobody knows if all equipment is ordered, party done by lead buyer, purchase.
- Different equipment delivered than ordered
- Equipment ordered used old drawing
- Equipment is there but drawings missing
- Materials not always shown on drawing or 3D model like screws, railing when build on different yard, this is also not ordered
- Bill of material information not up to date so wrong equipment is ordered
- Information copied from previous ship but not all information is adjusted for new ship with new equipment (new engines)
1. Wat op tekening staat is anders dan in casco
2. Motor stond te laag op fundatie voor de koppeling
3. Ballistische platen te zwaar om te hijsen
   Verschillende ballistische platen door twee pakketten aan snijfiles
4. Accu kon niet onder het console vandaan gehaald worden
5. Elektrische kabels te weinig vanwege verschillende system opties
6. Tijdens proefvaart koppeling in puin draaien
7. Motor fundaties niet op de juiste hoogte
8. Amox platen die niet paste
9. Paneeltje wat net niet lekker past
10. Casco bouwers hebben verschillen oplevering, pijpen zitten er bijvoorbeeld wel of niet in
11. Andere motoren waardoor die niet op de fundatie paste en er koelwaterleidingen zaten
12. Aanpassingen vanuit productie in tekening, maar worden niet aangepast wegens tijd, geld overwegingen
13. Leidingwerk was niet waterdicht
14. Equipment staat bij zelfde type boot op een andere plek
15. Volgen tekening precies maar staat iets niet goed op waardoor het in productie ook niet goed gaat
16. Logistiek vertraging van materialen en equipment
17. Vertrouwen op het 3d model
18. Details op tekening die niet worden gebruikt
19. Pijp een halve meter verschuiven terwijl daar een ander system zit
20. Er worden dingen aangepast of net iets anders uitgevoerd.
21. Er is iets niet duidelijk, dingen pakken net anders uit, we krijgen andere pompen binnen, fundaties gaan fout,
ja dat houd je niet tegen.
22. Pijpspoels passen niet past op de fundatie
23. Als er pijnspoelen niet kloppen, dat soort dingen, hoe kan dat nou wat is de bedoeling nou.
24. Componenten die binnen komen, niet weten waar die thuis horen
25. Als de fundatie niet klopt met de ship engineer afstemmen
26. Geen informatie of verkeerde informatie
27. Incomplete informatie, dus dan vraag ik een tekening op van een pomp, dan willen we gewicht hebben, capaciteit hebben, hoeveel draadjes er naar toe moeten, dat krijg je dan, maar niet waar de fundatie plaat zit
28. Part nummer in IFS verkeerd gezet.
29. Als er een probleem is in productie eigenlijk meteen aanpassen in de tekening
30. Dat is dan besteld door inkoop, maar dan is het de verkeerde
31. Als de ship engineer besluit er moet ergens een spant komen, en ik heb daar een pijp neergezet, dan moeten we dat wel met elkaar bespreken.
32. Even klepje in de wand moet open, anders kan je er niet bij, dat zijn hele praktische kleine dingen, maar dat zijn wel dingen die vaak fout gaan ook.
33. Vragen uit productie over casco bouwen, dan zitten alle doorvoeringen aan boord, dus koelwaterpijp moet van voor naar achter
34. Een voorbeeld piping die dwars door de wand heen gaat op kniehoogte in het model.
35. Dan zet ik dat in een lijst bijvoorbeeld ventilatie roosters. Dan zorg ik dat dat de volgende keer anders gaat
36. Groot gebrek geen feedback op tekeningen
37. Kleine wijzigingen: bouten, niet goede bouten, bematingen zijn niet goed materiaal niet goed, eigenlijk aan einde van project dus echt kleine details.
38. Daar komt een vloer in maar die is niet in polen gemaakt fundatie is wel al gemaakt maar die zitten niet op de goede plek want de platen die erin komen van die traan platen, die heb je in staal en aluminium.
39. Trapgat, in werkelijkheid most die kleiner zijn dan die op tekening staat, bij de 07 was het zo moesten zee een stukje in maken en nu was het weer zo. In polen hebben ze gewoon de tekeningen gevolgd, waar het dus wel nog fout op stond.
40. In elk project heb je dingen die niet goed zijn, dat er fouten in zitten, en met elke boot wordt het beter.
41. Het is hoog het waait, in theorie zou het kunnen maar als het waait dan waait de plaat er vanaf
42. Je kunt niet overall lassen. Dan moet je daar wel rekening mee houden dus dat hoort er ook bij
43. Excel lijst met afmetingen en die moet kloppen met tekening maar er waren wel veel dingen die niet klopte
44. Fundatie van de kast aanpassen, IFS nummer stond er niet wel in excel maar niet op tekening
45. Besluiten die genomen moeten worden duurt lang
46. Een andere is compleetheid of ja, de maten van hoeverre een pakket up to date is.
47. Er missen dingen, bijvoorbeeld een tekening, we hebben bijvoorbeeld een GA, een back arrangement, je gaat steeds diep op in, totdat je op een gegeven moment de fundaties enzo hebt.
48. In de constructieve tekeningen hebben we niet de dikte van de plaat meegenomen dus plaat was te dun
49. Stoelen zaten hoger dan de andere rij stoelen doordat fundatie verkeerd op tekening stond
50. De leiding zit hier niet goed
51. Kast onder de trap die daar weer weg moest kunnen bedacht door engineering maar moeilijk in de praktijk
52. Maar op tekening staat dus de fundatie getekend, maar er komt een hele andere in
53. Als er aanlopers zijn, dan veranderen die tekeningen
54. Stuurmachine compleet in het maagzijn liggen maar tekeningen zitten er niet tussen
55. Aanloper kan zijn dat engineering de fundatie waar iets op komt et staan komt uiteindelijk de equipment en die is in een keer een stukje groter, dat die er niet op past, waarschijnlijk oude informatie gebruikt
56. Feedback valt tussen wal en schip
57. Situatie awareness in huidige erp system lastig nummers zijn niet logisch
58. Kleinere dingen dan denken we van bekijk het lekker met je tekeningen we zoeken het zelf wel uit
59. Afgelopen 3 keer de stuurmachine van een supplier gekregen en nu is het van een ander.
60. Gaan er dingen fout, dingen zijn niet besteld als iets niet op tekening staat, dan wordt het ook niet ingevoerd.
natuurlijk

61. Want in het begin zijn er best wel wat dingen ontdekt zeg maar, wat je meteen in een begin stadium had kunnen veranderen, maar dat is nooit eigenlijk goed opgepakt, zelfde fouten

62. Ook als er veel mensen aan boord zijn of dingen die in het beginstadium mis gaan, verkeerde tekeningen, verkeerde spullen

63. Soms de nazorg, dat dingen in het system blijven staan omdat die niet goed worden weggeboekt

64. verschillende redenen of de leverancier heeft iets niet geleverd of het is in een verkeerder container gegaan

65. Engineering levert wel eens te laat op of verkeerde documenten.

66. Dat de parts niet juist gevuld zijn. Niet de juiste informatie in een part zit.

67. Niemand weet of alles besteld is

68. Ja de tekening moet gewoon goed zijn, maar wat is gewoon goed? Onjuist stuklijst, in technische tekeningen zitten altijd fouten

69. Structureel interference tussen verschillende systemen, een romp en outfitting systemen, de clash daar tussen

70. We storen een bak aan tekeningen over iemand heen en dan is het van succes he

71. Miscommunicatie, interpretatie verschil dan al lastig ja . dan zegt klant jullie zouden alles geven, ja maar die tekeningen maken wij nooit

72. Maar wat wel vaak naar voren komt zijn fouten op tekening

73. Vragen niet niet altijd beantwoord worden uit productie, duurt lang?

74. Daar zijn bepaalde afmetingen en gewicht van bepaald maar het kan zijn dat een andere werf daar helemaal niet mee uit de voeten kan

75. Wat ik zeg snijmachines zijn te groot of te klein, pipping machines om te buigen, dat zijn mallen maar soms hebben die een ander radius

76. Als wij die snijfile naar Amerika sturen en ze meten die daar op dan is dat 400*400 inch. Dus dat is lastig want wij werken in mm.

77. Als er een staalplaat mist dan moet dat op die lijst gezet worden en dat verwerkt worden zodat het er de volgende keer wel op staat

78. Ja daar gaat het vaak fout, dingen die niet opgestuurd in, of de verkeerde dat gebeurd nog als eens

79. Wij sturen alles op profielschetsen van alle profielen, om te laten zien van hoe werkt dat, hoe ziet dat eruit. Want dat weten ze niet

80. Verschil tussen 2d en 3d model

81. Productie net anders dan op tekening

82. En daar hadden ze de posities van gewijzigd en de krachten waren veranderd maar dat hadden ze niet doorgegeven.

83. Maar dan krijg je een tekening naar binnen gestuurd en dan staat er revisies, nou dan ben je eigenlijk al te ver in je werk om dat te kunnen veranderen

84. Andere equipment dan de vorige keer waardoor het lager niet past.
Top three errors or in Dutch “aanlopers” that obstruct the progress of building a ship.

Method
The aim is to get insights in situations where an error occurred that obstructed the development of a ship. Not only situation from development engineers and production employees are asked but also other stakeholders to get a better understanding of errors during the whole development process from different perspectives. During the development of a ship, multiple types of errors can occur. These errors have different factors that causes the errors. Below the process is explained how insights are gained about what type of errors occur, what the factors are that causes the errors and which of these factors are most obstructing for the progress of a project. This process consists of 3 steps (an adjusted from the Nominal Group Technique (NGT) is used from Deip et al. (1977)). The initial idea was to use the Nominal Group technique (NGT) from Deip et al. (1977), which means a session with different stakeholders from a project and then do a session as described below. The idea was to do a session but because of politics within the organization, some of the involved employees explained they would not be able to speak freely in a group, so I did the session on an individual basis. Purposive sampling is a non-probability from of sampling. The researcher does not seek to sample research participants on a random basis. The goal of purposive sampling is to sample cases/participants in a strategic way, so that those sampled are relevant to the research questions that are being posed (Bryman, 2012). I wanted to hear different perspectives on problems that occur during the project, that is why different project team members.

Step 1.
Three obstructing situations are collected from 11 different stakeholders (PM, planner, purchase, Eng ship, Eng mech. Production) in which error occurred, that obstructed the progress of building a ship. By asking what, why and how? Examples or obstructing events are described in the tables on the next page. In the first column, my interpretation of the errors is show, in the second column the causes described by the interviewees, in the third column the example is explained and in the fourth column the effect of the error is described.

Step 2.
For the three situations, defined: 1. Error category, error, description, appearance, data source, how reported, cause of error, source of error, implication scale, how handled, corrective action. See Excel file “MOST UP TO DAT RCA”.

Step 3.
Discuss list of factors with stakeholders and let them prioritize top three factors which are most obstructing/with a high impact (focus on production and development engineering) and ask why it is important fro them. This leads to factors that are most important for the different stakeholders to be handled with high impact.

Why do errors occur during the development of a ship?
Causes of errors during production:
• Production does not use information from engineering
• Information delivered by engineering not suitable for production
• Revisions in drawings from engineering not clear
• Wrong, missing, unclear or not up to date engineering information
• Wrong, missing, unclear or not up to date information delivered by supplier
• No standard way of delivering information by supplier (incomplete information)
• Late, no, wrong delivery of materials/equipment by supplier
• Different understandings of information
• Information systems that are not configuring with each other
• Not enough engineering capacity or time at start of a project
• Plan approval from internal/external client
• Rework of hull constructions
• No overview if all materials/equipment is ordered
• Slow reaction via email
- No standard procedure checking drawings
- No clear standards for commissioning
- Decisions not being made during the development of a ship
- Not enough knowledge about regulations and applying them
- Failure to fulfill commitments (missing deadlines)
- No capacity to process feedback from production
- Management does not update about process decisions
- Not enough knowledge about IFS system and its structure

Options for rating the categories
- Rate on a scale from 1 – 7

Causes of errors in production information:

Inconsistency of information sources
For example, between information displayed in the 2D drawings and the 3D model but also within the details of a drawing. This causes that wrong equipment is delivered or that production or foundations on the wrong place of have wrong height. Drawings might be updated but 3D model is not because it is adjusted by other engineers abroad.

Incompleteness of information
IFS is currently used to store drawings. The drawings and 3D model are dynamic and become more complete during the development of the ship. Vendor data, BOM in all phases of the process during the process information flow.

No having most up to date information available for task
The process of revisions and adjusting information takes time as multiple stakeholders are involved. Because of multiple reasons information should be adjusted (client request different, engineer adjustment, remark from production). Revisions to late, production already to far, engineers do not always fully know how far production is.

Mistakes in information delivered
A 2D diagram seems to be possible on paper but when a tasks needs to be performed by production it becomes much harder. This is cause by a lack of situational and task awareness both for engineers and production.

Different interpretation of information
Production interpretation of information different than engineering meant with it.

Feedback on information not processed
Feedback on information process to learn from mistake made in previous ships.

Why do errors occur during the development of a ship?
Inspired by human error theories in operational processes (INPO, 1985; Rasmussen, 1980), six categories are distinguished that will be used to understand human performance problems in the shipbuilding process. The six categories that are used are: (1) Human (failure to follow procedure), (2) Information (lack of knowledge and training), (3) Miscommunication, (4) Process (deficiencies in planning and scheduling), (5) Managerial (deficiencies in supervision) and at last (6) Standards and procedures (deficiencies in procedure or documentation). These categories are used as they are proven categories and other theories build on the findings (Reason, 1990). The six categories are used as a guidance to understand obstructing events described by the Damen employees. Quotes describe below are freely translated from Dutch to English by the researcher.

Error categories
The 70 situations, discussed in the interviews are explored to find the root causes of errors. These situations are caused
by 115 root causes (one situation can be caused by multiple root causes). The root causes are categorized into six main categories, based on the findings from the interviews and literature about errors in operational processes. The six sources of causes are Human, Information, Communication, Process, Managerial and Standards. Below the six categories are shortly explained. There are multiple other categories that cause have been analyzed, but for this thesis project I have restricted myself to these six as they will give sufficient input for improvement of the shipbuilding process of Damen. In Figure 1 an overview is shown of the categories, and sub categories.

**Incorrect management or supervision**
Deficiencies in managerial decisions about options in the ship. The planning of the work that needs to be performed, for example the hours spend by engineering.

“We asked for budget to be able to integrate the as build situation in the model as multiple ships are being build, but they did not approve. Besides this the product group does not make decisions about options which makes a mess of the 3D model” - P3

**Inappropriate process**
Deficiencies in the current process structure and how actions and tasks are performed.

“We made an agreement that engineers have to visit the ship at least once a week to discuss potential “aanlopers” as the engineering of the ship has not finished yet, we have to discuss solutions together” - P19

**Inadequate standards**
Deficiencies standards about what to do and how to do it. Standards are regulations, handbooks and rules. For example the procedure to check drawings.

“responsibilities for filling in IFS”

**Inadequate information**
Deficiencies in information content, which means that information shared among team members is incomplete or incorrect or outdated. Because of inadequate information, inadequate decisions are being made (Sassou and Reason, 1999).

‘mistakes cutting files, 1 into 2 tugs this happens, it needs to be galvanized, in hot and cold zink. It is solved but measure new once, make a modification sketch. Check situation on board, measure, draw new once that you need to production support. They come check and approve. Make them again. But you need new hinges, you cannot use these any more, that takes time. Depends on ship if it has Fifi or not but for sea chest you have 12 of them and depends Fifi class. But it is about checking the drawings.’ - P21

**Inadequate communication**
Deficiencies in communication between team members which means sharing information but with a time aspect.

‘Most important is to keep contact and share problems with engineering and come up with ’ - P19

**Human causes**
Human errors deals with human interpretation of information, the actions, skills and knowledge of individuals. (Ollikainen and Varis, 2006) discuss this issue and is on an individual level.
Figure 25. Categories and sub categories of errors
<table>
<thead>
<tr>
<th>Main category</th>
<th>Sub category</th>
<th>Explanation and examples</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Incorrect management / supervision</td>
<td>Deficiencies in decision making</td>
<td>Not making decisions or postpone them, not aware of effect of decisions on other systems</td>
<td>2%</td>
</tr>
<tr>
<td></td>
<td>Poor teamwork coordination</td>
<td>Not knowing if everything is ordered, no clear responsibility, no clear contact person, not know who has right information</td>
<td>3%</td>
</tr>
<tr>
<td></td>
<td>Inconvenient planning and control</td>
<td>Not adhere deadlines, which can lead to inadequate information. Not adjusting information.</td>
<td>8%</td>
</tr>
<tr>
<td></td>
<td>Revision process time consuming</td>
<td>No time, money, capacity to process adjustments, indirection communication makes process time consuming</td>
<td>3%</td>
</tr>
<tr>
<td></td>
<td>Delivering no/wrong materials/ equipment too late</td>
<td>Different equipment than needed or expected</td>
<td>3%</td>
</tr>
<tr>
<td></td>
<td>Work pressure, condition to perform tasks all departments</td>
<td></td>
<td>3%</td>
</tr>
<tr>
<td>Inappropriate process</td>
<td>Low priority for checking drawing, procedure</td>
<td>Procedure for checking drawings/3D model not always followed</td>
<td>3%</td>
</tr>
<tr>
<td></td>
<td>No clear agreements about what in 3D model or not, what information suitable for production, SEPI, different expectations about delivery (client and supplier)</td>
<td></td>
<td>4%</td>
</tr>
<tr>
<td>Inadequate standards</td>
<td>Incomplete content</td>
<td>Missing dimension in drawings, or in IFS, Information lost in system</td>
<td>9%</td>
</tr>
<tr>
<td></td>
<td>Incorrect content or documents (Not up to date)</td>
<td>Revision number incorrect, BOM not up to date, dimensions in drawings incorrect.</td>
<td>14%</td>
</tr>
<tr>
<td></td>
<td>Unclear and inconsistent content between information and documents</td>
<td>Which information correct, drawings or model? Not all drawings revised. Different cutting file packages.</td>
<td>5%</td>
</tr>
<tr>
<td>Inadequate information</td>
<td>Not update team members about revisions in documents or on board</td>
<td></td>
<td>5%</td>
</tr>
<tr>
<td></td>
<td>Information not available, too late/ not clear there to find it/multiple sources and time consuming</td>
<td>Time to adjust 2D and 3D time consuming.</td>
<td>7%</td>
</tr>
<tr>
<td>22%</td>
<td>Inadequate communication</td>
<td>No feedback; no feedback from engineering on feedback from production</td>
<td>Feedback previous project not processed, different tools being used (SnagR, PFLists/people have own lists) no problem reporting or adjusting, documentation of problems lost in system</td>
</tr>
<tr>
<td>-----</td>
<td>--------------------------</td>
<td>------------------------------------------------------------------</td>
<td>--------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td></td>
<td></td>
<td>No communication or adequate between systems (hardware and software)</td>
<td>IFS, AutoCAD and Nupas/Cadmetric</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>23%</th>
<th>Human causes (failure to perform tasks)</th>
<th>Incorrect application of rules or plans (rules based)</th>
<th>Applying tolerances, not following drawings, collisions in model not adjusted, IFS not filled in correctly</th>
<th>5%</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Actions made was not intended (skill based)</td>
<td>Copying information incorrect or incomplete, routine actions of engineers and production foremen</td>
<td>3%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Inadequate design (theoretical information hard in practice)</td>
<td>Practical skills of employees inadequate, deficiencies in practical knowledge</td>
<td>6%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Behaviour inappropriate, Equipment not ordered/lost/double, action intended but not achieved as knowledge is lacking (knowledge based)</td>
<td>Wrong interpretation of information, checking drawings hard</td>
<td>3%</td>
</tr>
</tbody>
</table>
### Appendix E. Keywords literature research

<table>
<thead>
<tr>
<th>What I wanted to know</th>
<th>Key words</th>
<th>Literature found</th>
</tr>
</thead>
</table>
|                                    | Interface engineering and production | Smulders, F.E. (2006)  
|                                    | Boundary objects                 | Carlile, P. R. (2002)  
|                                    |                                  | Carlile, P. R. (2004)  
| Knowledge exchange                 |                                  | Nonaka, I. (1994)  
| Awareness                          |                                  | Endsley (1994)  
|                                    |                                  | Dourish, P., & Bellotti, V. (1992, December)         |
| Mental models                      |                                  | Rouse, W. B., & Morris, N. M. (1986).                |
| Errors                             | Human errors                     | Sasou, K., & Reason, J. (1999)                        |
| Ship building                      | Shipbuilding process             | Evans, J. H. (1959)  
|                                    | Social process                   | Bruinessen, van T.M. (2016)                         |
|                                    | Lean product development         | Mascitelli, R. (2011)                                |
| Technology Acceptance              | Technology Acceptance model      | Davis (1989, 2000)                                   |
Appendix G. Topic guide

For the interviews with the different stakeholders, a topic guide was used. Semi structured interviews were conducted to be able to be flexible and respond to the direction in which the interviewee take the interview. But some guides is needed and I wanted to address topics as described below. For the different participants, the guide was slightly adjusted. This type of interviewing allows some room for the interviewee to pursue topics that they are interested in.

Topic guide

Introduction of my research (improve communication between production and engineers)

Background information about interviewee
- Name
- Job function
- How he/she got there
- What projects/teams
- Overview tasks

View on cross functional project team

Information exchanged between team members

Examples of errors in projects
- What?
- Who where involved?
- How detected?
- How solved?
- What caused the error?

Error classification, which is necessary for error prediction, can be done on different levels. Reason (1990) distinguishes three levels at which classifications are made: the behavioural, contextual and conceptual levels. These corresponds approximately to the ‘what?’, ‘where?’ and ‘how?’ questions about human errors.

How can errors be prevented?

View on communication between production and engineering
- How?
- How often?
- Satisfied with how it is going?
- What can be improved?
- In different project compared
- View on collaboration between production and engineering
- Important for you when working together with team members?
- Experience production abroad?
- How communication going with them?

Based on the topics described above, introduction questions were asked to be able to put the answers in perspective “please tell me about ..”. Follow-up questions were asked with the aim to let the interviewee elaborate on his her answer “what do you mean by..?”. Probing questions “earlier you said... Could you explain a bit more”. Specifying questions like “What did you do then?”. Besides these type of questions, structuring questions were used “Now I would like to discuss...”. During the interviews the interviewee was given the opportunity to reflect and amplify and answer by allowing pauses in the conversation.
Appendix F. Overview all interviews main research

Below the participant numbers and roles are described, interviewed during this project.

<table>
<thead>
<tr>
<th>Participant number</th>
<th>Role</th>
</tr>
</thead>
<tbody>
<tr>
<td>P1</td>
<td>Project Manager</td>
</tr>
<tr>
<td>P2</td>
<td>Project Manager Assistant</td>
</tr>
<tr>
<td>P3</td>
<td>Mechanical Engineer</td>
</tr>
<tr>
<td>P4</td>
<td>Mechanical Engineer</td>
</tr>
<tr>
<td>P5</td>
<td>Ship Engineer</td>
</tr>
<tr>
<td>P6</td>
<td>Ship Engineer</td>
</tr>
<tr>
<td>P7</td>
<td>PM engineering ship</td>
</tr>
<tr>
<td>P8</td>
<td>Production Foreman</td>
</tr>
<tr>
<td>P9</td>
<td>Production Foreman</td>
</tr>
<tr>
<td>P10</td>
<td>Material Coordination</td>
</tr>
<tr>
<td>P11</td>
<td>Purchase</td>
</tr>
<tr>
<td>P12</td>
<td>Project Planner</td>
</tr>
<tr>
<td>P13</td>
<td>Document Controller</td>
</tr>
<tr>
<td>P14</td>
<td>Director Production</td>
</tr>
<tr>
<td>P15</td>
<td>Project Manager Engineering Ship dtc</td>
</tr>
<tr>
<td>P16</td>
<td>Director Business Unit</td>
</tr>
<tr>
<td>P17</td>
<td>Engineer ship</td>
</tr>
<tr>
<td>P18</td>
<td>Production Foreman</td>
</tr>
<tr>
<td>P19</td>
<td>Project Manager Production</td>
</tr>
<tr>
<td>P20</td>
<td>Manager contracting yard support</td>
</tr>
<tr>
<td>P21</td>
<td>Hull Coordinator Galati</td>
</tr>
<tr>
<td>P22</td>
<td>External expert Hans Hopman</td>
</tr>
<tr>
<td>P23</td>
<td>PLM</td>
</tr>
<tr>
<td>P24</td>
<td>Contracting manager</td>
</tr>
<tr>
<td>P25</td>
<td>PF site team Vietnam</td>
</tr>
<tr>
<td>P26</td>
<td>PM engineering</td>
</tr>
<tr>
<td>P27</td>
<td>Yard Support drawings</td>
</tr>
<tr>
<td>P28</td>
<td>Alphatron</td>
</tr>
<tr>
<td>P29</td>
<td>BAM</td>
</tr>
<tr>
<td>P30</td>
<td>Fokker</td>
</tr>
</tbody>
</table>

Extra IT manager
Appendix H. Decision protocol

The decision protocol has been used during the midstream modulation sessions with the four participants.

Decision protocol

Opportunity - What are you doing?
Perceived state of affairs eliciting a response
Issue, problem, question, decision, occasion, advance, problem definition, problem statement.
How you think about an opportunity can open up or close down your reflection upon it.
- How is your project going?
- Describe an issue you are working on or thinking about right now?
- When did you first become aware of this issue?
- What made you become aware of it?
- Is there anything you are struggling with, or trying to figure out?
- What has happened since the last time we talked?

Considerations - Why are you doing it?
Selection criteria that can influence the response
Goals, values, criteria, factors, conditions, system conditions.
These can be material, social and human.
System conditions influence and are influenced by human decisions.
What is at stake and what can be done about it
- What is important for you to consider when responding to this opportunity?
- Why does your response to this opportunity matter?
- What is at stake here?
- Why is it done this way?
- What do you think about that? How do you feel about that?
- Why did you say that?

Outcomes - Who might care what you do and how you do it?
Effects of selecting alternatives in light of considerations
Developments, consequences, ramifications, effects.
Explicitly future-oriented and speculative.
Can trigger new reflections and additional considerations and alternatives.
Probe your expectations about which alternative you will choose, the short term effects, and who might be implicated in the longer term.
- What do you think you will end up doing?
- What do you think will happen?
- Who might benefit, who might be not?
- What concerns or complications might arise?
- Assuming you are successful, what do you imagine the long-term effects of this project could be?
- What if everybody in your field adopted the procedure that you are describing?

Alternatives - How else could you do it?
Perceived courses of action available for responding to the opportunity
Options, choices, responses.
Can be tactical and material (using a different chemical) or strategic and social (reformulating a mission statement).
List the normal options for responding and brainstorm alternative, novel responses.
- What options do you have for responding to the opportunity?
- Are there any other possibilities here?
- What else could you do?
- How would [somebody else] approach this problem?
- What if you chose to do nothing?
Main findings expert session

- Problem solving role engineer find out where problem is coming from and propose a solution to production, and capture the solution for the next ship, that it will not happen again. During production often first solution and afterwards as build situation drawn, otherwise one week further before drawing is done. Sketch often used.
- Feedback to engineering has different channels, via project manager, call engineer or visit engineer. When told to project manager does not always reach engineering.
- New PLM system, will it change the situation? How include information exchange explicit for PLM system?
- Communication is timing and content
- Progress report, pictures of section, who should see problems? Engineer of foreman?
- Observe what is the truth? Drawing, 3D model or the ship? It is about observing if the ship is correct or the drawing. There is a mismatch
- Scanning the ship and then 3D glasses
- Feedback from production, it would be nice to have one platform where all feedback from one project can be collected and should be processed before starting with new ship.
- Keep it visual
- Capture the problems is important and the next step, what is the follow up?

[O] Dat je het in beeld laat zien, het probleem dat als je het gaat beschrijven, dan krijg je interpretatie verschillen.

[O] dat gebeurd natuurlijk continu aan boord maar dan heel kleinschalig. Als er een systeem geroute is in 3D dan krijgen ze een pijpspoels van, dus standaard alle lijntjes en coördinaten erop, zo op het main deck met een pijp, materiaal erop dit en dat. Dan kunnen ze denken, ja dat is leuk maar het is toch niet zo handig, we gaan het een halve meter opschuiven, dat gebeurd gewoon weleens. Niet wetende dat daar een kabelbaan moet lopen eigenlijk.

The whole transcript of the expert session can be found in Nvivo.
Appendix J. Interaction diagrams
Information flow when foundation is incorrect in vessel, Gorinchem formal way:

1. Classification society
   - Makes decision about most appropriate solution
   - Send drawing

2. Project Manager
   - Exchange info about solution
   - Calculate and draw solution

3. Engineer
   - Visit the ship together and discuss alternatives and considerations
   - Send drawing to yard

4. Production foreman
   - Sees on board that foundation is not right
   - Can adjust solution

Information flow when foundation is incorrect in vessel, abroad formal way:

1. Engineering NL
2. Project manager NL
3. Site team Galati
4. Project Manager Galati
5. Ship coordinator
6. Production foreman

- Calls PM and Eng to visit ship
- Visit the ship together and discuss alternatives and considerations
- Send drawing to yard
- Can adjust solution

- If site team does not know answer, Netherlands is being contacted
- Time consuming process

Information flow when foundation is incorrect in vessel, abroad formal way, when site team does not know answer:

1. Engineering NL
2. Project manager NL
3. Site team Galati
4. Project Manager Galati
5. Ship coordinator
6. Production foreman

- Calls Ship coordinator explain problem
- Send drawing to yard
- Can adjust solution

- If site team does not know answer, Netherlands is being contacted
- Time consuming process

- Calculation
- Solution
- Drawing
- Approval

- Project
- Manager
- NL
- Coordinator
- Engineer
- Production
This is a general and simplified overview, there are variants on this process for projects.

Missing drawings in system - wrong information copied form previous project - design not suitable for production - information from supplier old, or supplier uses old information - information not complete - different details in drawings

Late or no communication about revisions between actors (revisions because of regulation change, request from client, supplier delivery) - Information adjustments inconsistent between different drawings - no discussion if adjustment can be done - Information different in 2D drawings and 3D model
Questions not being answered or too late, officially no direct communication between engineers and production to answer questions

As-build information not saved or changed in 2D/3D model, feedback previous ship not taken into account for next ship or lost in system
## Appendix K. Communication means

<table>
<thead>
<tr>
<th>Type of interaction</th>
<th>When used</th>
<th>Positive</th>
<th>Negative</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Video conferencing</strong></td>
<td>Production meetings with multiple actors (PM, MC, PF, PME) to discuss progress Structural and formal. Once a week or two weeks depending of stage of project</td>
<td>- Direct, real time interaction - Multiple actors involved - Can see the face of the other person - Direct feedback between engineering and production - Non-verbal communication possible</td>
<td>- Multiple actors involved, chaos - Needs to be arranged - Time difference is challenging</td>
</tr>
<tr>
<td><strong>Skype for business</strong></td>
<td>One-on-one communication between actors when a problem occurs or to inform other Structural or ad hoc Once a week or two weeks depending of stage of project</td>
<td>- Direct, real time interaction - One-on-one contact - Chat function also can be used - Non-verbal communication possible</td>
<td>- Direct interaction - One-on-one contact - Time difference is challenging</td>
</tr>
<tr>
<td><strong>E-Mail</strong></td>
<td>One-on-one communication between actors when a problem occurs or to inform other Ad hoc questions, and to share progress reports Multiple times per week</td>
<td>- Can share pictures of the ship - Have information black on white - Sender and receiver can think about answer on question</td>
<td>- Indirect interaction - Chance on miss-interpretation of question/information is high - Sender depends on receiver when a reaction comes - No direct feedback between actors - Engineers complain too many emails</td>
</tr>
<tr>
<td><strong>Calling</strong></td>
<td>One-on-one communication between actors to discuss questions or to inform other Ad hoc questions one-on-one Multiple times per week</td>
<td>- Direct interaction - One-on-one contact - Personal - Quick problem solving - Consultation between actors</td>
<td>- When explaining something not having a visual with it, no awareness of problem, depending on knowledge of actors - Time difference is challenging</td>
</tr>
<tr>
<td><strong>Face-to-face</strong></td>
<td>One-on-one or multiple communication between actors to discuss questions and give updates, informal Ad hoc questions one-on-one One few times per project (1-3 times)</td>
<td>- Can make small sketches and discuss solutions - Two persons look at the same (same awareness) - Social presence, non-verbal communication possible - Important for lowering boundary between actors - Direct feedback between actors</td>
<td>- When geographically separated impossible to have face-to-face interaction often</td>
</tr>
</tbody>
</table>

*“Dat in ieder geval een keer in de zoveel tijd en via skype. Skype 1 op 1 is veel makkelijker dan een conference call. Als je met een groep mensen zit gaat iedereen roepen en dan wordt het chaos.” - Engineer 4*
Conclusions

Should be used structurally between engineering and production to be able to discuss potential problems in the future, instead of only getting feedback when problems occur.

It is also useful to discuss ideas by engineering if they are okay for production and if solutions are accepted by the Project Manager.

Quotes

“En toen heb ik het overgenomen, en dan zijn we bezig met engineering om de laatste details uit te brengen. Elk kabeltje wordt nagekeken, die dingen. En dan productie begeleiden of helpen waar nodig is. Dat is eigenlijk hoe het is. En waar dan het strakke communicatie belangrijk is vind ik dan persoonlijk is wij zetten dingen op papier, wij kunnen dingen uitvinden, maar wij weten eigenlijk vaak dat productie die weert het ook even goed hoe ze het echt dingen tot in detail kunnen gaan afwerken en dergelijke.” - mechanical engineer (p3)

“videoconferencing alleen als er problemen zijn, dat zou een vast ritueel moeten zijn, ook over dingen die goed gaan, als er iets een klein beetje fout gaat dat daar feedback van komt.” - Ship engineer (en1)

With a language barrier communicating via Skype is hard, but it is useful to have one-on-one communication between engineering and production.

“just to see eachothers face” - engineer 3

“[D] Hoe krijg je zo een vraag dan?
[PF2] via de mail of via Skype. We Skype elke week twee uur en gewoon om elkaars gezicht even te zien, dat is altijd fijn dan via de mail. En de rest gaat via de mail. - mechanical engineer (p3)

Als we tijdens engineering iets moeten veranderen dan moet ik eerst een mailje typen, afbeelding erbij, schetsjes dit en dat. Als ze hier zitten loop je er even langs, dit en dat dit is de bedoeling hup gedaan. - mechanical engineer (p4)

Sending an email is useful for complex problems but it can cause misinterpretation easily. Email should be combined of a follow up of a one on one meeting between engineers and production.

Too much emails are send with many person in the cc

Pictures can be shared via email which is useful.

“En dan vraag ik altijd naar je nog updates, nog dingen waar je tegenover loop? En problemen. Nou en hij maakt heel veel dus ik ben wel op de hoogte van hoe de schepen eraan hoe zijn. Ze doen alleen maandelijks een foto reportage sturen. Ik ben zelf van mening dat het eigenlijk wekelijks zou doen, dat je dan veel meer ziet, maar ik doe het zelf wel wekelijks hier, zij doen het dus maandelijks. Maar dat is de afspraak die staat en nou daar kan ik wel duidelijk in zien wat daar gebeurd.” - project manager (p1)

“Communiceren, blijven communiceren en praten zodra je niet meer met elkaar praat past het mis. Als je niet openstaat voor elkaars opmerkingen en kritiek, dus bellen en email. Ik kan een aardige mail sturen of een hele onplezierige.” - production foreman (p18)

Direct communication lines are needed for quick problem solving and getting feedback.

The problem with calling is the lack of visual interaction explaining a problem it is hard over the phone as an engineering and production have different mental models.

[1-DW] heb je verbeterpunten voor communicatie tussen productie en engineering?
[PF9] Ja wat ik net zei, dat engineering wat meer op de werkvloer komt, niet dat ze bellen, maar dat ze zelf een bepaalde ronde doen. Dat is wel het belangrijkste want theorie en praktijk is toch heel verschillend.

[g] en wat is het voordeel daarvan?
[PF2] dat je meteen dingen kan oplossen,
[en2] je kijk samen naar hetzelfde, je krijgt niet een mailtje of iets
[PF2] je kan het ook makkelijker uitleggen,

Essential to get to know eachother, knowing eachother lower the boundary to communicate, give feedback and ask questions between actors.

Possibility to share sketches, problems are solved based on sketches and revisions often.

“En dat je geen dingen en op moet, wat je heel vaak ziet dat als er iets mis is op te tekenen, dan komt de voorman naar engineering toe en de vraag: Hoe gaan we het oplossen? En op engineering maken we een schetsje van nou dat wezen zo op en ze gaan ze door. Als je dan een werf op een andere locatie hebt, dan gaat dat via de mail.” - Ship engineer (p6)

* Ja die terugkoppeling blijf ik wel vragen, doordat ik elke keer aan boord ga en vraag: lukt het?
Als je dat vraag zeggen ze altijd ja ja ja ja, en als ik dan vraag: en hoe zit het met dat? Dan zeggen ze ah wacht kom even mee. Ze zeggen altijd ja ja ja maar als ik dan specifieke vraag, want vaak weet ik waar het pijn gaat doen bij productie, van lukt het daar? Dan zeeggen ze van jaa nou dit en dit en dit. En dan pak ik dat wel mee ook. - mechanical engineer (p3)
Appendix L. Scope cyber to reality

Virtual Reality

- IVR: Immersive Virtual Reality
  - Facilitate collaboration of multiple co-located or dislocated people
- SIVR: Semi-immersive Virtual Reality
- HIVR: Hybrid Immersive Virtual Reality
- NIVR: Non-immersive Virtual Reality

Augmented Reality (AR)

Mixed Reality (MR)

Reality

- Reality (virtually shown)
- CAVE
- HMD (Head-Mounted Display)
- SCREEN/WALL
- WEARABLES
- DEVICES
- (360) VIDEO
- 3D LASER SCANNER

Cyber

- CAD model
- Replace our view of the real world with computer-generated images inside the virtual world

Virtual

- Virtual Presence
- HMD (Head-Mounted Display)

Reality

- Reality (virtually shown)

MR & AR

Augmented Reality and Mixed Reality

Leave the user visually aware of the real world, observe the virtual world through some devices.

Virtual Presence

Reality

Cyber

CAD model

Replace our view of the real world with computer-generated images inside the virtual world.

Appendix L. Scope cyber to reality
Appendix M. Morphological chart

A morphological chart is developed to make sure different solutions are explored for the communication methodology. First information forms, communication methods and collaboration tools are explored based on literature, afterwards input from the sessions is added.

Information types that help shaping a shared situational awareness between team members that are distrusted. Based on Sonnewald (2004) about virtual collaboration between scientists. Interpersonal information exchange. Collaborate face-to-face or remotely to get a shared understanding of the current situation. Collaboration, by definition, is a process of assembling knowledge from different parties towards a common goal. Tables below are based on Endsley and Bolstad (2003) and are adjusted. Social emotional and contextual information are harder to communicate than task and process oriented information.

<table>
<thead>
<tr>
<th>Information type</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Social emotional information</td>
<td>Interpersonal information:</td>
</tr>
<tr>
<td></td>
<td>- Skills - Work styles - Personality - Emotional state - Attitudes</td>
</tr>
<tr>
<td></td>
<td>(tensions, frustrations, disagreement, feedback, questions, jokes,</td>
</tr>
<tr>
<td></td>
<td>enthusiasm)</td>
</tr>
<tr>
<td>Contextual information</td>
<td>Framework for understanding:</td>
</tr>
<tr>
<td></td>
<td>- Culture - Goals - Expectations - Routines</td>
</tr>
<tr>
<td>Task and process information</td>
<td>Who, what, where, when, how tasks performed:</td>
</tr>
<tr>
<td></td>
<td>- Tasks currently performed</td>
</tr>
<tr>
<td></td>
<td>- Problems that occur</td>
</tr>
</tbody>
</table>

Table 2: Information types that are shared during the shipbuilding process

Forms in which information can be shared called communication between engineers and production.

<table>
<thead>
<tr>
<th>Communication form</th>
<th>Sender</th>
<th>Receiver experience</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Verbal, speech, Audio</td>
<td>Speak</td>
<td>Listen</td>
<td>Calling, face-to-face</td>
</tr>
<tr>
<td>Textual, written</td>
<td>Write</td>
<td>Read</td>
<td>Emails, drawings</td>
</tr>
<tr>
<td>Photographic, visual image</td>
<td>Take picture</td>
<td>View</td>
<td>Take pictures daily progress</td>
</tr>
<tr>
<td>Video</td>
<td>Take video</td>
<td>Watch</td>
<td>Recording millstone activities</td>
</tr>
</tbody>
</table>

Table 3: Communication forms that can be used

Communication characteristics; formality, time, predictability, frequency, place, interaction. These characteristics influence if collaboration between team members is possible.

<table>
<thead>
<tr>
<th>Communication characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Formality</td>
</tr>
<tr>
<td>Time</td>
</tr>
<tr>
<td>Predictability</td>
</tr>
<tr>
<td>Place</td>
</tr>
<tr>
<td>Interaction</td>
</tr>
<tr>
<td>Frequency</td>
</tr>
<tr>
<td>Direction</td>
</tr>
<tr>
<td>Recordable/traceable</td>
</tr>
<tr>
<td>Identifiable</td>
</tr>
<tr>
<td>Structured</td>
</tr>
</tbody>
</table>

Table 4: Communication characteristics
Collaboration tools categories. Only face to face communication and collaboration is not technology mediated.

<table>
<thead>
<tr>
<th>Collaboration tools category</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Face-to-face</strong></td>
<td>For a perfect collaboration environment, individuals should be collocated and can share any type of information</td>
</tr>
<tr>
<td><strong>Telephone</strong></td>
<td>Simple from of audio conferencing, often between two people (interpersonal), not possible to share information</td>
</tr>
<tr>
<td><strong>White board</strong></td>
<td>Collocated, of take picture of it and share distributed. Place where multiple used can care diagrams, drawings. Screens can be synchronized</td>
</tr>
<tr>
<td><strong>Video conferencing</strong></td>
<td>Computer network between two or more persons needed at different locations. Audio and visual information is transmitted. Remote locations(Dourish&amp; Bly, 1992; Fish, Kraut, Root, &amp; Rice, 1993). Video-conferencing includes continuously updated visuals of collaborators, diagrams, physical objects, or computer screens. Examples of video-conferencing are group video-conferencing in dedicated rooms and desktop video-conferencing[4]</td>
</tr>
<tr>
<td><strong>Audio conferencing</strong></td>
<td>Two or more persons connected, communicate via audio. Happens that people talk at the same time. Examples of audio conferencing include phone calls, conference calls, or conference calls where people are also sharing views of images or documents.[4]</td>
</tr>
<tr>
<td><strong>Chat/instant messaging</strong></td>
<td>Real time interpersonal communication, often two people</td>
</tr>
<tr>
<td><strong>File transfer</strong></td>
<td>Transfer files, drawings or pictures via internet.</td>
</tr>
<tr>
<td><strong>Email</strong></td>
<td>Transmission of message, between two people or multiple people with asynchronous message. In Damen used to conform agreements made over the phone.</td>
</tr>
<tr>
<td><strong>Program sharing/ application sharing</strong></td>
<td>Shared applications allow remote team members to work together synchronously on an object such as an electronic document, electronic white board, concept map or database (e.g., Roseman &amp; Greenberg, 1996).</td>
</tr>
<tr>
<td><strong>Shared repositories and workspace</strong></td>
<td>Data stores that allow group members to view and update shared work objects, such as scientific data, research notes and documents (e.g., Fowler et al., 1994; Kovalainen, Robinson, &amp; Auram€aki, 1998)</td>
</tr>
<tr>
<td><strong>Collaborative virtual environments</strong></td>
<td>Collaborative virtual environments (CVEs, such as multi user dungeons(MUDs) and MUD object oriented system(MOOs), offer virtual spaces in which team members are represented by avatars (graphical icons) and can communicate synchronously, often through text-based applications, e.g., instant messaging applications (e.g., Churchill &amp; Bly, 1999).</td>
</tr>
<tr>
<td><strong>Collaborative wearable tools</strong></td>
<td>Combination of multiple persons, audio and visual communication possible, just like sharing information real time. One person can walk around while others behind desk</td>
</tr>
</tbody>
</table>

Table 5: Collaborative tools
Input for morphological chart from expert session (two papers below) and input from focus group (on top)
<table>
<thead>
<tr>
<th>Functions:</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Detect the real ship</td>
<td>3D Scanning of ship</td>
<td>Take picture with phone</td>
<td>Drone camera</td>
<td>360 pictures real ship Go Pro Omni</td>
</tr>
<tr>
<td>Compare real and 3D model</td>
<td>With drawings on ship</td>
<td>3D scan and 3D model</td>
<td>Hololens (Volvo)</td>
<td>Fieldbit</td>
</tr>
<tr>
<td>Report and collect errors</td>
<td>Checklist</td>
<td>IFS</td>
<td>Excel list</td>
<td>Online project management tools</td>
</tr>
<tr>
<td>Communication engineer and foreman</td>
<td>Facetime</td>
<td>Calling</td>
<td>Chat</td>
<td>Virtual environment</td>
</tr>
<tr>
<td>Visualize 3D model</td>
<td>AR ship on paper 3D model</td>
<td>VR</td>
<td>HMD Cave</td>
<td></td>
</tr>
</tbody>
</table>
AlphaEye, compare 3D model and video conferencing

Current ways of detecting, indicating and correcting errors
Take picture with mobile phone or camera, put it in snagR and send email
Main findings focus group  
“We have to do it together”

When working with a yard abroad standard boundaries are encountered like:

- Culture difference
- Geographical distance
- Language difference
- Time difference
- Not understanding each other

PERSONAL LEVEL:

- Level of flexibility of individuals to anticipate to changes
- Responsibility that is given and that is taken by individuals
- Attitude of individuals proactive versus reactive
- Knowing what other needs (experience of engineer to know what production needs) practical knowledge and experience of engineers is less
- Decision making
- Follow rules of the boss or think for yourself
- Involvement of individual
- Priorities of individuals

<table>
<thead>
<tr>
<th>Enablers</th>
<th>Barriers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Short, direction communication lines</td>
<td>Hierarchy in the organization leading to indirect communication lines (time consuming)</td>
</tr>
<tr>
<td>Share all information and explain</td>
<td>Only instructions given by boss</td>
</tr>
<tr>
<td>Why something is done in a certain way</td>
<td>Only formal communication</td>
</tr>
<tr>
<td>Informal communication</td>
<td>Wait for orders</td>
</tr>
<tr>
<td>Pull information by prod</td>
<td>Everything should be black on white nothing without drawing</td>
</tr>
<tr>
<td>One-on-one communication</td>
<td>Fear for being punishment and making mistakes</td>
</tr>
<tr>
<td>Feedback</td>
<td>Fear of taking responsibility</td>
</tr>
<tr>
<td>Sketching is enough</td>
<td>Money to adjust drawings, official way of communication</td>
</tr>
<tr>
<td>We are equals</td>
<td>Knowledge of employees not fully used in production</td>
</tr>
<tr>
<td>Face-to-face communication is essential</td>
<td></td>
</tr>
</tbody>
</table>

Main takeaways:

- Every production employee should have access to the 3D model
- We have to do it together
- Giving responsibility creates involvement
- Knowledge of engineers not practical anymore
- Casco check is an critical moment during production (Accepting a casco quality influences outfitting phase)
- Vision from the board is needed, standard with PLM or not and build ships in production
Appendix O. Findings usability tests

What was needed for the session:
- Computer is needed at engineering side
- Software to create a session (and accounts)
- Software in which session takes place
- There was a connection with a computer (hardware)
- The computer connected to the production side
- Wifi connection needed
- Firewall problems could have occurred with testing
- A session needed to be created up front
- The whole session could be recorded

Production side
- Production foreman should be able to start the session
- Production foreman should be able to make pictures and send them to engineering immediately
- It is not allowed to walk with glasses like that on board of the ship
- With head mounted, it was hard to focus the camera to the right position

Screen sharing
- The screen was to small at the side of the foremen could not see the details on the screen
- There was a chat function but the foreman could not read it properly

Engineering side
- Engineer should be able to share drawings
- Engineer should be able to share print screens of the 3D model
- Now there is a noise cancellation at production side which does not make the environment too noisy.
- Engineer was pointing at the screen to explain something to the foreman, but the foreman could not see this, these type of interactions are

Information exchanged should be captured
- The information that is exchanged like pictures made, sketches shared they need to be captured at a central point after a session
Technical points of improvement
- Phone or table would be preferred as alternative tool for production.
- Do not see where camera is, because it is on your head, hard for production foreman to point at right place.
- The tool depends on a working internet connection, the question is if it will be possible to use the tool if the foreman is working on a really big ship.
- Screen was small at Foreman side and could not see information.
- With the system used for prototyping, an engineer should create a session up front, which means that ad hoc interaction is not possible.
- If files should be shared during a session they needed to be uploaded in the software up front, when getting questions it is hard to know what information will be needed.
- The most important part is to capture and store the pictures made during the session.
- The visuals were moving a lot when the foreman is moving.

Economical considerations
- The device is expensive, a tablet of phone with Skype might do the same

Social Considerations
- Engineers and production foremen should both be willing to use the device
- Engineers and production should have time to have real time interaction.
- The product is big and others will see you walking with it.

Observations
- Internet/3G/4G/Wifi connection is needed
- The exchange of documents was not working completely, documents needed to be improvement in the software up front
- You do not want the whole session recorded, only the final outcome should be captured. These are small innovations that can improve the quality of the ship.
- Taking pictures and sharing them took quite some time
- It was not managed to share drawings back
- The video was moving a lot when the engineers is walking

Conclusion: The AlphaEye is an expensive device compared to having a tablet or phone with Skype for business. The added value of the head mounted device was not clear over having a mobile phone with Skype to have video communication.
Appendix P. Business case for pilot test

This research is mostly about intangibles values like mutual responsibility, commitment and shared understandings and awareness of engineers and production foremen. It is hard to express these intangibles values in money, which makes it difficult to calculate the estimate the Return of Investment of the proposed solution, but an estimation can be made on the costs.

Costs for Damen when staring a pilot test at a yard

In this scenario the cheapest solution is proposed for doing a pilot test for a first of series or a standard ship that is being build on a remote yard. Depending on the complexity of the solution being implemented, the cost price on one ship is:

<table>
<thead>
<tr>
<th>Getac tablet (break-proof) 3G version</th>
<th>Costs $ 1799,- 1.</th>
</tr>
</thead>
<tbody>
<tr>
<td>- eBorwser (possible on Windows tablet)</td>
<td></td>
</tr>
<tr>
<td>- Skype for business</td>
<td></td>
</tr>
<tr>
<td>- Outlook</td>
<td></td>
</tr>
<tr>
<td>- SnagR (now)</td>
<td></td>
</tr>
<tr>
<td>- IFS</td>
<td></td>
</tr>
</tbody>
</table>

For a network connection there are three main options: In appendix P the three options are discussed.

1. The device as a 3G/4G internet connection
   + No dependency on Wifi connections
     - Device is needed and a SIM card for every device
     - Not clear if connection will work in big steel constructions
2. There is Wifi at the yard or
   + One solution for multiple ships
     + Future proof solution
     - Not clear if Wifi connection can reach to the core of the ship
     - If all production employees have access to Wifi, the may get distracted form their work
3. Wifi is installed on every ship during the new building process.
   + Know there is a Wifi connection
     - Invest in separate Wifi units for every ship

Based on the pros and cons, it is recommended to invest in Wifi at new build ships.

| Wifi at new build ship (per ship) | € 500,- |

Why should we invest now?

For production it is essential to have most up to date information and to act quickly. Interaction with engineering is needed during the production support. Costs of errors can be reduced. Of a network connection there are three main options:

Appendix Q. Personal evaluation use MM sessions

This is the first time MM is used as a method in the design process. Attention will be paid to the methods used during the research and in particular the method of Midstream Modulation (MM) as a method in the design process.

MM method applied in design process
In this section I will reflect on the application of MM during the design process. I started the project with the goal to improve the communication between engineers and production. I did know anything about shipbuilding, so I wanted to use these sessions first the get an idea about the shipbuilding process.

The upstream vs downstream perspectives
During the MM sessions it becomes clear that the solution that is proposed will not prevent errors, but is more a fire fighting solution when errors occur. When conducting with the client, they want a fire-fighting solution instead of a real solution for problems that occur during the production of a ship. As a research I was in between these two perspectives.

Results of the sessions were not explicitly presented to the participants, for further research this should be done to actively let participants see their input in the process. I had hard times in communicating how their input steered my project. For me it was looking how the data gathered could be communicated back to the participants, only at the end it became more clear how my project was steered by them. Looking back at the process, findings from the meetings should have been shared immediately with the participants.

There as not been a pilot test with decision making protocol, in the design process. This would have been better to understand the process of such sessions. Beside this checking quotes with interviewees would have been better for the reliability of the quotes. It is necessary after an interview immediately take a moment to work out the session and send the results to the participants.

Experience of Midstream Modulation in the design process
For designers new way of working to fully involve stockholders in the design process, scary process, give them part of ownership of the design. At start of project did not fully understand this, to give them more ownership, more times should be needed to meet with them. Besides this for all parties it should be clear what the idea is behind the meetings, so actively involve them in the design process. I did not articulated this explicitly as it was also quite unclear for myself at the start how MM could be used in the design process. This would help both the participants and the designers to clarify that input actively will be used. It is hard for a designer in the fuzzy front end of a project to be able to articulate what the aim is of the project. On the one hand MM could be an interesting method to steer the direction of the research, but is can also be confusing for the participant who are not used to work on “wicked and ill-defined problems”. Influences of managers who are not part of the MM session but also want to steer the direction of the research.

At the start of the research, the researcher was not familiar with the method which caused some uncertainties on how to apply the method in the research. The key was just go in the field, ask if it would be possible to involve them in my research as they are experts and I want to learn.

The next step was to define who should be involved with a higher interaction. Two engineers and two production foremen are involved as the research topic is about the collaboration between engineering and production. As the research is about innovating the current communication process between engineers and production, the four employees should be willing to think along.

By the dialogue part of ownership is shared.
Create an environment in which feedback can be given. During the sessions the researcher tried to create an environment in which the participants are able to speak freely. The researcher was open for feedback. MM means giving away a part of the ownership of the solution and the researcher needs to give away a part of the control which is uncomfortable. This is hard to describe how much ownership is shared, as this is a research project the researcher worked full time on, while
the four interviewers are only involved a few times.

Outcome incremental innovations

One of the engineers described that it is hard to think how the job can be done differently as they just want to build ships. Their goal is to build a ship, not to redesign how they do it. During the research the four employees discussed their daily work and they reflected from their perspective if they would use it. Interesting to is that ‘this is the future’ is mentioned but on a short notice they do not see much changing in their way of working. When asking about the future they also have difficulties To visualize it different from it is now. This makes it hard to develop radical innovations with the method. As the employees think in their day to day tasks and radical innovation that have a big impact on their way of working are not seen as feasible. Discussing day to day constrains also restricted the researcher to think on the long term, which is actually needed for innovation. By means of midstream modulation in the design research, more incremental innovations will be supported. These innovation lies more closely to the daily life of the four participants. More radical innovation are seen as “the future” but the way of working will not change much in the coming years, and money should be invested to enable these innovations.

Relationship between researcher and the four participants - influence of opinion on researcher

Influence of one of the four, has a strong opinion about what the real problem is which will not be solved with a communication process and tool, but it is more about the culture of the organization. This influenced the researcher influenced confidence of the researcher. Over time the researcher and the four employees started to know each other. It was an advantage to build a relationship with the two production employees that they are from the same area. This made it possible to create a common ground. A few questions should be asked up front before deciding to involve participants.

MM is hard to use in the idea generation phase

MM sessions not used as a method to generate ideate in the ideation phase. Only to discuss ideas and the alternatives considerations it was hard for the employees to think of alternative ways of working compared to their current way of working (I don’t know..). Here the different mindset of the researcher and four participants became clear. They don’t know what is possible outside their way of working as they used to do it. This is something that became clear during the MM sessions. Social, technical and economical considerations described. Interesting considerations are discussed like the ways of use, people see you walking with it and it should always work.

MM as a method in the design process compared to other methods

The method of multiple interaction and facilitating a repetitive dialogue between the researcher and four participants. The added value of using MM in the design process that it is a real reality check during the research process. Disadvantage is that a research is influence highly by the participants chosen at the beginning of the research. As there were no clear guidelines for using the method in the design process it was a search on itself to explore how the method should be applied during the design process. Based on this research some guidelines could be formulated for other researchers decide to use the method during the design process;

1. Clearly state objective when approaching participants: you are expert I want to involve your situation. Together with you find out problems and how these can be solved. “you are the expert and I want to work with you to find out what you really need”.
2. Develop criteria for sampling: how do you know you have ‘right people’? Look for participants who are open innovation and willing to reflect on their current situation. Before starting the MM session questions can be asked to check their attitude towards innovations with questions like: To what extend are you open to new innovations?
3. Share the results after every session with the participants.

Comparable methods are context mapping and participation design. Midstream Modulation is a longitudinal method, during the sessions it was possible to refer back to previous sessions, the researcher also attended production meetings, so observations from these meeting could be discussed during the MM sessions. Observations could be validated with the participants.
Some critical notes on the application of MM by researcher

The trustworthiness of qualitative research is influenced by the bias of the researcher. Below some critical notes are described of the execution of the method by the researcher.

- At the start the research did not understand the method completely which leads to a search of how it should be applied. A pilot with the method should have been conducted to be able for the researcher to understand the method from the start.
- Six sessions are hold with the different participants. Flipse and Fisher used 12 sessions, this is something that should be recommended if another researcher will use the method in the design process, it is time consuming but the ownership will be bigger of the participants and a more in depth understanding will be created.
- The sessions were not only about the interaction but also about getting to know the context in which the interaction takes place.
- The decision protocol by Fisher has been used as a guidance but the researcher did not follow the protocol completely.
- The midstream modulation session helped me in getting a better understanding of the interaction between engineering and production compared to just interviewing interviewees one time.

Participant selection

Four participants are more involved in the process, give them part of ownership but was hard, they think on different level in their daily routines. This was a hard question for the research, the criteria were at least 2 foremen and 2 engineers. Preferably a younger employees. The problem was that foremen have a lot of experience and are older. For younger employees, shop floor employees should have been asked but they do not have much contact with engineering so this was a consideration made by the researcher.

Further research

Further research is needed to evaluate the application of Midstream Modulation as a method in the design process. There are multiple factors influencing the application and usefulness of the method in the design process. The interpretation of the researcher of the method, the type of design project and the type of participants that have been chosen all influence the added value of the sessions on the design process. This was just a case study of applying MM as a method in the design process.
Appendix R. MM sessions

In this section some reflexive narratives are discussed form the Midstream Modulation sessions, these are just some examples per participant. All the transcripts and quotes can be found in Nvivo.

<table>
<thead>
<tr>
<th>De Facto modulation</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>De facto means identify aspects that significantly influence participants’ work. Asked participants how decision are made, in projects. Participants identify specific influences on their work.</td>
<td>En waar dan het stukje communicatie belangrijk is vind ik dan persoonlijk is wij zetten dingen op papier, wij kunnen dingen uitvinden, maar wij weten eigenlijk vaak dat productie die weet het ook even goed hoe ze het echtdingen tot in detail kunnen afwerken en dergelijke, dus ik probeer daar dan wel enorm veel te gaan navragen van hoe deden jullie het in het verleden? Want ik kan het wel zelf gaan bedenken, er 8 uur insteken om het op papier te zetten, maar als productie zegt van hé [Naam participant] maar waar kom jij nu mee. Ik smijt het over boord en we doen het gewoon zoals het altijd doen. Dat zou ik zonde vinden van het geld dat we erin steken voor het ontwerpen. - P3 interview #1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Reflexive modulation</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reflective modulations are signs of recognition that specific de facto influenced work in a specific way. These reflections can be initiated by the interviewer of by the participant themselves. Words that indicate a reflection are:</td>
<td>I-DW] Hoe komt dat dat zij er zo over denken? [P-TM] Ja dat weet ik niet, dat kan ik me ook niet voorstellen omdat ik zelf zo niet ben. Ik sta te popelen om elke keer aan boord te gaan. Ik kan er geen verklaring aan geven</td>
</tr>
<tr>
<td>“I am not sure..”, “I think that maybe..”, “I would say..”, “I am not sure but..”</td>
<td></td>
</tr>
<tr>
<td>Awareness of one’s own - Values, assumptions, and thought - Interactions within larger social systems - Decision making</td>
<td></td>
</tr>
</tbody>
</table>

Participant 3
Participant 3 is Project Manager Engineer Mechanical and worked on multiple projects during the project.

Frustrations
- No proactive communication if deadlines not held
- If decisions are not being made by the Project Management or the Product Group
- If there is not enough time to engineer the details
- Feedback can be processed but afterwards not picked up for the next project
- There is no job preparation in Gorinchem
  [I] maar hoe komt dat? [P3]ja omdat ze niet echt een werkvoorbereider hebben, dat zij ze zelf. De voorman pakt 10 tekeningen en die zorgen dat deze week 10 tekeningen worden geïnstalleerd en dan zijn die tekeningen, daar staat daar een motor op, maar op de tekening staat niet wat er naast staat. Dus dan denken. Ze of we pakken een pomp dan staat de pomp voor een ander systeem er niet op. dat ze denken oh die pomp kan beter 3 cm naar daar wie heeft dat verzorgen dan zouden ze wel kunnen denken oh pas op volgende week komen ze met een andere tekenpakket. |
- When working with a yard abroad collaboration is harder because of language barrier, cultural differences, you cannot see each other as often, compared to when you are co-located with production.

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What goes well

- Engineering and production relationships, let production be valued and also explain why a direction has been chosen.

- Explain the why behind an idea to production for awareness

- React to questions from yard quickly, to build trust. Explaining not knowing the answer on a question is also an reaction to production

- Visits the yard to ask production how they would do something. The engineer learns from this and production feels valued and listen to.

What will be done?

- ik horde dit ook van iemand anders, maar waarom is dat dan zo anders?
- ze willen geen verantwoordelijkheid dragen. Daar gaat het helemaal over. Ook al als ze iets anders doen, ook al kan het beter zijn. Ja en er zegt iemand, maar het is niet volgens tekening ingebouwd. Ik kan wel het argument aan halen, het is beter maar ze worden er op afgerekend. En die verantwoordelijkheid willen ze niet pakken.

What will be done?

- What goes well

  - Engineering and production relationships, let production be valued and also explain why a direction has been chosen.

  - Explain the why behind an idea to production for awareness

  - React to questions from yard quickly, to build trust. Explaining not knowing the answer on a question is also an reaction to production

  - Visits the yard to ask production how they would do something. The engineer learns from this and production feels valued and listen to.

What will be done?

- Worden aanpassingen door productie die bij de vorige worden nu gedaan doorgevoerd naar de volgende?

- Ja die terugkoppeling blijf ik wel vragen, doordat ik elke keer aan boord ga en vraag: lukt het? Als je dat vraag zeggen ze altijd ja ja ja, en als ik dan vraag: en hoe zit het met dat? Dan zeggen ze ah wacht kom even mee. Ze zeggen altijd ja ja ja maar als ik dan specifiek vraag, want vaak weet ik waar het pijn gaat doen bij productie, van lukt het daar? Dan zeggen ze van ja nou dit en dit en dit. En dan pak ik dat wel ook mee. Kijk het gaat altijd zo zijn of er wordt iets mee gedaan. En dat heb ik nu wel gehoord van punten die we wel al opgelost hebben, dan zien ze dat ook direct, dus dat is voor hun ook wel een stimulans om te blijven communiceren naar ons toen. Voor wat hoort wat, want ze gaan niet blijven verwachten als wij er niets mee doen, dus ze moeten zich gewoon gewaardeerd voelen. Dus dat probeer ik altijd wel te doen door terugkoppeling te geven van, we hebben beslist van we gaan er iets mee doen ja of nee en hoe kan je zeggen van waarom doen we het niet of je hebt groot gelijk we gaan het meteen aanpassen. Dat laat ik direct weten, stel je voor we gaan er nog een bouwen dan heb ik het wel gezegd dat hun opmerking heel terecht was en dan weten ze dat, en dan ja voelen ze zich gewaardeerd en dat het de volgende keer ook zo moet zijn.

What will be done?
• Less mail contact, direct communication is preferred
  [I] en wat bedoel je dan precies met communicatie,
  [P3] duidelijk naar elderen verwachtingen communiceren, wat je van een persoon verwacht ten opzichte van een persoon. Als je naast elkaar zit niet mailen maar gewoon elkaar aanspreken, of naar iemand toe lopen. Dat is zoveel beter dan een mail sturen.

• In Gorinchem engineers are called and they visit the ship for questions, aborad it has been done via email.
  [I] (24:54) maar hoe gaat dat nu?
  [P3] met een foto camera, ze hebben een camera, want ik denk dat de gsm van de voormannen nog uit de middeleeuwen is, maar meestal hebben ze een fototestel op zak. En dan draadje in de computer. Dan duurt het een eeuwigheid voordat het op de computer staat en op mail, maar ja. Hier bellen ze gewoon van kom eens langs. Maar in Vietnam krijg je gewoon foto’s.

• Building relationship with yard essential
  [I] zijn er projecten geweest waarbij je niet goed up to date was?
  [P3] (23:53) in het begin was het bij Vietnam wel zo, we kregen geen, ja we kregen wel fotos maar van feedback omdat communicatie is heel moeilijk met vietnamesen dan ben ik me zo aan het concentreren om ze te verstaan dan zeggen ze wat en dan ben ik dorode draad van het verhaal kwijt. Dat is echt verschrikkelijk, dan zetten ze het vaak wel op een mail dat ze de teelfoon niet durven te nemen. Maar ik ben er nu twee of drie keer naar toe geweest en dan is het direct weer anders. Dat is gewoon ernaar toe gaan of zij hier, dat geeft een totaal andere situatie. Je leert de mensen namelijk kennen, je gaat samen een keer wat eten en dan is het direct veel gemoeilijker om mails te sturen of je te bellen. Dus dat is wel ja dat is wel handig.

Design Criteria
• Enthusiasms and interest in what the other is doing
  [P3] (20:58) voor samenwerking is het belangrijk dat de ander enthousiasme en interesse toont en dat die zijn best doet, dat vind ik belangrijk.

• Personal contact should be build between project team members
  [P3] (22:12) dat persoonlijk contact moet altijd eerst opgebouwd worden. Op de een of andere manier als je mensen niet kent dan zijn ze schuchter.

• Structural interaction with production and engineering, production then can ask questions
  [P3] met de 40 meters, zeker de eerste boten van jongens zorg dat je elke week twee uur je gezicht laat zien aan boord, als is het voel krijgen met de praktijk, dan ben je dichter bij de voorman en dan durft die vragen te stellen aan jou in plaats van die email. Ik ga elke week aan boord nog steeds en er komen elke keer weer vragen naar boven.

• Visual image needed
  [I] email en foto’s?
  [P3] (15:14) ik vraag altijd om fotos, een beeld geeft zoveel meer dan 1000 woorden. Ik ben wel een visueel iemand maar als ze dan uitgelopen, dit hoekje en dat heokje ja dat zie ik dan niet.

• The production foreman should have the device, one single point of contact, give a reaction is essential. One single point of contact needed between engineering an production.
  [I] (23:08) wie zouden dan zo een tablet moeten hebben?
  [P3] de voormannen, die is alsnog altijd eindeverantwoordelijke. Hij moetweten wat er speelt onder zijn werkvolk. Ik denk dat als je data an doe jongens geeft dan weet hij ook niet wat er gaande is. En dat is heftige hier ook, van engineering moet altijd hetzelfde aanspreekpunt zijn. Als hij het niet weet dan is het prima om het aan iemand anders te vragen maar ik vind wel je moet wel het antwoord voorzien aan de werf. Voor mij is een antwoord ook: jonegns da tweet ik niet dat moet ik uitzoeken, dat moet ik navragen. Dat si ook een antwoord snap je

• The too, it should be working at all time

Evaluation Design
• Less emails to be send
  [P3] (26:40) de type fundtie van skype voor busineus gebruik ik elk uur, om dinen maklijkere en sneller uit te leggen in plaats van mail te sturen.
  [I]wat is het voordeel?
  [P3)minder formee, veel infromelere en mensen voeln zich minder aangesproekn op de persoon, want vaak als je een mail stuur dan zet je iedereen in de cc en dan voelen ze zicht direct gepakt. Dus als ik een opmerking heb, dan zekre in het begin. En als het een opmerking is dan hoeft niet eideren te weten dat er een keer een foutje is geweest. Fouten is menselijk dus dan stuur ik enkel naar hem een email of skype voor businessvan let op daarop en daarop dat was niet de bedloen, dat is veel amnikkeliger, veel persoonlijker en infromeel. Als je ziet hoeveel emaisler rond gaan hoeveel mensen er in de cc staan. Daar wordt je helemaal zot van. Deze week en vorige week krijg ik 100 emails per dag.

• When calling now, teh engineer ask for an email with pictures to get an understanding of the situation
  [P3] ja opzich wel, vaak hebt ik in antallia aan de telefoon dan hoor ik op de achtergond geslijp en gelas en geklop, dan zeg ik stuur anders maar een email met een paar fotos erbij, dat zou inderdaad dan handig zijn.

• Added value of a tablet
  [I] heb je het idee dat het wat?
  [P3] (20:07) ja met tablet vind ik dat wel, dat zou wel helpen. Vaak maak je een screenshot van het 3d model met pijltjes en dat zit je met snagitte werken van dat en dat en dat moet je opletten, vaak wordt dat mis geinterpreteerd. Dis snagit pijltjes. Met live beelden kan je echt zeggen van nee niet dat maar...

• It should be simple and easy
  [P3] (42:35) dus er moet altijd een afweging gemaakt worden, en zo een tablet daar zie ik echt wel de voordelen van in. Maar het moet niet te moeilijk worden want dan is de kans op foutmagre te groot. Zoals dat 3d scannen en dergelijke, ik snp het wel maar is het nodig. Nou ik ben ook maar een engineer.

Participant 4
Participant 4 is Project Manger Engineer Mechanical and worked on multiple projects during the project.

Frustrations
• Information package other product group mistakes in there, engineering and production build own routines to be able to send information that is incorrect. When using it by another product group, takes a lot of time to find out the problem
• Reaction to production within a day to keep the going
  [P4]ja dat is echt belachelijk
  [I] wat gebuerd er dan met het vertrouwen aan de kant van de werf?
  [P4] het duurt te lang we doen het zelf wel. Daarom is het essentieel dat je productie support binnen een dag afhandeld als er iets is. Of binen twee dagen, zo kort mogelijk
• Central knowledge
  [I] waarom niet?
• Frustrations when solving problems of others
• Not receiving answers on questions
  :En dat is mijn contactpersoon in productie op vakantie en de project manager bemoeit zich nergens mee die denk project is klaar, zoek het maar uit. Dus dan ben ik degeen die er nog zit en dan moet ik het oplossen. Dus dat is een fout, je krijgt de verkeerde infromatie en je boorduur je er weer op verder. Je krijgt niet vaak verkeerde informative maar vaak incomplete, dus dan vraag ik een tekening op van een pomp, dan willen we gewicht hebben, capaciteit hebben, hoeveel draadjes er naar toe moeten,
dat krijg je dan, maar niet waar de fundatie plaat zit. Dan moet je daar weer achteraan. Normal proberen we na te streven een compleet product package van leverancier te krijgen. Een hele file met alle pompjes etc, maar dan zijn zee r 3 of 4 vergeten want die zijn niet goed, dan sturen ze die los na en dan klopt je revisie weer niet. Dat sort pratische dingen, en dan wordt het een beetje een rommeltje. Dus hier zit er bij mij wel wat frustratie bij omdat het eigenlijk niet mijn pakkie aan is. Dit zou door Project management moeten worden afgestemd met de klant want het is uiteindelijk zijn boot, wat willen jullie. Daar krijg ik gewoon geen reactive op, dan heb ik daarover gemeld 3 of 4 keer. Na ¾ vragen en geen response dan wordt het een richtings verkeer dan werkt het niet. Hebben nu met garantie claims te maken, een boot gaat weg, je krijgt altijd claims, daar ontkom je niet aan, en daar heb je een bepaald budget voor. Dat gaat via de service department en die hebben ondersuening van engineering nodig, want wij hebben die boot gebouwd. Ik krijg een claim, ik snap er helemaal niets van want ik heb die boot nooit gebouwd, wil je er even induiken, dus die support doe ik nu nog voor de 07

- Lack of feedback to engineering
- Autonomy of an engineer is essential for commitment, if everything is pre-defined
  “Groot gebrek geen feedback op tekeningen, omdat er veel lagen zijn, engineer, lead engineer, pm engineer, pm. Hele toren, engineering maakt een tekening en dat wordt een keer bij vergadering besproken maar dat komt niet altijd terug bij de engineer als er iets anders moet. Gebeurd niet lead engineer met engineer, ass pm met engineer, niet goed voor ontwikkeling als je precies taken krijgt van je moet lijnje van links naar rechts trekken. Sommig vinden het fijn.” -P4

What goes well
- Low boundaries between engineering and production because of reciprocity between engineering and production
  “Voormannen zijn heel laagdrempelig, dus als er iets is even aan de telefoon. Volgende keer zeggen ze van zo en zo doen. Dan zet ik dat in een lijst bijvoorbeeld ventilatie roosters. Dan zorg ik dat dat de volgende keer anders gaat. Fp die zei voor de volgende boot. En anderom ook.”

Design Criteria
- Compare 3D with reality
- Capture problematic area and for outcome of session

Evaluation Design
- Added value of the design for engineering
  [P4] (35:30) hier in Gorinchem dank je zo aan boord stappen dus dan niet direct, maar in het buitenland zeker wel want dat is de enige manier waarop je kan naboosten hoe we hier nu werken.
  [I] dat heb ik nu aangenomen die manier van werken dat je dat wilt, maar denk je dat dat ook zo is? Hoe jullie contact hebben hier dat je dat in het buitenland ook wilt?
  [I]waarom?
  [P4] omdat anders die response tijd veel te lang is wat je net zegt met Galati, een mailtje sturen een print screen, daar gaat gewoon een week of twee over, dat kan niet. Als er en fundatie aangepast moet worden en die moet geschilderd worden, snap je dat ebt al lemaal door dus je wilt zo snel mogelijk in zo kort moeilijke tijd problemen afhandelen. We kunnen niet heen en weer vliegen om continu van he is dat maar op. Ik denk dat dan dat real time me ekunt kijken, dus in plaats van dat de voorman zegt van he kom eens aan boord, hoe gaan we dat doen. Dat zo een man in Galati weet ik veel skyp je of de helm opzet van jk eens even mee, dit gaat er mis hoe gaan we dat doen? Dat heeft 100% zeker toevoegde waarde.

- How tool can be applied during the production phase, structural and ad hoc
  [I] maar hoe zie jij je dat dan voor je? Meer ad hoc of meer wat je structureel zou moeten doen?
  [P4] ehm, ja dat is. Ik denk dat je het zoveel structureel moet doen bijvoorbeeld en keer in de week een soort van productie vergadering, ja dan is het niet echt een productie vergadering maar ik kan me voorstellen dat als je een keer in de week of een keer in de twee weken een vaste afspraak hebt staan met de productie daar, en je loop teens een rondje aan boord en we kijken even, oh je hebt dat gedaan aan boord, mooi. Snap je dat is dat structurele. Maar er zijn antuuriik ook ad hoc dingen in Gorinchem ook gewoon. Er staat een leverancier en iets klopt er niet even snel meekijken daar onckom je niet aan. Ja en hoe vaak iets ad hoc is dat weet je natuurlijk niet. Maar het zou zeker, dit mogelijkheid zou je wel moeten hebben denk ik. Om maar te voorkomen dat iedereen eindeloos gaat mailen naar de project manager, dus en zo, dat duurt veel te lang.
Thinking along, capturing the real ship and compare it to the 3D model

‘Ik’ maar hoe kan je het probleem gedeeltelijk vangen?

[P4] Nou door foto’s, ja het zou mooi zijn als je dat combineer met een 3D scanner, stel nou voorman belt, fundatie past niet ik heb hem aangepast, ik even met me mee, en dat je dus inderdaad inscant en dat je dat over je 3D model heen kan leggen. Van oh hij heeft het zo aangepast en dan kan je heel makkelijk die informatie aanpassen.

[P4] ja ik kan me wel voorstellen dat als je een situatie aan boord hebt en je hebt het ervaring als voorman met de ingenieur en je wilt dat vastleggen, dat je inderdaad iets hebt waar je het meteen vast kan leggen dat je niet meteen, dat je niet alleen een camera hebt dat je het bespreekt en daarna moet gaan dieken van o ja ik moet nu in het model prn screens gaan maken hoe we het gaan doen. Het zou wel handig zijn als je klik foto of ik scan het even in detail in, ik stuur het even door dat je die functies wel hebt.

How the device could be used in production

‘Ik’ maar hoe zie je dat dan voor je heeft zo een voorman dat altijd zit?

[P4] ja, of er zou iets aan boord moeten liggen een tool, een ipad of een helm, in ieder geval niet dat die moet gaan wachten van of shit ik heb het niet bij me of voor mij staat er een klein container op de werf dan kun je daar die helm even uit pakken, petje eet en aan boord. Dat je ook wel meteen direct actie kan ondernemen.

[P4] het mooie is dat je het vastlegt, kijk je kunt real time meekijken van we hebben het zo en zo gedaan, ja okay leuk, dan heb je nog steeds je informatie niet. Ja dan weet je het wel maar dina is het niet vastgelegd, als je het alleen maar real time doet. En ik zit nog veen verder te denken. Stel dat je aan boord maak je zo een scan ergens van, dat die voorman een opmerking erbij kan schetsen ofzo.

Participant 8

Participant 8 is production foreman in Gorinchem, working on the same project as participant 4.

Frustrations

- If a revision is made, engineering already knows about it for 3 weeks, they should communicate about it already. Information adjusted without updating about it.

‘Ik-DW’ heb je een voorbeeld wat er moeilijk gaat tussen engineering en productie?

[P-PF] een voorbeeld als er dingen achter onze rug om veranderen. Dat is voor ons best wel een probleem als we ergens aan bezig zijn in ons werk en ze gaan dan ik noem maar een bijvoorbeeld. Wij zijn aan het schilderen, wij krijgen een tekening van een ladder. Hier zijn ze in de tekenkamer al twee weken mee bezig of drie weken. He als ze dan even een belletje doen naar ons van dat ladder gaat veranderen. Maar dan krijg je een tekening naar binnen gestuurd en dan staat er revisies die, en dit gaat veranderen. Nou dan ben je eigenlijk al te ver in je werk om dat überhaupt nog te kunnen veranderen. De huidige ship ingenieur doet het erg goed, de trekt aan de bel, maar andere ingenieurs die hoor je niet. En die sturen hop die tekeningen.

- 3D model essential to understand 2D drawings
- On the one hand decisions are not being made anymore
- Engineers who are not aware of a standard

“maar dat er nieuwe ingenieur zaten die geen weet hadden van onze standaard tekeningen of te weinig. En die dan soms zelf weer nieuwe dingen zaten te bedenken. Over hele leuke dingen door ons helemaal beproef systeem, daar zaten ze iets helemaal nieuw te bedenken, en die zie dan van [pf] kijk eens mee van dit kan toch nooit goedkomen. Ja en dat is een stukje bedeleiding bij engineering”

- No job preparation in Gorinchem

Het zijn soms zulke grote projecten dan staat er zo veel geprijseld op zo een tekening, dan wordt je er ook geen wijs uit. Dus of ik maak er een vergrotingen uit voor die jongens, ik stop er een fototjes bij of ik laat groet tekeningen afdrukken. En dan zorg ik dat ze bij de boot afgeleverd worden en dat geld hetzelfde als voor de stelling, die moet er staan. Ik kan niet zeggen jongens hier heb je de tekening ga maar, want dan staan ze 5 minuten later weer bij mijn bureau, van hoe kom ik daar bij?. Ja daar moet ik van te voren wel over nadenken. (38:28) Maar zo komt er wel veel van een voorman af. En dat is bij Amos en in Rotterdam daar zit veel meer werkvoorbereiding in.

- Giving feedback is hard for production to engineering, they also need to move on, when calling feedback is not
always captured.
Kijken andere aanlopers hebben dan geven we echt wel door aan engineering. Maar wat voor ons lastig is met het doorgeven. Wij werken heel veel met de telefoon. Je bent aan boord dus je constateer je iets daar heb je een vraag over dus je gaat bellen met Eng mech of met Eng ship en dan geef je het door van het zit niet goed. We gaan het zus en zo oplossen en dan moeten zij dat verwerken. En dat valt ook wel een tussen wal en schip.(25:03) Het is voor ons lastig om het hard door te gene met een emailje en een foto erbij. Dat is gewoon lastig, daar kom je niet aan toe. Wij zijn ook bezig.

- When product sold to client the design should be changed under time pressure
[I-DW] Dit is nu de 4e, gaat het process nu soepeler?
[P-G] Ja gaat zeker soepeler, maar die boten zijn niet met elkaar te vergelijken. De eerste was helemaal nieuwe voor ons. De tweede ging best een stuk makkelijker, de derde was weer lastiger want die moest helemaal verbouwd worden. Daar hebben we 10.000 uur extra aan bested omdat er stuk aan moest en een heli dek erop. En deze is nog niet verkocht dus dat is eigenlijk weer back to basic alleen wel met helideck. Je weet niet als deze verkocht wordt of die dan weer helemaal over de kop moet.

- Incomplete information, is now filled in by knowledge of the production foremen
[I-DW] Wat voor informatie gebruiken jullie allemaal?

What goes well
- Seeing each-other on a regular basis makes communication easier.
“hun zie je regelmatig aan boord, maar ik heb ook meegemaakt die zie ik nooit aan boord. Dan denk ik hoe kan dat nou? Dat vind ik ook gek, die hoor je alleen aan de telefoon als je wat wilt weten. Dan wordt de communicatie ook wel moeilijker. Als je zee en keer aan boord ziet lopen, en dan kan je meteen wat vragen dan lopenze mee, dat werkt veel fijner.”

- The collaboration is good in current project, proactive engineers and they knwo what is needed by production
[I-DW] En hoe vind jij nu dat de samenwerking tussen productie en engineering gaan?
[P-G] Bij dit project gaat het super, ga nee goed dat je dat zegt. Bij dit project gaat het best heel goed. Met de project manager engineering hebben we wat minder mee omdat hij meer het management doet. Hij was moeilijk te vangen voor ons. Zijn de scheepsbouw en werktuigbouw, nou daar kan ik heel goed mee door de bocht.

- Being aware of where engineering is working on and push and pull of information.
[I-DW] Dat merk ik ook omdat je veel langs komt.
[P-G] JA en dat is voor ons ook heel belangrijk om langs te gaan, soms spelen er dingen die ik dan daar oppikt zodat ik werkzaamheden kan stopzetten. Dat is voor mijn informatie opvangen want een engineer zit anders in elkaar dan een voorman. Een engineer is bezig om iets te ontwerpen, te bedenken en die heeft niet in de gaten van aan boord, zijn ze al zo ver daar mee of aan boord zijn ze de voorbereidingen al aan het treffen, al spulletjes bij elkaar aan het zoeken. Dus ik doe heel vaak uitluisteren, en er is ook heel veel overleg tussen de schip engineer en mij omdat er nog steeds dingen zijn die weer anders zijn op deze boot. En dat is het beste om in overleg te bespreken van, heb je daar wel eens aan gedacht, en dan is het van ooh nee dat moeten we nog doen of daar zijn we mee bezig.

- When an engineer has practical experience he knows what is expected by production, and understands what practical problems can be. Engineers with understanding and awareness of what production needs.
[I-DW] Hoe komt het dat je met hem zo goed kan samenwerken?
[P-G] omdat hij de ervaring heeft van hoe bouw ik een boot en hij weet wat wij nodig hebben, hij levert het pakket compleet aan en hij levert de rest van de informatie aan. En dat is met de mech eng nu ook, die weet ook wat wij nodig hebben en wat de aanlopers kunnen zijn.
Design Criteria

- Awareness of engineer of status of the ship
  [I-DW] Wat zouden we daar anders aan kunnen doen, hoe zou je dat op kunnen oplossen?
  [P-PF] nou de ship engineer doet dat goed, maar andere engineers die zouden meer het besef hebben van, wat heeft het voor consequenties al slik dat ga doen. En wat zijn andere opties, kunnen we het op een ander manier doen. Vaak krijgen we een tekening die verander of gewijzigd is. En dan hebben ze daar mooi iets met laswerk gedaan, en dan zeg je later, dit kan eigenlijk niet meer, het had ook met een paar boutjes gekund. Dan gaan we terug bellen en dan lossen we dat wel op, maar soms hebben we dingetjes die ze veranderd willen hebben die eigenlijk het station al gepasseerd zijn.

- Foreman should be able to start up a session, a connection needs to be made between engineering and production
- The tool should fit into the daily routine
- The tool should not be to obvious see you walking with it
- Tool should work at all time
- When real problems occur. Calling not enough, interaction is needed
  [P-PF] (28:30) communicatie is telefoon, een prachtig hulpmiddel, mail een prachtig hulpmiddel, maar als je echt met een probleem zit, dan is het wel heel handig als je even bij elkaar zit en een schets kan maken en dan verhelderd dat veel meer. Want het is, ik leg een probleem voor en dat kan ik via de mail doen, via de telefoon en dat gaat naar de PME ship en die schuift het weer door naar een van zijn onderdanen, of in de urkaine of noem maar op, en dan zie je precies dat het net niet is wat je bedoelt of precies niet.

Evaluation Design

- Easier to explain with video communication
  "want je kan daar best wel eens dingen in het buitenland hebben van ja hoe ga ik dat nu doorgeven aan…"

- Having a mobile phone would be preferred over a tablet, you can put it in your pocket
  (…) Maar voor dingen vastleggen is het wel handig, absoluut. Maar dan moet je wel een toelichte hebben. Ik moet niet naar het kantoor te hoeven lopen om een ipad te halen en dan aan boord om een ding te doen en dan heb je dat ding weer weggebracht en dan zie je weer iets. Dat moet echt iets zijn van ik pak het uit mijn zak, ik maak een fototje.

Participant 18

Participant 18 is production foreman in Gorinchem, during the project working in multiple projects in Gorinchem and abroad. Participant 18 also work together with participant 4.

Frustrations

- Sending an email but not knowing if an email has been received, no answer
- Earlier in the supply chain should feel responsible for what happens in production
  [P-PF] (21:43) maar dat is bedrijfsmatig, een damen. Dat is de damen manier. Zo gaat het bij damen. Als je vroege bij damen kwam dan ging je eerst even door producitie al was het maar even voor twee weken maar wel langs producitie. Ga eerst maar eens lekker op een boot zitten en slijpen
- Reinventing the wheel for projects because problems and solutions are not captured, managed and reused for new projects.
  [P18] (21:52) volgend jaar op zometeen als deze weg is, dat we gewoon de tweede gaan bouwen. Dezelfde, alleen een andere engineerings groep. Dan moet je er eens tussen gaan zitten om te kijken wat er gebeurd… dan gaan we waarschijnlijk het wiel weer opnieuw uitvinden... als je er een nieuw team op zet. Een nieuw engineering team, want dat kan. Het wilt niet zeggen dat ze weer beschikbaar zijn. Maar dan zou het zo moeten zijn dat engineering zeg maar informatie haalt bij de vorige engineers en dan hoop ik dat er iets opgestagen is van hoe we het hebben gedaan, of wat er toen afgesproken is. Ook over systemen. En als dat niet gebeurd is, dan zit de volgende die de tweede gaat doen, weer opnieuw het wiel uit te vinden.
  [I] en stel je voor dat er juist een ander productie team komt?
  [P18] (21:52) dat kan, die mogelijkheid is er absoluut. Dan lopen ze waarschijnlijk weer tegen dezelfde problemen aanlopen als dat we toen al besproken hadden, en toen hebben opgelost. Als dat gedocumenteerd is, en je kan het terug vinden. Dan zou je dat...
in principe kan je daar gebruik van maken dan hoef je niet echt een vraag te zijn. Maar als je dat niet doet en diegene weet niet waar die vandaan moet halen of waar die dat moet vagen of dat daar helemaal geen communicatie is. Dan gaat de waarschijnlijk opnieuw het wiel uitvinden. Dan gaan we het weer over iets lulligs hebben.

[P18] (23:49) dat hebben we toch al eens beslist hoe we dat gaan doen.

[i] Wat heeft dat voor invloed op jullie?


• Practical experience of engineers
• Responsibility for improving products, time and money


“Dat ere en koelslang ergens naartoe moet of er een bout moet, vaak nullige vragen die eigelijk wel weet als je je tekeningen pakket voor elkaar hebt en kijkt. Met de tekeningen kom je vaak een heel end, daarom altijd terug kunnen vallen op engineering mocht je vragen hebben. Alleen je moet rekening houden dat het langer duurt.”

What goes well
• Engineers pro actively visiting the ship.
• 3D model to understand to future state of the ship.

[I-DW] Gebruik jij het 3D model?
[P-PF] Altijd als die beschikbaar is.

[I-DW] waar gebruik je die voor?
[P-PF] (53:31) Dan krijg ik een heel goed beeld van hoe het eruit moet komen te zien in 3D, dat kan in 2D ook maar in 3D loop ik er echt door een boot heen. En dan zie je ook kasje hier, kastje daar op een tekening heb je dat veel minder gevoel. Als ik 3D alles staat en ik zie dat ere en electro kastje ergens in een hoekje zit, dank an ik erop klikken en kijken van goh wat is dat. Als ik dat gemist heb op de tekening omdat dat minder makkelijk te lezen is. Nu wandel ik door een boot, dan kan ik rondkijken en dan zie ik wat van he, even teking erbij zoeken. Van hee daar moet ik ook nog wat mee doen. Het is gewoon een handige en onmisbare tool.

Design Criteria
• The tool should be robust
• Should be able to make picture and send it

[E-PF] (19:00) je informatie bijhouden en beheren en noem maar op, en gebruik van maken.

Evaluation Design
• The proposed solution is not the solution for the real problem of Damen,

[I-DW] maar wat bedoel je precies met informatie?

[P-PF] Als je goede duidelijke tekeningen hebt verstrekt, een duidelijke Pmer een goede bouwvergadering belegt over het project dat veel dingen duidelijk zijn en op papier ziet dan is dat heus wel te behappen. Maar al seen pmer het te druk heeft en een engineer te druk met te veel projecten en van oja dat moet ik nog doen en ik kijk van de week nog even. Ja dank om je in de knoei, (15:29) Meestal als iemand een vraag stelt, dan zit die er gelijk al mee. Dan wilt die eigenlijk gelijk antwoord en die begrijpt ook wel dat er niet altijd gelijk kan, maar het kan niet zo zijn dat je dan tien keer moet vragen van heb je nog aan mijn vraag gedacht. Als je dan tien keer oja oja krijgt dan noem ik dat een stukje des interesse. Prioriteiten stellen en als je dat niet aan kan dan moet je bij je baas zijn of ik kan het niet aan. Zo moet je hem bekijken. Dit is een dure oplossing en het is nog niet de oplossing. Want een engineer heeft ook niet altijd de tijd om mee te kijken, die kijkt dan even mee en dan is het, het zal wel of wat zie ik nou. Dat is niet de oplossing.

• Preffers email over real time communication

“Skype is leuk dat je elkaar kan zien in een meeting ofzo maar met onze vragen heeft dat geen zin. Kan je beter gewoon een
Economical considerations, it should be paid from the ships that are sold in production and he is leak, what you also see is also leak. I think also he must also be paid, I think in the business. He must be paid and where. Of the things that lie here.

Added value of having 3D model or AR to detect problems in production and this is very good. (37:16) you must see, my 3D is in reality. Because you also see that there are so many pipes. And you do not always have everything in a ship, so you must keep track of where a pipe comes. So we often hang a box here and everyone must be there. Then there must be an electrician, a person from the building, etc. I come with my pipe and then we sit and measure. And then we often, then I take my laptop and then we watch in 3D. So that box must also come there, and so we sit and measure. And if you do that, you can just say, I can do this and then you can look from now.. so that is very helpful.

Added value versus costs, but innovation is also needed and I think that is also very useful? And in standard boats is very much standard, now we do not have much more standard, earlier you only had a tugboat. We often have things that we have to figure out and measure and then I think this can really have added value. Besides that it costs a lot of money, but of course that also deserves it. I think it is a very useful tool. And I think we must always keep developing, you have to do this, you have to have room, I think that this technique is still in the shoes of children, but it can also be very quickly. I think that is a stumbling block that it is a huge cost. That is really quite expensive. But.

(P18) (44:27) I think we always need to continue developing so that we do it right, you need space for it, I think that this technique is still in the shoes of children, but it can also be very quickly. I think that a stumbling block is that it is an enormous cost. But the best is that it costs you more.
Appendix S. Validation intended use

The proposed tool and process can be validated with the following questionnaire, during the research project there was not enough time to validate the results, but it is a recommended next step for Damen.

### Appendix 1. TAM2 Measurement Scales and Reliabilities

<table>
<thead>
<tr>
<th>Intention to Use</th>
<th>Perceived Usefulness</th>
<th>Perceived Ease of Use</th>
<th>Subjective Norm</th>
<th>Voluntariness</th>
<th>Image</th>
<th>Job Relevance</th>
<th>Output Quality</th>
<th>Result Demonstrability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assuming I have access to the system, I intend to use it.</td>
<td>Using the system improves my performance in my job.</td>
<td>My interaction with the system is clear and understandable.</td>
<td>People who influence my behavior think that I should use the system.</td>
<td>My use of the system is voluntary.</td>
<td>People in my organization who use the system have more prestige than those who do not.</td>
<td>In my job, usage of the system is important.</td>
<td>The quality of the output I get from the system is high.</td>
<td>I have no difficulty telling others about the results of using the system.</td>
</tr>
<tr>
<td>Given that I have access to the system, I predict that I would use it.</td>
<td>Using the system in my job increases my productivity.</td>
<td>Interacting with the system does not require a lot of my mental effort.</td>
<td>People who are important to me think that I should use the system.</td>
<td>My supervisor does not require me to use the system.</td>
<td>People in my organization who use the system have a high profile.</td>
<td>In my job, usage of the system is relevant.</td>
<td>Having the system is a status symbol in my organization.</td>
<td>Although it might be helpful, using the system is certainly not compulsory in my job.</td>
</tr>
<tr>
<td>Perceived Usefulness</td>
<td>Using the system enhances my effectiveness in my job.</td>
<td>I find the system to be easy to use.</td>
<td>Subjective Norm</td>
<td>Voluntariness</td>
<td>Image</td>
<td>Job Relevance</td>
<td>Output Quality</td>
<td>Result Demonstrability</td>
</tr>
<tr>
<td>I find the system to be useful in my job.</td>
<td>I find it easy to get the system to do what I want it to do.</td>
<td>(Cronbach’s $\alpha$ ranged from 0.82 to 0.97 across studies and time periods)</td>
<td>(Cronbach’s $\alpha$ ranged from 0.86 to 0.98 across studies and time periods)</td>
<td>(Cronbach’s $\alpha$ ranged from 0.61 to 0.94 across studies and time periods)</td>
<td>(Cronbach’s $\alpha$ ranged from 0.82 to 0.91 across studies and time periods)</td>
<td>(Cronbach’s $\alpha$ ranged from 0.80 to 0.93 across studies and time periods)</td>
<td>(Cronbach’s $\alpha$ ranged from 0.82 to 0.98 across studies and time periods)</td>
<td>(Cronbach’s $\alpha$ ranged from 0.80 to 0.97 across studies and time periods)</td>
</tr>
</tbody>
</table>

**Note:** All items were measured on a 7-point Likert scale, where 1 = strongly disagree, 2 = moderately disagree, 3 = somewhat disagree, 4 = neutral (neither disagree nor agree), 5 = somewhat agree, 6 = moderately agree, and 7 = strongly agree.