Improving Change Management

" A response to growing complexity in managing offshore equipment"

Huisman
Worldwide Lifting, Drilling and Subsea Solutions

TU Delft Delft University of Technology

Msc. thesis Alexander Mulder
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Thesis details

Improving Change Management
" A response to growing complexity in managing offshore equipment"

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Preface

By presenting my thesis report an end has come to a long but interesting period in Delft. I am very grateful to fulfil the final part of my Masters and I would like to take the opportunity to reflect and pronounce a word of thanks.

Two years ago I started at Huisman Global Services as part of Huisman Equipment BV with an interesting, but highly specific and practical assignment. It took me a while to figure out what graduation, in particular performing research and writing a thesis was all about. From a practical point of view I seemed to quite easily understand what the problem was and why the specific department where I was writing my thesis was experiencing this problem. However performing research and writing a thesis is a bit more than "jumping to conclusions"…Along the journey of graduation I gradually began to understand theoretical concepts that lay behind what you actually see in practice. The development of these skills together with the continuously gaining of new insights resulted in this actual thesis report.

Thanks to the help of many – *many* – great people I have the privilege to present this thesis that I feel proud of. Primarily many thanks to my committee: Marcel Hertogh, Rob Schoenmaker, Martijn Groenleer and Richard Verkerk from Huisman Global Services.

While writing my thesis report I had the great privilege to receive advice from Minke, Eline, Carla, Jolanda, Melanie, Lisa, Anton, Tijmen and Jan. Many thanks to all of you! And last but not least thanks to my parents and sister for their unconditional confidence.

Alexander Mulder
Delft, March 2015

Summary

Disclaimer → Read this thesis from the following perspective: the recommendations for the improvement of change management are obtained from the investigation of three incidents, which generates critical findings from time to time.

Situation

1. Projects in the offshore industry increase in size and complexity (the turnover of large projects is going up)
2. Projects become more complex because:
    a) Software systems increase in complexity and have a shorter lifespan than traditional construction elements of the equipment
    b) The demand for new equipment in the offshore industry is still rising, which means that an increasing amount of equipment enters the operational life cycle after completion. All the equipment is maintained by Huisman Global Services. The ever-increasing amount of equipment in operation frequently requires requests for change of the software systems due to its high complexity, which asks for proper change management.
    c) The requirements according to safety and reliability are increasing
3. The traditional work approach, which has proven itself in the past, is no longer sufficient enough with increasing complexity. This means that organizations and processes must comply more stringent requirements.
4. Due to the rising demand for new equipment and their complexity the pressure on the organization is increasing. The organization must be able to recruit suitable staff timely and develop and implement appropriate processes for change management. This appears to be difficult because:
    a) Because it often becomes urgent when incidents have occurred, this also creates awareness of this development and the need to respond in time
    b) Sufficiently qualified staff is needed to have the capacity to set the implementation of the change in motion. Currently an increasing amount of projects are accepted and many projects enter the operational life cycle and must be maintained by Huisman Global Services as part of Huisman Equipment BV. This requires adjustments within an organizational point of view.

Complication

Huisman Global Services is experiencing problems with the increasing amount of requests for change arising from growing complexity in projects of the clients from Huisman. The increasingly complex projects require extra functionality of software systems that operate the equipment. This results in frequent requests for change of the software.

Several incidents have occurred over the past years and Huisman expects that the root causes for incidents lay in the change management protocol that is not functioning properly. The service department expects that changes are implemented according to a system change management protocol.

Investigating the causes for the incidents and finding solutions has a high priority for Huisman Global Services in order to reduce the number of incidents to a minimum. A specific incident on the Seven Oceans vessel, which contains Huisman equipment, in 2013 did not result in actual damage. Future incidents may just bring along fatalities. This incident will be used for the investigation of the root causes in this research. Incidents like these need to be foreseen in the future to prevent possible serious injuries and preserve the reputation of the company. Furthermore incidents are costly and highly time consuming.

Approach

A large variety of changes to complex products and systems (CoPS) in the offshore industry are requested and one of the main challenges is to manage all these changes properly. This therefore leads to the following research question:

How can companies in the offshore industry cope with changes to complex products and systems in order to avoid incidents, during the operational phase of the life cycle?

In order to find an answer to this research question five sub-questions are formulated to find answers to parts of the main research question that eventually form a combined answer to the main research question.

1. **What are CoPS and changes in the offshore industry and how are these concepts defined in literature?**
2. **What are requirements for applying change to CoPS during the operational phase of the life cycle**
3. **What are strengths and weaknesses of the current approach on how changes are treated?**
4. **What are root causes of incidents in the offshore industry related to the implementation of changes during the operational phase of the life cycle?**
5. **What insights and conclusions can be generated from the findings from this research?**

Three specific cases, all pipelay incidents, are selected to investigate their root causes. By means of a Tripod Beta Incident Analysis (TBIA) and an Ishikawa diagram the root causes will be investigated and they will be devided into technical, process and organizational, and human factors.

Results

By means of this research is attempted to find an answer to the main research question by creating insights in the root causes of three pipelay incidents.

Performing incident investigation methods, root causes are grouped into different categories. A distinction is made between technical, process, organizational and human factors. The main goal is to improve and to create lessons learned from these incidents and that the organization and employees especially know HOW to learn from it. These findings can be used to improve the change management process.

Important results:

1. **Incident analyses are mostly focused on the technical events that led to the actual incidents. Lack of focus towards process/organizational and human root causes**
2. **Incident analyses are rarely linked back to create lessons learned and prevent incidents from occurring again**
3. **Little support for thorough incident analysis**
4. **Customer requirements with respect to the ordered equipment are insufficiently mapped, especially/specifically when a change needs to be implemented**
5. **Employees are insufficiently aware of the existence of a system change management protocol**
6. **Employees are insufficiently trained in order to use the system change management protocol**
7. **Lack of uniform contact lines to illustrate how and to who should be communicated**

<u>Future research</u>

Taking into account that this research is performed within one single company the recommendations can only be made for Huisman Global Services as part of Huisman Equipment BV. To be able to provide recommendations for the entire offshore industry research can be performed in a wider perspective. A set of five recommendations for future research is given, which meet the limitations of the research and provide the opportunity to create feasible input for the offshore industry in general.

1. The results of the research performed in this thesis are depending on its specific context. By means of future research can be recommended to select more and different cases and from other industries in order to make a comparison regardless of the context in which the cases were selected.
2. Selecting more and different cases and creating a more complete perspective from different departments within a company can generate a database containing of situations that can be compared on general findings. By means of a large and more complete data set a fit-for-purpose solution can be provided for the entire offshore industry.
3. A step further could be the investigation of a platform for the exchange of the details of incident analyses. At this platform information can actively be shared and used as input for the prevention of incidents in the future.
4. Performing comparative studies with respect to change management standards that are suitable for the specific context of the offshore industry. Select the best standard that leads to a fit-for-purpose design of a change management protocol.
5. Research plan-do-check-act cycles (PDCA) because planning and doing are abundantly performed because of the rising demand of complex equipment, however checking and acting seem to be less represented. PDCA might be of use for the entire offshore industry.

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Abbreviations

ABS = American Bureau of Shipping
BP = British Petroleum
BRF = Basic Risk Factor
CH = Chapter
CMS = Change Management System
CoPS = Complex Products and Systems
CS = Control Systems
ETO = Engineering To Order
FMEA = Failure Mode Effects Analysis
FMECA = Failure Mode Effects and Criticality Analysis
HFE = Human Factor Engineering
HGS = Huisman Global Services
HOF = Human and Organizational Factors
ITIL = Information Technology Infrastructure Library
PLC = Programmable Logic Controller
QESH = Quality, Environment, Safety & Health
QHSE = Quality, Health, Safety & Environment
RASCI = Responsible, Accountable, Supports, Consulted, Informed
RQ = Research Question
SCADA = Supervisory Control and Data Acquisition
SCP = System Change Procedure
SPAC = Standards, Policies or Administration Control
SQ = Sub-Question
TBIA = Tripod Beta Incident Analysis

1. Introduction

In this chapter a problem description is given and the research problem is defined. Subsequently, the main research question and its sub-questions are presented. Thereafter, the approach of this research projects are discussed, as well as the delineation and deliverables of this research project.

1.1 Problem description

At the beginning of 2013, an incident occurred on the Seven Oceans vessel at Berth in Norway. The Seven Oceans is a pipe-lay vessel in the fleet of the company SubSea7. SubSea7 is a company that holds its expertise in the design, fabrication, installation and commissioning of seabed to surface projects(SubSea7, 2014). Huisman has been working closely with SubSea7 for years. In 2007 the Seven Oceans vessel was completed and installed with pipe-lay equipment by Huisman (Huisman Equipment BV, 2008).

During the development of the Seven Oceans vessel, SubSea7 had requested for the installation of a spooling tensioner on one of its vessels. The tensioner is a specific piece of equipment used to lay pipe on the seabed. Huisman installed this tensioner at the end of January 2013. The equipment runs on specific software to carry out the operational tasks.

However, on the 12th of February 2013, a 400mT tensioner started moving unexpectedly when 'synchro' mode was active. This resulted in specific equipment being out of control. The reel started running in an opposite direction of the tensioner and subsequently the tension on the pipe sections increased severely which lead to a situation that the pipe section could break and fall onto the deck of the ship(Verkerk & Ee, 2013).

It is found by Huisman that the incident was a result of two different versions of software systems that were operating parallel to each other whereas it should have been one version of the software system. This occurred while implementing a request for change. This shows that errors can occur when changes are applied to custom made equipment during the operational phase.

Despite the fact that there were no actual injuries to people or damage to any equipment an incident like this brings damage to the reputation of a company, which is in this case Huisman BV. In the future the client might reconsider business agreements as improvements lack and incidents continue to happen. Therefore, it is of great importance to investigate how these errors can occur and possibly can be prevented in the future.

1.2 Research problem defined

Huisman Equipment BV is a Dutch company that designs, builds, installs and maintains large and highly sophisticated equipment for the on- and offshore industry. Within this company several departments are involved in the actual design, building, installing and maintenance of the equipment.

In this business they work with innovative and complex products. The highly complex offshore equipment can be accommodated in a general category of *Complex Products and Systems* so called CoPS(Hobday, 1997). Through this type of products, changes are often made in the design of the equipment during the development. In order to deliver a desired end product it is important that the different departments within Huisman cooperate sufficiently about these changes. However, the incident of the Seven Oceans vessel shows that Huisman not always succeeds in providing what they had aimed for.
Currently, Huisman uses a change management protocol in order to deal with changes during the operational lifecycle of the equipment. Could the Seven Oceans incident have been foreseen if all the steps within the system change management process had been taken properly? Or might there be more explanations in other fields of expertise?

It seems like the problem that Huisman experiences has to do with changes that are not structurally implemented however it comes down to the change management protocol that is not functioning properly. In other words: the service department of Huisman wants to improve change management or to be specific the change management protocol in order to guide the implementation of change structurally. A question that rises from this goal is why it is not functioning properly at the moment?

The improvement of the change management protocol has a high priority for Huisman especially to minimize incidents. This incident did not result in actual damage but next time the impact of the incident can bring along fatalities. Thus incidents like these need to be foreseen in the future to preserve the reputation of the company. Furthermore incidents are costly and highly time consuming.

1.2.1 General problem

In general offshore equipment is designed, built and maintained within multi-firm alliances(Hobday, 1997). This means a lot of companies are involved when an incident occurs. In the case of the Seven Oceans can be described as an alliance between Huisman Equipment BV who provides the equipment, SubSea 7 who is the owner of the vessel and an oil company like for example Shell for whom the pipeline is put in place. Therefore, an incident as occurred on the Seven Oceans effects not only Huisman and SubSea 7 but also indirectly Shell. Many other alliances like this example may arise in an environment as described. Therefore, improvements within Huisman can also be applicable to other companies or at least they might influence the way that other companies deal with change.

In addition, Huisman is not the only company that experiences these problems(Saipem QHSE, 2008). More companies that operate in the offshore business and businesses in general with the same criteria like complex tailor made products and systems, capital intensive and many different departments. The lessons that will be learned for Huisman will be applicable for other businesses within the same sector.

1.3 Research questions

The main research question of this thesis focuses on change management within the offshore industry on CoPS that are tailor made and are capital intensive(Hobday, 1997). During the operational life cycle of the CoPS, offshore companies like Huisman maintain their own CoPS that have been installed on vessels and offshore platforms. During the life cycle of the CoPS maintenance needs to be performed and several changes need to be implemented in collaboration with the client. Changes are frequently requested because of the constantly evolving software that runs the equipment whose inner workings are always changing(Sheard, 2012, p. 6). A large variety of changes are requested and one of the main challenges is to manage all these changes properly. This therefore leads to the following research question:

How can companies within the offshore industry cope with changes to CoPS in order to avoid incidents, during the operational phase of the life cycle?

1.3.1 Sub-questions

In order to answer the main research question a set of five sub-questions is formulated which will be presented in this paragraph. The sub-questions are formulated in such a way that the answers contribute to the answer of the main research question.

1. **What are CoPS and Changes in the offshore and how are these concepts defined in literature?**

2. **What are requirements for applying change to CoPS during the operational phase of the life cycle?**

3. **What are strengths and weaknesses of the current approach on how changes are treated?**

4. **What are root causes of pipe-lay incidents in the offshore industry related to the implementation of changes during the operational phase of the life cycle?**

5. **How can the existing situation be improved according to the gained insights from this research?**

1.4 Research delineation

This research will focus on complex products and systems in their operational life cycle. In particular is focused on products and systems that are maintained by Huisman during the operational lifecycle. Specific focus areas of this research are the changes that are frequently requested in order to retain the functionality of complex products and systems. Companies like Huisman implement changes that are requested by the client because they are responsible for the maintenance of the equipment during the operational life cycle. Sometimes Huisman itself initiates changes because they deliver full operational support on-board of the vessel of the client. Sometimes incidents occur during the implementation of a change, which results in undesired situations. Changes are implemented to very complex equipment. Complexity is illustrated here by the large amount of different parts the equipment contains of. There is no standard solution for a change and there is no standardized equipment, which means everything is one of a kind. This complexity and the frequently requested changes can lead to incidents. Three specific cases, where Huisman was involved, are selected to investigate the root causes of incidents. The incidents that occur during the implementation of changes during the operational lifecycle will be investigated. It is not yet particularly clear what the root causes for these incidents are. The incident on the Seven Ocean in 2013 is one of three case incidents that will be used to investigate the system change management procedure that is used to maintain the complex products and systems during the operational life cycle. The definition of this scope corresponds to the research deliverables of this thesis, which will be explained in paragraph 1.5.

1.4.1 Research deliverables

The research objectives focus on the actual incident(s) that have occurred and the procedure (system change procedure) that has been used.

1. *Provide insights in complexity of CoPS, Changes and Change Management in the offshore industry.*
2. *Investigate root causes for incidents due to the implementation of changes by analysing the incidents in the offshore industry.*
3. *Find requirements for success in managing changes (the reduction of incidents) in complex offshore industries.*
4. *Provide an explanatory analysis on the relation between incidents and change management in this complex offshore environment.*
5. *Provide recommendations to improve the process, which is used to implement change.*

1.5 Outline of the thesis

Figure 1 illustrates the content of the chapters of the thesis and the corresponding answers to the subquestions. The answers to the subquestions together form the answer to the main research question.

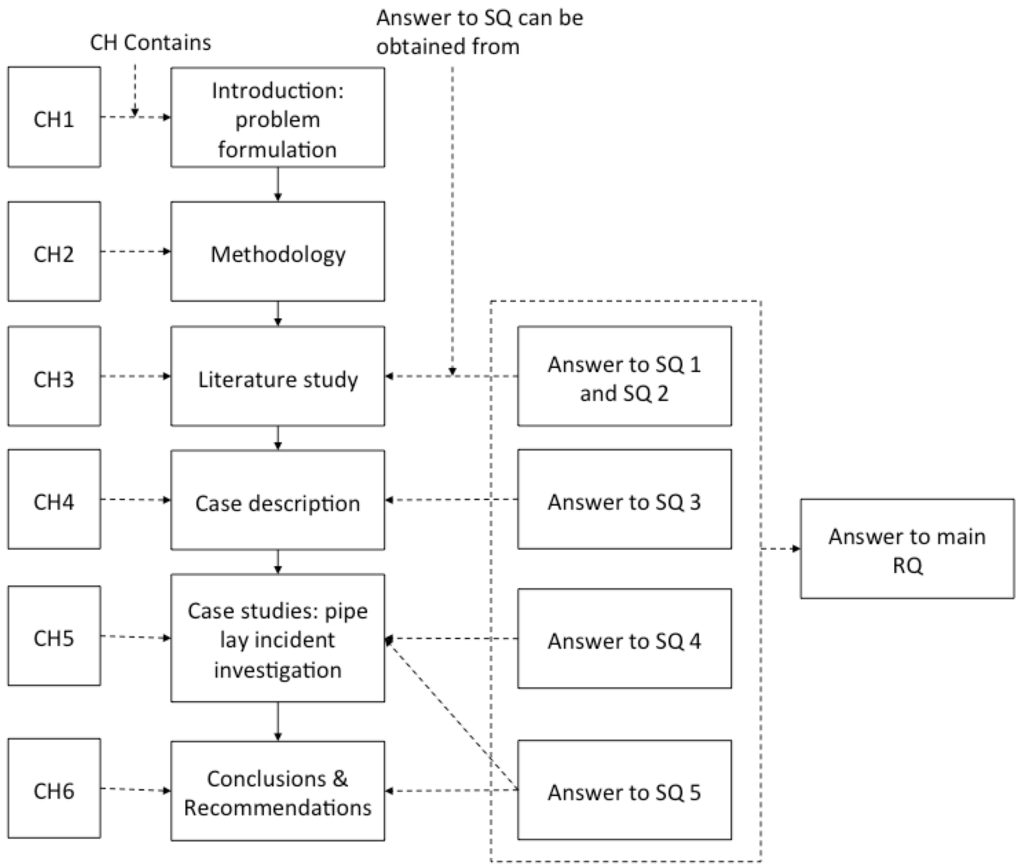

Figure 1: Chapter overview and answering of research questions

In chapter one the problem formulation is described and the main research question and corresponding sub questions are formulated. In chapter two a methodology is described for the execution of this research. In chapter three a theoretical description of the context of this research is described. The first two sub questions are answered in chapter three by investigating what complexity is and what CoPS are specifically in the offshore industry. Furthermore attention is paid on how changes implemented during the operational life cycle. Chapter three concludes with a theoretical framework and ten tables that contain requirements for the implementation of changes during the operational life cycle from a technical, process/organizational and a human point of view. In chapter four the case study performed at Huisman Equipment BV will be described. Simultaneously subquestion three will be answered in chapter four. In chapter five the case studies are performed in the form of the analysis of three pipelay incidents. The analysis results will generate an answer to subquestion four. Chapter six provides an answer to sub question five and concludes on all the findings from the case studies and reccommendations will be formulated.

2.

Methodology

This chapter will describe appropriate methods and approaches in order to answer the research questions of the previous chapter. Since a research is a complex matter that needs to be executed in a structured manner six basic steps of Leady and Ormrod(Leedy & Ormrod, 2010) are used to develop the approach. Subsequently, two different research strategies; desk research and case study research, which will be used during this research project, will be explained. Finally, these research strategies come together by executing an expert validation. In this chapter the usefulness of an expert validation will be briefly discussed.

2.1 Research approach

The first chapter has introduced the problems concerning the implementation of change during the operational lifecycle of the complex products and systems. In order to retrieve more insight into the context of this problem a method of Leedy and Omrod(Leedy & Ormrod, 2010) for research design is used, which is shown in the table below.

Phases	Explanation
1	Research begins with a problem: an unanswered question in the mind of the researcher
2	Research defines the goal in terms of a clear statement of the problem
3	Research subdivides the problem into appropriate subproblems
4	Research posits tentative solutions to the problem(s) through reasonable hypotheses. These hypotheses direct the researchers to appropriate data
5	Research looks for data directed by the hypotheses and guided by the problem. The data are collected and organized
6	Research interprets the meaning of the data, which leads to a resolution of the problem, thus supporting or not supporting the hypotheses and/or providing an answer to the question that began the research cycle. At this point, one or more new problems may emerge

Table 1: Research cycle obtained from Leedy and Omrod (Leedy & Ormrod, 2010)

This methodology gives a clear overview of six steps to fulfil a research project. The first, second and third step is to identify the situation and the problem, which has been investigated in the first chapter. From the fourth step this methodology will not be followed exactly.

In this research a literature study will be conducted in order to retrieve more information about the offshore business. Thereafter, by executing interviews and analysing different incidents, data will be generated. Finally, conclusions and recommendations could be withdrawn. The methodology of Leedy and Omrod(Leedy & Ormrod, 2010) shows in step 6 that by answering the research question, new questions can arise. Therefore, it is not unlikely that this research project provide input for future research (chapter 6).

The steps of this methodology will be used in this research as guidance. In figure 2 on the next page a method inspired by Leedy and Omrod is shown. Also, the way of generating data is presented in this figure. During this research two different types of data collecting will be used. The first one is desk research, which is shown as the third step in figure 2. This is a way to develop a theoretical context around the undesired situation. The steps to take in this literature study will be discussed in the following section.

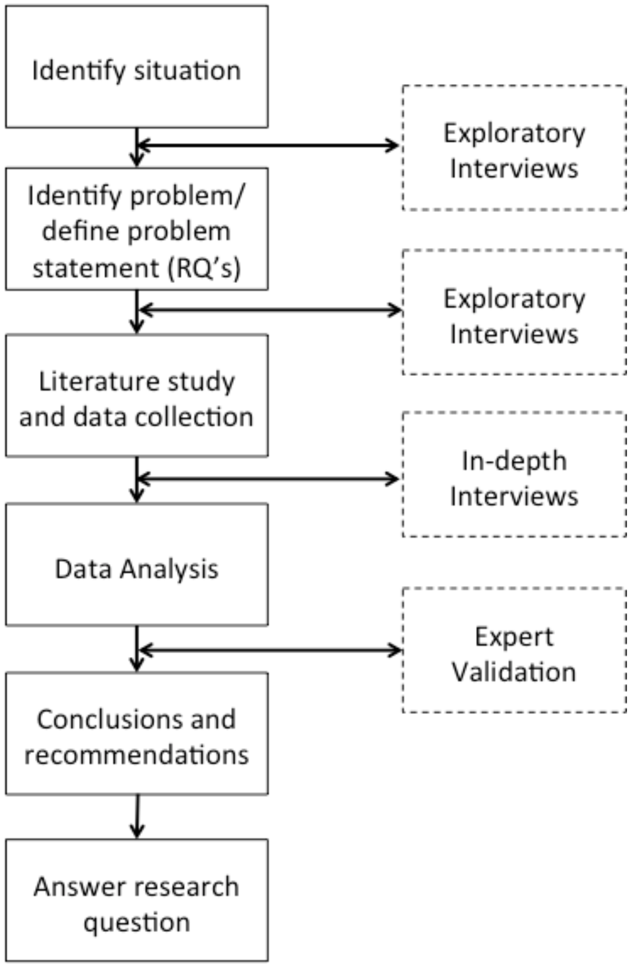

Figure 2: Research design inspired by Leedy and Omrod(Leedy & Ormrod, 2010)

2.2 Literature study

In order to investigate the theoretical context of this research as the offshore business, the company, the incidents, the procedures and available standards a combination of literature study and interviews are performed. Starting with literature that describes the complexity of the products and systems that are characteristic for the offshore industry. Complexity in general is studied and is divided in three categories. These categories explain many characteristics of the equipment that offshore companies design, build, operate and maintain. Specifically is chosen to study the characteristics of so-called complex products and systems. Prior to the investigation of the characteristics of complex products and systems the organizational characteristics of an offshore organization by means of Mintzberg are described. The link between a request for change, complexity and the occurrence of incidents raises new focus areas for the literature study. The topic of change to a complex product or system is investigated together with two different standards that describe change management within a marine/offshore environment and a software environment.

To eventually provide recommendations on how to improve change management in an offshore company a case study will be performed within specifically an offshore company called Huisman Equipment BV. A detailed introduction to this company will be given in chapter 4 and specific protocols that are used within this company are described. The standards that are described chapter three will be used to describe the protocol. Furthermore an analysis technique called Ishikawa diagram is used within Huisman Equipment BV to investigate root causes for unsatisfactory project deliveries. Within this research literature on root cause investigation methods and Ishikawa diagrams is studied in order to investigate if this technique is applicable for the investigation of incidents.

Literature that is studied on root cause/incident investigation methods also confirms that there are several categories that can contain root causes. These insights will be used to get hold of information that will be gained from interviews of employees who were specifically involved in an incident.

The link between change management, incidents and incident analysis methods will be used to generate learnings from the incidents that are studied in order to improve change management that described the implementation of change to complex products and systems during the operational life cycle.

The second way of data collecting will be executed by research within the case company Huisman Equipment BV specifically Huisman Global Services. Within this case company several types interviews are held as well as incident analysis are performed, which are the following:

2.3 Case study

In this section the different methods to generate data are discussed. The first two methods are generating qualitative data by asking questions. In paragraph 2.3.1 more information is given about exploratory interviews and in paragraph 2.3.2 are the in-depth interviewing is presented. This section will be finished by explaining the method of *incident analysis*, which provides more insight into three different cases (paragraph 2.3.3).

2.3.1 Exploratory interview

Prior to desk research and actual literature study a lot of “exploratory interviews” will be performed, which means that by having an informal conversation with employees a lot of information is generated on what kind of in-depth interview questions should be asked to whom. Thus, the “exploratory interviews” reveals opinions of the employees and provides important insights in where to find correct and usable information for the desk research on the companies’ intranet. These exploratory interviews are performed initially during the first few weeks in order to gain information on what problems and struggles are considering the main research focus and initial problem statement within the company. In order to do so, interviews have been performed with employees within managerial and specialist functions but all within the Service department of the research company. The first set of questions can be seen in table 1 and appendix 6 and are asked to generate a basic representation of the situation.

1	Could you tell something about yourself and your career at Huisman?
2	Have you been involved in the Seven Oceans incident?
3	Have you been involved in an incident and could you tell something about it?
4	How does the SCM (System Change Management process work within the software department?
5	Who initiates a change?
6	Who budgets a change?
7	Who ensures that every involved employee is aware of the developments of a change?
8	Who is the owner of a change?
9	How do you use the SCM process?
10	How should the SCM system work?
11	What are requirements for a properly functioning SCM process?
12	What needs to be changed?

Table 1: Exploratory interview questions (appendix 6)

2.3.2 In-depth interviews

Desk research combined with the explorative interviews will lead to a relevant content and a structured plan for the research and a basis for the in-depth interviews. When the data is collected it should be analysed, all the observations need to be documented and after the analysis phase the “what do these observations actually mean?” question can be asked. Once the first set of interviews were performed and the results lead to insights into the initial problem statements (proposed by Huisman). What is actually the real problem and what are sources and causes for these problems? This information is valuable in order to focus on specific areas like the communication between different employees, departments, and other organisations. Questions are first of all asked on the basis on familiarity with the Seven Oceans incident and why this incident could have taken place in the vision of the involved employees. In the second place a more general set of questions is asked on the basis of the functioning of the Service department in particular. The main goal is to investigate items (main factors) that are causes for problems on a structural basis. Questions that are asked to interviewees can be found in table 2. The fully detailed interviews can be found in the appendix 6.

1	Could you tell something about yourself and your career at Huisman?
2	Could you describe problems/incidents that have occurred?
3	Have you been involved in an incident and could you tell something about it?
4	Have you been involved in the Seven Oceans incident and how were you involved?
5	How does the SCM (System Change Management) process work within the software department?
6	How does this system work for you? How do you use this process in your daily work?
7	When you start a job on a ship, what do you do from arrival until departure?
8	Who doe you deal with? Who do you communicate with? Who do you have to report on progress?
9	Who is the contact person in Holland and what does he do?
	IN GENERAL ACCORDING TO CHANGE MANAGEMENT
10	Are you familiar with the system change management procedure?
11	Who initiates a change?
12	Who budgets a change?
13	Who ensures that every involved employee is aware of the developments of a change?
14	Who is the owner of a change?
15	How do you use the SCM process?
16	How should the SCM system work?
17	What are requirements for a properly functioning SCM process?
18	What needs to be changed in order to function properly according to your perspective?
19	Discussing the existing system change management process togethe, please provide comments?

Table 2: In-depth interview questions (appendix 6)

2.3.3 Incident analysis

To obtain data to find root causes for incidents three incidents are investigated by means of incident analysis techniques. Incident analyses are performed to find learnings from the actual root causes that caused the incident.

The Tripod Beta incident analysis is used to reason back exactly what happened prior to an incident. Specifically the case company uses this incident analysis technique and the results of the incident on which this analysis is applied will be analysed in chapter 5. A despription of the Tripod Beta Incident analysis technique will be given in chapter 3.

The case company has also used an Ishikawa diagram (a type of root cause investigation method) to analyse an unsatisfactory project delivery. Whitin this research the Ishikawa diagram is used to investigate the root causes that caused the incident. The cause categories of which the Ishikawa diagram is build of can be identified in a specific manner. This is described in chapter 3 by means of a theoretical description of root cause analysis and specifically an Ishikawa diagram.

The occasion for this research is an incident on the Seven Oceans in 2013. The focus will be laid on pipe-lay incidents in particular. Information on pipe-lay incidents in the past will be gathered and will be analysed in the same way. Specific information according to the Seven Oceans 2013 incident in the form of a detailed Tripod Beta Incident analysis is available within the case company. In total there will be investigated three incidents as described below:

Incident cases

1. Seven Oceans 2013
2. Seven Oceans 2010
3. Saipem 7000

Data and results will be described on the following basis in chapter 5; at first the incident will be briefly described in the first paragraph according to what went technically wrong during this incident. The second paragraph will cover the tripod beta incident analysis (only for the Seven Oceans 2013 case), the execution of the Ishikawa diagrams for all of the incidents and the causes that are found in these analyses are chategorized towards technological, organizational/process and human root causes.

5.X	Case X
5.X.1	Case X description
5.X.2	(Tripod Beta analysis), Ishikawa observations. Ranked towards technological, organizational and human root causes

When different interviewees and respondents give comparable and the same answers the likeliness of the usability of the answers (data) increases. The answers that the interviewees give can be seen as requirements on how the change management system should perform. The interesting parts of the results are the different visions of different types of employees on how they think the system should perform and what works well and what needs to be improved according to them.

2.4 Expert validation

In order to validate the findings of the in-depth interviews and the indicident analysis an expert validation is conducted. These experts are employees from Huisman Equipment BV and specifically from Huisman Global Services.

Set up expert validation

In order to assess the validity of the findings, conclusions and recommendations conversations with experts will be planned.

To gain objective information on the outcomes of this research a variety of employees from Huisman Equipment BV need to be consulted. The research is specifically executed at the service department and considers the implementation of change during the operational life cycle of equipment. A validation considers a discussion on the findings that result from the research.

Employees from various functions and disciplines shall be consulted. A representative group of employees will be asked to give their opinion on the findings of the research.

What kind of employees should be consulted?

- Employees that hold a management position at the service department,
- Employees that hold coordinating functions,
- Employees that fulfil a specialist engineering function
- Employees that fulfil a service engineering function
- Employees that fulfil a quality monitoring function
- Employees that participate in company/organizational improvement groups

What kind of questions will be asked?

- Are the outcomes expected?
- Are the recommendations feasible?
- What are internal sugestions for improving the usability of test results?
- Should the research have been performed differently?
- What is the personal (from expert point of view) association with change management?
- What are personal sugestions on improving change management?

A prediction of the outcome

- Reccomendations may not be feasible in the short term
- A balance can be established on where the company is now according to change management compared with the period of performing the graduation research
- Insights in the limitations of the research from a practical point of view (maybe considering the implementation of an improved change management system)

3.

Literature study

This chapter will contain the underlying theoretical basis for the explanatory research. The main goal of this chapter is to present existing tools and theories in order to unfold the actual problem into relevant elements that together form a theoretical framework(Verschuren & Doorewaard, 2010). In this chapter sub-question one and two will be answered as well.

According to the theoretical clarifications around the context of this research a framework is presented in the last paragraph of this chapter. Within this literature study multiple aspects will be studied:

- ***Complexity***
- ***Complex organizations by means of Mintzberg***
- ***Complex products and systems***
- ***Changes to complex products and systems***
- ***Change management to CoPS: by means of ITIL and ABS***
- ***Incidents due to and while implementing change***
- ***Incident analysis***
- ***Tripod Beta***
- ***Root cause analysis (by means of an Ishikawa diagram)***
- ***Human and Organizational factors***

As a reminder of the scope of this research the theoretical demarcation is shortly discussed by means of figure 3.

3.1 Theoretical demarcation

Figure 3 illustrates the implementation of a technical or software change to CoPS that is currently in the operational life cycle. The changes are requested during the operational life cycle of the CoPS. During the implementation of a change there is a possibility that an incident occurs. Figure 3 contains underlying theoretical concepts according to the implementation of change, the occurrence of incidents during the operational life cycle of CoPS. To structurally elaborate on these theoretical concepts, it will be build up by starting with complexity in general (Paragraph 3.2).

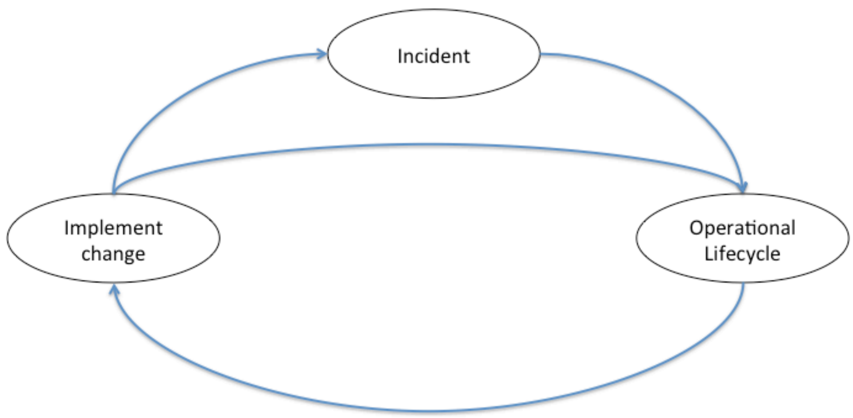

Figure 3: Schematic demarcation of focus area

3.2 Complexity

This thesis will cover three main types of complexity that make a distinction between technical complexity and complexity that arises from the environment and surroundings in which the engineering product operates. The distinction in complexity type is based on the work of (Sarah A. Sheard, 2010) an (Whitty & Maylor, 2009):

1. Structural complexity
2. Dynamic complexity
3. Socio-political complexity

Structural complexity is explained by means of three variables: size, connectivity and architecture. The size is characterized by the number of elements, number of instances and type of elements in the development process(Sarah A. Sheard, 2010). Thus structural complexity is mainly based on the number of different components that behave in a system. The nature of these components' interactive behaviour is defined in the dynamic part of complexity(Whitty & Maylor, 2009). The dynamic complexity is divided into short-term and long-term. Short-term dynamic complexity is characterized by the nonlinearity, dynamic emergence and sudden rapid change in system behaviour(Sarah A. Sheard, 2010). Sheard and Mostashari describe the long-term dynamic complexity as changes in number and types of elements and their relationships(Sarah A. Sheard, 2010). The third type of complexity is socio-political complexity where human cognitive limitations, multiple stakeholders, global context, environmental sustainability, economics are grouped amongst(Sarah A. Sheard, 2010). Complexity in engineering has both technical and non-technical aspects. Technical aspects contain of mainly complex software, interoperability of software that used to be designed to work separately and constantly evolving interdependent systems that are constantly changing(Sheard, 2012). The technical part in engineering and problems that occur due to this part of complexity are frequently the understandable part. Sarah A. Sheard stresses in her dissertation that engineers that have to deal with unknown and unapproachable socio-political problems are much less understandable because they have neither the aptitude nor the training to understand this type of complexity(Sarah A. Sheard, 2010).

3.2.1 CoPS of the offshore industry

The offshore industry contains of large companies that design, build, operate and maintain offshore structures, vessels, equipment and platforms. Offshore companies can be characterized as engineering-to-order (ETO) companies(Hicks & McGovern, 2009). The offshore industry delivers complex products and systems. Besides, they operate in a complex environment, which is characterized by constantly changing factors over time(Iansiti, 1995; Sheard, 2012). Practical examples of changing factors in the environment are unpredictable weather and constantly evolving safety instructions in different parts of the world.

In literature CoPS is defined as: "high cost, engineering-intensive products, systems, networks and constructs(Hobday, 1997). CoPS are an umbrella term for offshore equipment.

Such kind of industries can best be described by making a comparison between mass production industries and industries that are involved in designing, building, installing and maintaining CoPS. The equipment that operates in the offshore industry is not exactly mass production. In (Appendix 3) a table is presented that makes a distinction between CoPS project organisations and mass product organisations. The organisations that respectively produce CoPS and mass products are discussed with the help of six factors(Hobday, 1997):

1. Product characteristics
2. Production characteristics
3. Innovation processes
4. Competitive strategies and innovation coordination
5. Industrial coordination and evolution
6. Market characteristics

The most important findings according to the comparison of CoPS project organizations and mass product organizations are discussed here:

An organisation that deals with CoPS is usually characterized by complex component interfaces between different departments within the organisations and between organisations(Iansiti, 1995). Industries that produce mass products are characterized by simple interfaces. Product characteristics of CoPS project organisations are furthermore characterized by high unit costs versus low unit costs for mass production commodity goods(Hobday, 1997). The product lifecycle of CoPS lasts for decades whereas mass products have a relatively short product lifecycle(Hobday, 1997). Employees that work for a company that produces CoPS, often hold very specific embedded knowledge in order to fulfil highly specified tasks(Hobday, 1997). Furthermore, CoPS consist of a large amount of tailored components whereas mass products contain standardized components(Hobday, 1997). The production characteristics of CoPS versus mass production are mainly characterised by individual stand-alone products versus batches of products(Hobday, 1997). This can be recognized in the offshore industry because most of the equipment like cranes and pipe-lay towers are engineered to order(Hicks & McGovern, 2009).

Highly sophisticated products like CoPS are very innovative and are tailor made for specific clients that play a specific role in the offshore market(Tatikonda & Rosenthal, 2000). The innovation processes within the offshore industry is user-producer driven which means that innovative ideas arise while using the products in practice and this is communicated with the supplier company(Barlow, 2000). The CoPS are furthermore made in product-based multi-firm alliances where few companies are involved in the design, building, operating and maintaining the eventual asset like for instance a ship or rig(Hobday, 1997). Companies that are specialized in mass production goods are usually characterized by its supply chain structure and it is a single firm that produces all products in mass quantity(Hobday, 1997). In mass production companies the overall research and development is stored in multi-firm alliances(Hobday, 1997). The overall market characteristics for the CoPS companies and the mass-product companies appear as a duopolistic structure for CoPS companies and many buyers and sellers for the mass product companies(Hobday, 1997). CoPS companies are business to business and mass product companies are business to consumer(Hobday, 1997).

Now that the complexity characteristics of CoPS and the organisations in which they are made are set against mass products a focus is laid on changes during the lifecycle of the CoPS and the management of these changes. Considering the complexity of the CoPS and the offshore industry, a change is not something that can be implemented uncontrolled at any time. The next paragraph will focus on the characteristics of change and the management of change.

Intermezzo

Typology of an offshore business

Research is performed in the offshore industry but what kind of industry is this and what are its characteristics? Henri Mintzberg has described several organizational structures that cover all types of businesses. The offshore industry can best be described by means of an adhocracy(Mintzberg, 2007). An adhocracy is an organizational structure that is characterized by the complex, dynamic and turbulent environment in which the industry operates(Mintzberg, 2007). In order tot display the organizational structure of an adhocracy graphically the general structure of an organizational structure should be explained. In figure 4 an illustration has been provided on a general organizational structure which is built up from a strategic apex, a technostructure on the left side, support staff on the right side, middle line and at the bottom the operating core. Shortly described, starting from the top: the strategic apex contains of people who carry out the overall responsibility of the organization, the strategic apex must ensure that the companies' mission is executed effectively(Mintzberg, 2007). The technostructure within an organization is the domain of analysts who influence the work of other employees. They do not execute the job their selves but are responsible for the design of work tasks, planning and the training of operators. The support staff is responsible for facilitating everything that is needed in order to let the organization function properly. An example of a facility that is part of a support staff is the IT department, which facilitates all laptops and Internet infrastructure within the company. The middle line contains the connection between the strategic apex and the operating core where the top management is connected with the department managers.

This layer consists of operators and are directly involved in the production of the products and systems. Figure 4 gives a graphical representation of the organizational structure as described in this paragraph.

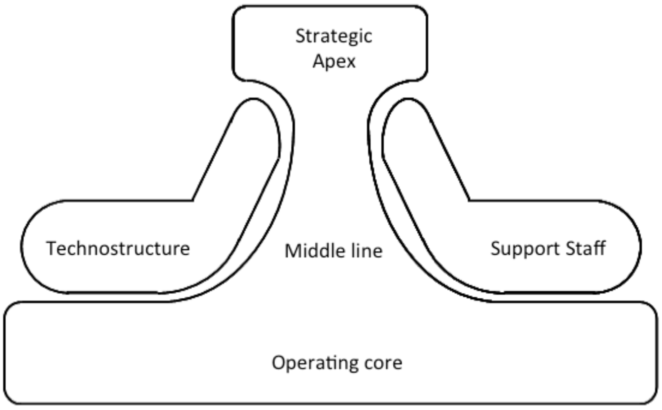

Figure 4: Organizational structure according to Mintzberg(Mintzberg, 2007)

The organizational structure of specifically an offshore business can be characterized as specifically an operational adhocracy (within the adhocracies) with elements of a line-staff organization and a matrix organization. An illustration of the representation by Mintzberg is given in figure 5.

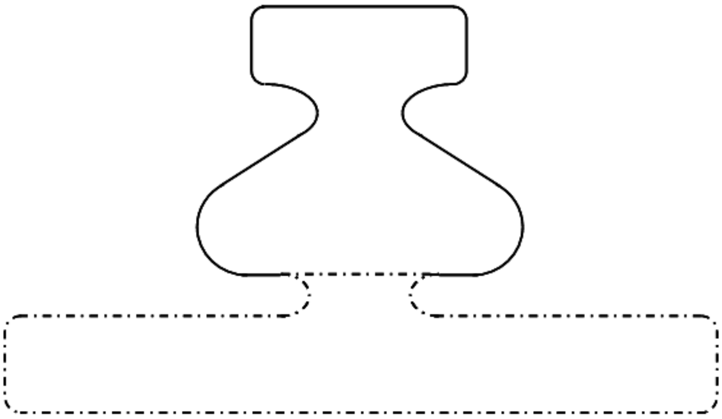

Figure 5: Adhocracy according to Mintzberg(Mintzberg, 2007)

3.2.2 Changes to CoPS

As mentioned in a previous paragraph, the offshore industry is an industry that operates in a complex environment and designs, builds, installs and maintains CoPS. Besides, the CoPS require several changes during its lifecycle in order to maintain functionality as requested by the client(American Bureau of Shipping, 2013). Therefore, changes are frequently requested due to all facets of complexity see paragraph 3.1. The structural complexity describes a high level of interrelated technical or software elements. The dynamic complexity describes the volatility of the systems and the socio-political complexity describes the complexity of the environment in which the business (and its products and systems) operates. These different types of complexity make it likely that many changes are frequently requested in order to retain the functionality of the products and systems.

One of the main challenges about changes, and at the same time a major reason why changes should be managed, is that change to a particular element of the CoPS propagates to other elements of the product or system(Eckert, Clarkson, & Zanker, 2004). If the implementation of a change is not managed in a controlled way it could result in catastrophic accidents(Cranch & Delaney, 2010; Verkerk & Ee, 2013). In order to fully understand the concept of change and the urge for change management, change will be investigated in detail.

Changes are frequently requested during a CoPS's lifecycle (Sudin & Ahmed, 2009). Specifically complex software systems increase in their complexity and according to Lehman's laws of software evolution it can be stated that software must continually adapt to its environment otherwise it becomes progressively less usefull(Guowu Xie, 2009). The software is intensively used and actively maintained and therefore can be stated that software is continually undergoing change(Guowu Xie, 2009). A change is defined as the modification of CoPS or components in order to meet engineering specifications and design criteria (Ahmed & Kanike, 2007; Huang & Mak, 1999). Changes can be triggered at any point in the product lifecycle (Ahmed & Kanike, 2007) and can be carried out in two situations (Sudin & Ahmed, 2009):

1. Change can rectify errors (Reactive)
2. Change could be aimed to improve the product and to prevent errors from occuring (Proactive)

The lifecycle of CoPS contains of a development phase, manufacturing/building and testing phase and the operational/service phase. In either of these phases changes are made to resolve errors or changes made to improve the CoPS. According to research of Sudin and Ahmed (2009), product improvements are the main driver in the development phase. In the operational phase a lot more error correction changes are made compared to product improvements(Sudin & Ahmed, 2009).

In addition to the distinction between reactive and proactive change, a distinction can be made between internally and externally initiated changes. External changes are changes that are initiated by parties outside the company as for instance customers, suppliers or from contractual agreements (Ahmed & Kanike, 2007). Internal originators of changes are the employees that have operational experience, have manufactured/assembled the CoPS, have produced or build the CoPS. Research of Ahmed and Kanike shows an increase of internal changes towards the operational/service phase of the lifecycle. This is compared with a decrease of the external changes towards the operational/service phase of the lifecycle (Ahmed & Kanike, 2007).

In this paragraph is described why changes are requested so often based on the characteristics of complexity. The question that arises from the change requests, which can occur under a variety of factors, is how are the changes managed? The next paragraph will *focus on this question by describing two standards for change management that are respectively used for software changes and changes in the marine and shipping industry.*

3.2.3 Management of changes to CoPS within the offshore industry

Changes are necessary to reach initially defined standards of the CoPS or to resolve errors(Eckert et al., 2004). But how are these changes managed in an organized manner, especially in a complex environment with complex equipment and systems that are highly connected with each other? This complex environment can be illustrated by emergency systems (fire protection, gas detection, life saving, life support), hazardous areas, supervisory control systems (highly sophisticated software systems) and communication between different disciplines, departments, locations, offices and vessels throughout a variety of time zones(American Bureau of Shipping, 2013).

Two standards that describe change management in detail are investigated. They are briefly discussed below and a more elaborated explanation can be found in the appendix 4. ITIL (Information Technology Infrastructure Library) provides a framework to implement mainly software changes. This software standard is chosen due to the frequent requests for change that occur in software driven equipment. Since the specific area of scope is the offshore industry the search for change management standards was specifically narrowed towards the marine and shipping industry. This makes ABS a suited change management standard.

Change Management according to ITIL

ITIL gives a description of how to create a clear scope to perform change management to a request for change of certain software of the equipment, project or business. According to ITIL the specific goal of change management is set together with a change management procedure and the roles and responsibilities that are defined in the procedure.

As stated previously the offshore industry is a complex business that requires a systematic approach for implementing changes(Barlow, 2000). Because of the highly sophisticated equipment and systems (CoPS), requests for change frequently occur. Software updates or modifications might be requested or the hydraulic, electrical or mechanical functions must be upgraded. In either of these disciplines errors can occur as well and generally the overall objective of change management and of the ITIL standard is to deal with internal and external change requests to CoPS(Barlow, 2000; Hobday, 1997; Lacy & MacFarlane, 2007). More specific the objective is to make sure that changes are recorded properly, evaluated, authorized, prioritized, planned, tested, implemented, documented and reviewed in a systematic manner(Lacy & MacFarlane, 2007). By performing change management employees, departments and, companies try to reduce incidents, disruption of equipment and the chance that equipment needs to be build again or needs to be modified because of remaining inaccuracies(Whittleston, 2012).

Changes take place in various phases of the lifecycle of CoPS(Ahmed & Kanike, 2007; Sudin & Ahmed, 2009). Main reason to manage change is to keep an overview of what is changed and on which other components or systems these changes propagate(Eckert et al., 2004). Working in such a systematic way creates a controlled risk exposure and information on the variety of components and systems that are influenced by the change minimizes disruption which eventually leads to a successful functioning CoPS in the first time(Tatikonda & Rosenthal, 2000). Summing up the main goals of change management according to the ITIL standard:

1. Controlled risk exposure
2. Severity of the impact of changes and disruption can be minimized
3. Being successful the first time

<u>Change management according to ABS</u>

The ABS provides a standard for management of change for the marine and offshore industries, which makes it suited for this thesis. Specifically a US standard is chosen since many offshore businesses are performed in the Gulf of Mexico, near the coast of Houston, Texas. Many catastrophic accidents were the result of inadequately managed changes and a well documented “management of change program” can contribute towards the reduction of incidents in the offshore industry(American Bureau of Shipping, 2013). The management of change flow chart according to the ABS standard briefly consists of six steps (American Bureau of Shipping, 2013):

1. Initial review
2. Senior review
3. Detailed risk assessment
4. Approval
5. Implementation
6. Verification and closeout

3.3 Incidents that can occur due to the implementation of change

Investigations of major incidents show that technical, human, operational as well as organizational factors influence the incident sequence(Vinnem et al., 2012). Various tools are available to analyse incidents and different tools can expose different categories of incident causes, a Tripod Beta Analysis and an Ishikawa diagram are two different types of tools that have previously been used to analyse incidents in the offshore business and will be discussed below.

3.3.1 Incident analysis by Tripod Beta Incident Analysis

When an incident occurs an incident analysis can be performed according to the Tripod Beta Incident Analysis (TBIA). This is a technique that is commonly used in the oil and gas exploration and production industry and the supply industry for oil and gas. TBIA promotes thorough incident investigation with clear, concise and consistent reporting(Gower-Jones, Graaf, & Doran, 1998). The associated approach contains of three phases. The incident (first phase) is described in terms of hazards, targets and events. The second phase consists of the examination of the circumstances in which the incident has occurred. The scope of this phase is mainly on-site activities, but when it is required the scope may also be broadened in order to focus on off-site activities as well. The focus in the second phase lies on which parts of the control and defence systems failed to work. The third phase focuses on the underlying causes for the incident. TBIA system states that once an incident or hazard occurs when there are failures in the controls or barriers. The controls and barriers are parts of the process where wrong decisions could be made and cause accidents. Gower-Jones et al. (1998)(Gower-Jones, Graaf, Production, & Doran, 1998) state that not only hardware barriers exist but also soft barriers like for instance procedures and training. However TBIA analysis focuses mostly on the hardware barriers. For each missed control or barrier a causal system can be set up as shown in figure 6.

Figure 6: Tripod causation path

This causal system consists of three phenomena namely "latent failures", "preconditions" and "active failures". Theory states that incidents are often a consequence of multi-causal events(Gower-Jones, Graaf, Production, et al., 1998). Combinations of remote causes, which are called latent failures and my have existed in the organization for a long time could lead to the preconditions that eventually lead to an incident. Examples of latent failures are the cultural mind-set or differences within an organisation, characters of people/employees or certain interpretations of business processes. Latent failures are quite often called external factors because they indirectly lead to an active failure. It is difficult to fully distinguish a latent failure since they are deeply embedded in the organization and require a structural approach to rectify. Latent failures can lead to preconditions for actual active failures. Preconditions are more specifically defined towards the active failure like inaccurate communication on specific software updates for instance. The active failure that results from (combinations) of preconditions is the failure that is experienced.

Advantages and disadvantages of the TBIA method

A large advantage of using the TBIA method is consistency in investigation of incidents and is also useful in investigating near misses. However it takes some time in order to get familiar with the working of this tool and the mind-set that is required for using this tool properly. Furthermore the TBIA is an efficient incident analysis methodology(Ji & Zhang, 2012). TBIA describes a consistent structure of investigating incidents and the methodology provides early feedback on potential incident causes, which makes it able to manage and control latent failures in an early stage(Ji & Zhang, 2012). A very relevant advantage of this methodology is the prevention of preference judgement and focuses on objectivity.

Disadvantages of the TBIA methodology lay in the theoretical background of the methodology. Underlying causes for incidents are grouped into eleven categories; so called Basic Risk Factors (BRFs). However the BRF's are not detailed enough to provide detailed information on specific underlying causes(Ji & Zhang, 2012).

Another method that focuses more directly on root causes, sub causes, sub-sub causes and so on is called the Ishikawa method. This method will be described in the following paragraph.

3.3.2 Root cause analysis and Ishikawa diagrams

Examples of detailed incident investigation methods that are frequently used in the offshore industry are root cause analysis (Pranger, 2009). A specific example of a root cause analysis that is commonly used for the investigation of undesired effects is called an Ishikawa diagram(Ishikawa, 1985). An Ishikawa diagram is an example of a cause-and-effect diagram and is frequently used in medical professions in order to investigate but also exclude causes for medical conditions.

An Ishikawa diagram is structurally built up in accordance to five basic rules. When these rules are followed a feasible Ishikawa diagram will be the result. According to Kaoru Ishikawa there are five general steps in designing a cause-and-effect diagram(Ishikawa, 1985). The result is illustrated in figure 7:

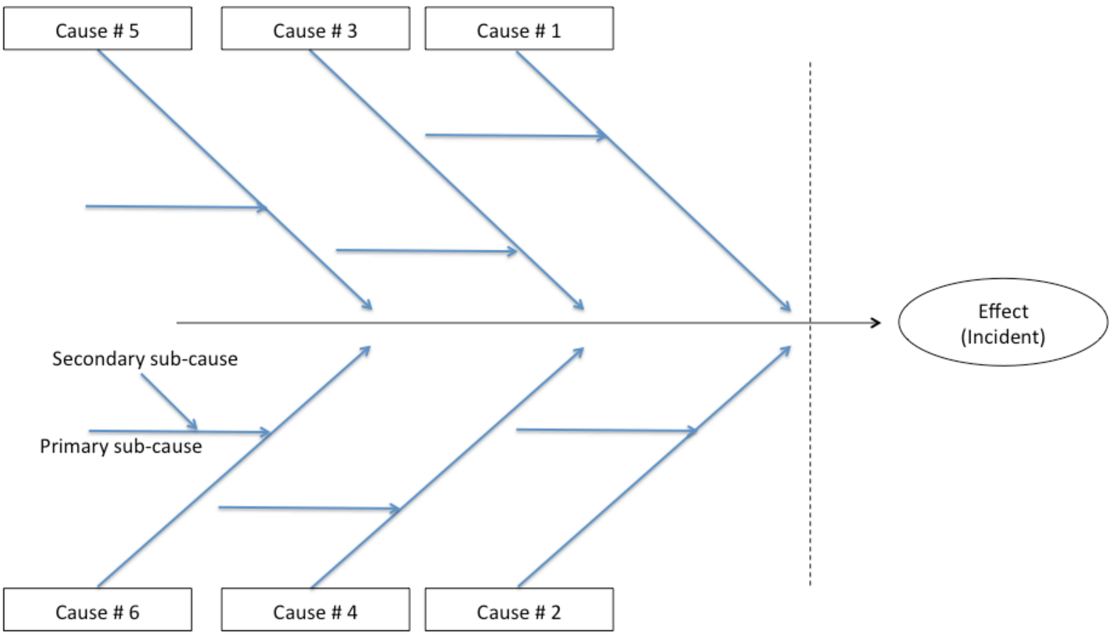

Figure 7: Ishikawa diagram from Aatsengel and Kurtoglu(Aartsengel & Kurtoglu, 2013)

1. Decide on quality characteristics
2. Write quality characteristic on right side
3. Write main factors that may be causing quality characteristic
4. Write detailed factors (primary sub-causes and secondary sub-causes) onto branch items that may be regarded as causes
5. Check if every possible cause is in the diagram

Results of an Ishikawa diagram

The problem/incident that is unravelled by designing an Ishikawa diagram provides insights into the causes of an incident by means of following the steps mentioned by Aartsengel and Kurtoglu(Aartsengel & Kurtoglu, 2013). The different categories of causes all have a causal relation to the incident. The different identified causes and its primary and secondary sub-causes all part of a specific category that can be focused on in order to investigate solutions for the problems/incidents. There are several categories of common causes that lead to the incident that is being researched. Several major cause categories have been formulated in literature and provide an impression on how the Ishikawa diagram works(Ji & Zhang, 2012).

Deriving causes in a structured matter is obtained from the theory of root cause analysis(Ji & Zhang, 2012). The focus of the cause categories for an Ishikawa diagram can be either obtained throughout discussion with involved parties in a more subjective manner or justified by asking 15 specific questions to deduce the cause categories in an objective manner(Aartsengel & Kurtoglu, 2013; Ji & Zhang, 2012), see table 4 (legend is presented in table 3). Questions are asked in 3 main categories and should be answered with yes or no.

(light green)	Individual Performance
(red)	Team Performance
(light blue)	Management System

Table 3: Legend

1	Was a person excessively fatigued, impaired, upset, bored, distracted or overwhelmed?
2	Should the person have had and used a written procedure but did not?
3	Was a mistake made while using a procedure?
4	Were alarms or displays to recognize or to respond to a condition unavailable or misunderstood?
5	Were displays, alarms, controls tools, or equipment identified or operated improperly?
6	Did the person need more skill/knowledge to perform the job or to respond to conditions or to understand system response?
7	Was work performed in an adverse environment (such as hot, humid, dark, cramped, or hazardous)?
8	Did work involve repetitive motion, uncomfortable positions, vibration, or heavy lifting?
9	Did verbal communications or shift change play a role in this problem?
10	Did failure to agree about the who/what/when/where of performing the job play a role in this problem?
11	Was communication needed across organizational boundaries or with other facilities?
12	Was a task performed in a hurry or a shortcut used?
13	Had a management been warned of this problem or had it happened before?
14	Were policies, administrative controls, or procedures not used, or in need of improvement?
15	Should an independent quality control check have caught the problem?

Table 4: Root cause investigation questions(Ji & Zhang, 2012)

The answers to the questions that are grouped in table 4 will lead to the following cause categories that form the basis of the Ishikawa diagram:

1. Procedures
2. Training
3. Quality Control
4. Communications
5. Management System
6. Human Engineering
7. Work Direction

All these categories represent areas in which primary and secondary sub-causes can be grouped and which are causes for the formulated problem/incident that should be investigated. Below the cause categories will be explained.

Cause category Procedures

Causes for incidents that lay in procedures may occur in several forms and can either be the result of a wrong procedure in general, an incorrectly followed procedure or the procedure was not used or followed at all. According to Ji and Zhang (2012) examples for possible reasons why the procedures were not used or followed could be because there is no procedure or the procedure is not available or inconvenient for use or the procedure is difficult to use(Ji & Zhang, 2012).

Training

Complex industries that operate in complex environments with CoPS require highly and specifically trained employees(Barlow, 2000). Training can also be a cause for incidents since there can either be no training available for work that definitely requires training or the purpose of the training is not sufficient. The practical result of no training or lack of training is that an incident could occur because an employee should have been aware of what to do when he was trained properly.

Quality Control

During the lifecycle of complex equipment changes are requested and implemented frequently(Vinnem et al., 2012). Changes are implemented either with a corrective function or an improvement function(Sudin & Ahmed, 2009). The main goal is that the quality of the equipment should be maintained and frequently controlled. Quality control is performed by quality inspections and these inspections can be the source for errors when they are performed incorrectly(Ji & Zhang, 2012). Either an inspection is not required at all, or the inspection that is performed needs improvement

Communication

Due to the complexity of offshore industries and the products and systems the industry works with, adequate communication is evident. Various departments and disciplines interact with each other and require proper communication. There could be lack of communication, no communication or late communication. There could be issues with the turnover process considering the changing of the day- and nightshifts. A simple misunderstanding or misinterpretation of verbal communication can lead to a severe incident(Ji & Zhang, 2012).

Management System

Management should represent different interests considering projects to be in time, within budget and maintaining the highest quality(Mantel & Meredith, 2009; Maylor, 2010). These interests could be in conflict with each other, the client may demand the project to be finished in a certain amount of time, but the engineers from the company that executes the project might not agree on the proposed amount of time because it is not possible. Perhaps there are causes for incidents due to lack of time for careful work in order to deliver the piece of equipment in time. According to Ji and Zhang (2012), management systems contain of standards, policies or administration controls (SPAC)(Ji & Zhang, 2012). Either there is no SPAC, or they are not strict or clear enough.

Human Engineering

Many people work in complex offshore industries and where people work it is likely that incidents can occur due to their actions(Hobday, 1997). People are involved in every business activity and every business decision. When a process or policy or a business decision is not clear to people, for instance because it has not been clearly explained or not clearly been communicated people can make mistakes and can form causes for incidents. A relevant and important cause for incidents can therefore be attributed to human engineering. Human engineering can be split up in four sub-categories that can all contain causes for incidents:

1. The human-machine interface
2. Work environment
3. The complex system
4. A “not-fault tolerant system”

Work Direction (preparation of an assignment)

Complex jobs require proper preparations and carefully selected highly trained workers(Ji & Zhang, 2012). However issues can take place in the preparation phase of a job; people might not prepare at all or the work permits abroad are not yet in time, the pre-job briefing went wrong or was insufficient. The worker himself can be fatigued or not qualified or specialized enough for a certain job. Along the execution phase of the job there might be supervision or maybe there is no supervision and errors and mistakes maybe overlooked(Ji & Zhang, 2012).

Advantages and disadvantages of the Root Cause Analysis

The combination of theory on root cause analysis and the specific technique “Ishikawa diagram” provides several advantages and disadvantages. The advantages of a root cause analysis are that the methodology is based on a set of well-defined operational definitions and questions. Secondly according to Ji and Zhang (2012): “*the root cause analysis is grounded in the human factors theory, which supports the fact that people are the key to*

organizational success and most often the source of most problems due to the design of systems and processes they use and the decisions they make as they do their jobs each day" (Ji & Zhang, 2012). Thirdly a root cause analysis will provide a clearly defined problem, a focused set of root causes and a divers set of corrective actions(Ji & Zhang, 2012; Pranger, 2009). Many years of research and application have discouraged incident investigators to primarily rely on their subjectivity when identifying root causes for incidents. The advantage of a fishbone diagram is that individual perspectives of involved employees can be captured in a figure and that the causes can be discussed with each other.
Disadvantages of a root cause analysis is that compared to other incident investigation methodologies, the root cause analysis is not clear on the relationship between errors, causal factors and root causes. Disadvantage of a fishbone diagram is that it is a methodology that is based on the subjectivity of involved people.

The next paragraph will elaborate on the quote of Ji and Zhang (2012) by focusing on the human and organizational factors. Ji and Zhang (2012) stress out in their theory that the root causes analysis is grounded in human and organizational factors. Therefore, the focus will be sharpened towards specifically the human, process and organizational role in the root cause analysis.

3.4 Human and Organizational Factors and Human Factor Engineering

The TBIA and the Ishikawa diagram as example of a root cause analysis, provide an opportunity to investigate possible causes for a predetermined effect. The possible cause categories imply that there are also causes that find their origin in the organizational setup of a company and human interactions that are required between involved departments and employees in order to get the job done. Major hazard risk management for offshore equipment is mainly based on improved understanding of the influence of organisational, human and technical factors(Gran et al., 2012). Human and Organizational Factors (HOF) and Human Factor Engineering (HFE) theories describe the causal relationships between human, organizational and technological factors that might cause incidents in the offshore industry(Ren, Jenkinson, Wang, Xu, & Yang, 2008). Incidents in the offshore industry are usually not caused by a single corrective change but by the conjunction of the effects (errors) that the changes have on different functional aspects of the complex piece of equipment(Ren et al., 2008). In the operational lifecycle of CoPS incidents are often initiated by errors induced by technical failures, HOFs or a combination of both(Barlow, 2000; Ren et al., 2008). The techniques that have been used in order to investigate incidents in the history of the offshore industry were traditionally focused on the hardcore technical design, construction and operation rather than on the human and organizational aspects(Ren et al., 2008). A systematic approach means that when an incident is analysed all functional entities, inter-relationships within subsystems and all undesired events are considered(Beard, 1989). Besides, the functioning of the CoPS can be maintained by implementing corrective changes or changes that improve the functioning of the CoPS(Tatikonda & Rosenthal, 2000). Two concepts of human and organizational factors will be introduced here according to Miller and Bea (Bea, 1998; Miller & Associates, 1999):

1. Human and Organizational Factors (HOF)
2. Human Factor Engineering (HFE)

HFE is a trend in HOF that is introduced to the offshore industry and is dedicated to applying this information to enhance human performance, safety, and quality of life in all aspects of a human's existence, including his/her job(Miller & Associates, 1999). A HOF program including HFE together contain of eight elements and ignoring any of these elements could lead to unsafe situations and an increase of the possibility for human errors. The eight factors are illustrated in the "triangle of effectiveness" and are illustrated in figure 8. The triangle is based on the degree of supportiveness of HOF elements (Miller & Associates, 1999), which are:

1. Management participation
2. Workplace design
3. Environments (external, internal and social)
4. Personnel selection
5. Training
6. Interpersonal relationships
7. Procedures (formal and informal practices that are followed in performing operations)
8. Fitness for duty

Figure 8: Triangle of effectiveness(Miller & Associates, 1999)

When taking into account all eight elements, an image is created on how incidents could occur from the human behaviour point of view.

The management participation is essential in a HOF program if there is no management support there is no incentive for developing any HOF program. Management should have a supportive role towards HOF; therefore management participation is situated in the most supportive (bottom) column of the "triangle of effectiveness".

The workplace design element illustrates insights into the human behaviour and insights into the capabilities and limitations of the offshore workers. These insights can lead to improved work environments, since these capabilities and limitations are taken into account at the work places(Miller & Associates, 1999; Rundmo, Hestad, & Ulleberg, 1998).

Environments (external, internal, and social) of offshore industries are complex. There are external, internal and social environments that all behave in a certain way and have a certain effect on the performance of an organisation. Not every environment is easy to control or predict(Bea, 1998).

Personnel selection. Personnel should be capable of working with highly complex equipment, knowing what to do in unsafe conditions and most of all, must be capable of working under much stress and a high workload. Personnel must be selected adequately in order to prevent incidents from happening due to human characteristics, which one could have been informed of on beforehand(Rundmo et al., 1998).

Training consists of safety training for offshore personnel in offshore environments, first aid training and emergency response training. These are formal training in order to get familiar with safety procedures and standards. But personnel can also be trained in company standards and procedures. When a company requires personnel to use a change management procedure when implementing change, they should be trained on the use of these procedures(Miller & Associates, 1999; Rundmo et al., 1998).

Interpersonal relationships in the offshore industry are often characterized as a one-way, top-down chain-of-command(Miller & Associates, 1999). The interpersonal relationships in the offshore world are shifting towards more team oriented, which aims for giving and taking input and comments regardless of hierarchical function or rank(Bea, 1998; Rundmo et al., 1998).

Job Aids focuses on a clear instruction in order to perform a job or a task in a safe and orderly manner. An important feature is that an instruction is not overwhelmingly complex or too time consuming to read properly. Incidents might occur if the instructions are of poor quality. Hazard signs and safety instructions in pictorial form are example of job aids that are easy to understand and to follow(Bea, 1998).

Fitness for duty means both physically and mentally being able to handle the job. People should be able to withstand heavy physical workload and mentally able to cope with working long distant jobs and being abroad for a long time(Bea, 1998; Rundmo et al., 1998).

Difficulties HOFs

However dealing with HOFs in the complex offshore industry are accompanied by some difficulties considering the HOFs according to Ren et al(Ren et al., 2008):

First of all it is difficult to agree upon what HOF really means since HOFs are applicable to various aspects of organizations. The management of organizations, responsibilities within organizations, responsibilities towards jobs and specific tasks, communication, training, the use of change management protocols to induce standardization of work procedures or the reduction of incidents due to human error. Secondly HOFs are hard to measure: how could factors individually be prioritized, how are they related to each other and how can they form an assessment framework together? Thirdly, it is difficult to collect adequate data from industries because HOFs are difficult to quantify. Fourthly it is hard to establish a uniformed framework to model HOFs related to offshore safety issues since all risk factors should be taken into account and it is unclear how all factors are related to each other. The relation of risk factors to each other requires great experience in understanding offshore safety issues (Ren et al., 2008). The fifth difficulty considers that it is hard to use conventional assessment approaches to deal with HOFs due to the fact that there is no clear quantification described for the incorporation of subjective perceptions or vague terminology that human and organizational factors are illustrated with(Ren et al., 2008).

3.5 Towards a theoretical framework

When summarizing the previous conducted literature study on the complexity of the offshore environment, the characteristics of CoPS and change management in the offshore industry, it is likely that incidents occur from a combined perspective of factors.

The complexity and the impact of incidents due to the implementation of change in the offshore industry require a thorough analysis. TBIA and an Ishikawa diagram are two examples of methodologies that are frequently practised to analyse incidents with CoPS. Focus in analysing the incidents due to changes, lay in the interaction of three fields:

1. Technology
2. Process/Organization
3. Humans

These three perspectives can be devided in several factors that are presented in the tables below. The technical factors are obtained from the technical departments, which represent the characteristics of the equipment that the offshore companies work with (chapter one and represented here below in table 5). The process and organizational factors are obtained from ITIL and ABS (paragraph 3.2.3 and represented here below in table 6) and the human factors are obtained form the Human and organizational theories (paragraph 3.4 and represented here below in tables 7-14).

TECHNICAL FACTORS

1.	Software
2.	Electrical
3.	Hydraulic
4.	Mechanical

Table 5: Technical factors

PROCESS/ORGANISATIONAL FACTORS (ITIL/ABS)

1.	Clear roles and responsibilities within management of change program
2.	Appropriate organizational preparation
3.	A written MoC program manual that includes MoC forms
4.	Pilot MoC program
5.	Training of personnel
6.	Attention when integrating change management protocol with existing protocols
7.	Company culture
8.	Record keeping

Table 6: Process and organizational factors obtained from ITIL and ABS

HUMAN FACTORS (HOF)

1.	Uniformity of rules regardless of position in company
2.	Easiness to read and understand company policies
3.	Establish offshore work schedules according to 24 hours rhythm
4.	Establish duty tour lengths to prevent fatigue
5.	Aggressively pursue safety issues by creating high level risk manager
6.	Employees identify and monitor unsafe acts themselves and make sure those acts are deleted from daily work routine
7.	Positive rewards for following company regulations
8.	Design all facilities to satisfy employees' needs to eliminate the workers' need to take unsafe short cuts
9.	Create and support company policy regarding maintenance of company assets
10.	Getting employee contributions when establishing rules
11.	Team responsibility instead of caste order of control
12.	Providing an overall worksite designed to match the workers' physical, mental and social capabilities

Table 7: Management participation factors

1.	Provided information (how many and in what form?)
2.	Shape, size, location and orientation of the controls and displays used by the workers
3.	The total arrangement of all of the hardware and software the worker uses
4.	Type of communication
5.	Frequency of communication
6.	Importance of communication

Table 8: Workplace design factors

1.	Allowing the physical environment to exceed known and established limits can increase the likelihood of an environmentally induced human error to occur on any offshore facility
2.	Dealing with different time zones
3.	Physical barriers between offshore vessels/rigs/platforms and onshore offices

Table 9: Environmental control factors

1.	There are jobs in every industry that require special human physical, social or psychological skills not possessed by the population at large
2.	Family circumstances
3.	Psychological health
4.	Physical health

Table 10: Personnel selection factors

1.	There are jobs in every industry that require special human physical, social or psychological skills not possessed by the population at large
2.	Family circumstances
3.	Psychological health
4.	Physical health

Table 11: Training factors

1.	Who is involved (department/expertise)?
2.	Who is responsible?
3.	What is exactly sold (contract)?
4.	Comfortable culture

Table 12: Interpersonal relationship factors

1.	Printed or pictorial instructions on how to accomplish a task or follow directions
2.	Operations and maintenance manuals, job procedures, hazard warnings, company policy and practice manuals, checklists, and other written materials

Table 13: Job aids factors

1.	Psychological, physical burdens or blessings
2.	Family circumstances
3.	Psychological health
4.	Physical health

Table 14: Fitness for duty factors

Technology is traditionally the component where the investigation for the root causes of incidents starts but due to the complexity of offshore organisations in general technology is not the only component that should be investigated(Miller & Associates, 1999; Ren et al., 2008). Complexity of an offshore organisation and its CoPS illustrates the interrelation of many characteristics. Many literature states that the origin of approximately 80% of the incidents in the offshore industry lays in human error(Ren et al., 2008; Rundmo et al., 1998). Therefore human factors may not be disregarded when investigating incidents. First of all traditionally technological sequence of events is created and investigated by means of a TBIA(Gower-Jones, Graaf, & Doran, 1998; Gower-Jones, Graaf, Production, et al., 1998; Turksema, Postma, & Haan, 2007). Disadvantages of a TBIA is that not all categories of root causes of incidents can be fully disclosed in an objective way which is required for this particular analysis(Ji & Zhang, 2012; Pranger, 2009). The root cause analysis in the form of a fishbone (Ishikawa) diagram is a technique to analyse incidents in a more subjective manner on the basis of discussion and group sessions of involved parties(Ji & Zhang, 2012). By structurally going through the root cause investigation questions that focus on individual performance, team performance and the management system, seven main investigation categories for the Ishikawa diagram are identified(Ji & Zhang, 2012). By focusing on "procedures" as the first root cause category from the Ishikawa diagram the change management procedure used for implementing change during the lifecycle of the CoPS is investigated. By investigating the concept of change and the implementation of change in a structured manner according to the ITIL standard is concluded that the main goals consists of minimal risk exposure, the severity of the impact of changes and disruption are minimized and first attempt to implement a change directly succeeds (first time right)(Lacy & MacFarlane, 2007; Whittleston, 2012). Considering the root causes category "human engineering" from the Ishikawa diagram the urge for the investigation of human factors as a cause for human error in offshore incidents comes into sight. Research according the HOF can be done in order to investigate true causes for incidents and find feasible results for the improvement of change management procedures with the incorporation of a spectrum of technological, process/organizational and human factors.

Therefore a theoretical framework of the interrelations of the main categories for root causes of incidents due to reactive or proactive changes(Bea, 1998) in the offshore industry is built up of technology, process/organization and people.

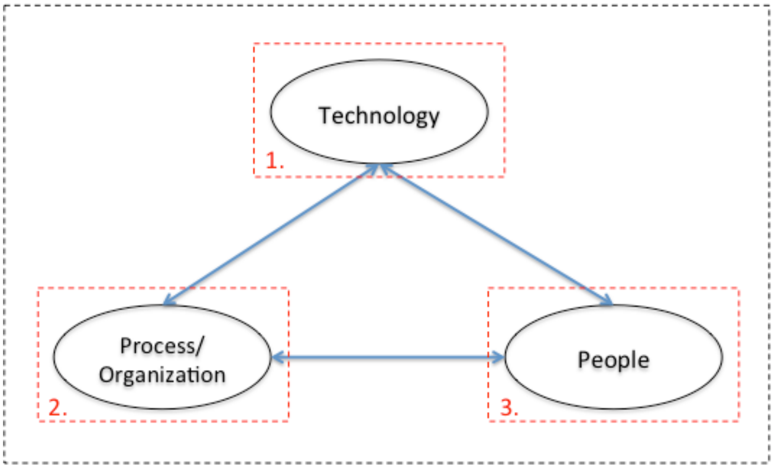

Figure 9: Interrelations between technology, process and organization, and people

The focus within this research by means of this framework lies on technology since of the "hard" technological knowledge that is the basis of the core business of an offshore company. An offshore company has a certain culture, which was experienced by the researcher where many standards and processes are in order to cope with the amount of work in a structured manner and tell how people should work. An offshore company is a multi-layer organization with various roles and responsibilities for employees. The core business is based on complex technical products and systems, which brings along organizational characteristics, certain protocols, processes and a specific corporate culture. At the same time this core business creates an environment where certain people work who think, behave, act and interact in a certain way. These findings create an image that can be captured in the framework as presented in figure 9. *Thus the main goal of this framework is to investigate, identify, structure and reflect on the causes of incidents that occur because of* *the implementation of change during the operational life cycle of CoPS. Root causes of incidents are based on an interrelation between technological, process/organizational and human factors.*

Furthermore the framework in figure 9 will help to perform the research. Combining theories on different subjects led to insights into the theoretical nature of change and the occurrence of incidents. In the following chapters these theories will be kept in mind while investigating the case company in chapter four and three pipe-lay incidents in chapter five.

4.

Case description

This chapter will give an in-depth description of the case company Huisman Equipment BV and the specific service department within Huisman Global Service. This is a specific company in the offshore industry and in this chapter will be described what complexity means in the context of the case company. A short general overview on the history of Huisman will be given in paragraph 4.1; secondly a sketch is made of the service department and the organisational structure of the company in paragraph 4.2. The system change management system that ought to be used to implement change is described in paragraph 4.3

4.1 Introduction to Huisman Equipment BV

Huisman Equipment BV is a worldwide operating company with extensive experience in the design and manufacturing of heavy construction equipment for world's leading on- and offshore companies. Founded in 1929 and originally a steel construction company, Huisman joined forces with engineering company ITREC in 1987 to develop products entirely under own management, from concept to installation. The product range of Huisman Equipment B.V. can be subdivided into seven main categories(Huisman Equipment BV, 2008):

1. Cranes
2. Pipelay Equipment
3. Drilling Equipment
4. Heave compensation
5. Winches
6. Vessel Designs
7. Specials

The products vary from stand-alone components to highly engineered integrated systems. The production is divided between production facilities in The Netherlands, China and Czech Republic. The construction of the new production facility in Santa Catarina, Brazil, has started in 2012. Additional sales, engineering and service offices are located in Slovakia, Brazil, Singapore and the USA (Huisman Equipment BV, 2008). The maintenance of the Huisman product range is executed by Huisman Global Services (HGS). HGS is part of the Huisman group and is charged with the maintenance of the Huisman product range. The Service department in which this research has been performed is part of HGS. Whenever Huisman Equipment B.V. delivers a piece of equipment to one of its clients the maintenance of this particular equipment will be carried out by the Service department of HGS. This means that, whenever the client requests for maintenance activities, service engineers of HGS will travel to the vessel that contains Huisman equipment (Huisman Equipment BV, 2008).

4.1.1 how does Huisman and in particular HGS work?

Huisman Equipment BV designs, builds, installs and maintains equipment for the on- and offshore industry. Once the equipment is delivered and installed on- or offshore it will be handed over to HGS. This means HGS will maintain the equipment during the life cycle of the equipment. But in the first place clients will come to the account engineers of Huisman Equipment BV in order to order a product or system that meets their expectations. When an agreement is made, the design will start or when it is an existing piece of equipment that has been designed and built previously a start can be made with the implementation of the changes. In order to implement a change in a structured and concise manner a protocol has been designed. The implementation of a change should be done according this protocol where exactly is described how a change is initiated until the change can be considered implemented. Paragraph 4.2 will discuss the change management protocol in detail.

4.1.2 Organizational structure of Huisman

In order to gain insights in the functioning of the organization of Huisman Equipment BV and HGS "Organizational Structures" written by Henry Mintzberg is used. Primarily Huisman can by characterized as an "adhocracy". Within HGS specifically the manager of the service department forms the connection with the general manager of Huisman Global Service and the operating core that contains of service engineers, specialist engineers and service technicians. This finally leads to the last layer within an organizational structure called the operating layer.

The organisation operates in a highly technical environment with a strongly innovative character. In an operational adhocracy the focus lays on the operating core. More explanatory characteristics for a company like Huisman Equipment BV according to Mintzberg is the importance of training of employees within the organisation(Mintzberg, 2007, pp. 282-283). The organisation can furthermore be characterised by its functional and market oriented characteristics, the strategic apex has a lot of external contacts, the operational core is combined with the board in an operational adhocracy, the middle line is comprehensive but combined with staff and involved in project works(Mintzberg, 2007, pp. 282-283). The technostructure is small and is combined in the middle of project works, support staff is very comprehensive and combined in project works as well. Furthermore the importance of informal communication is considered to be significant and the decision making process is combined throughout all layers. An operational adhocracy is a typical young organisation that has experienced an extensive growth within a relatively short amount of time, the technical systems of the company are highly sophisticated and often automated.(Mintzberg, 2007) The environment in which the organisation operates is very complex and dynamic and as earlier mentioned the environment could be quite turbulent as well considering the sometimes politically instable countries where is operated and the risks of working offshore brings along operations.

A representation is given on how the operational adhocracy looks "inside" for specifically Huisman Equipment BV and within Huisman Global Service. In order to create an image in which part of the company the graduation research is performed a rectangle has been tinted orange. This part of the organisation is the Service department and this department forms part of Huisman Global Service. The employees of the service department report to a project manager that every department like the service department has. In figure 10 this is represented as the rectangle with PM written in it. The service department has a specific project manager who will report to the general manager of HGS.

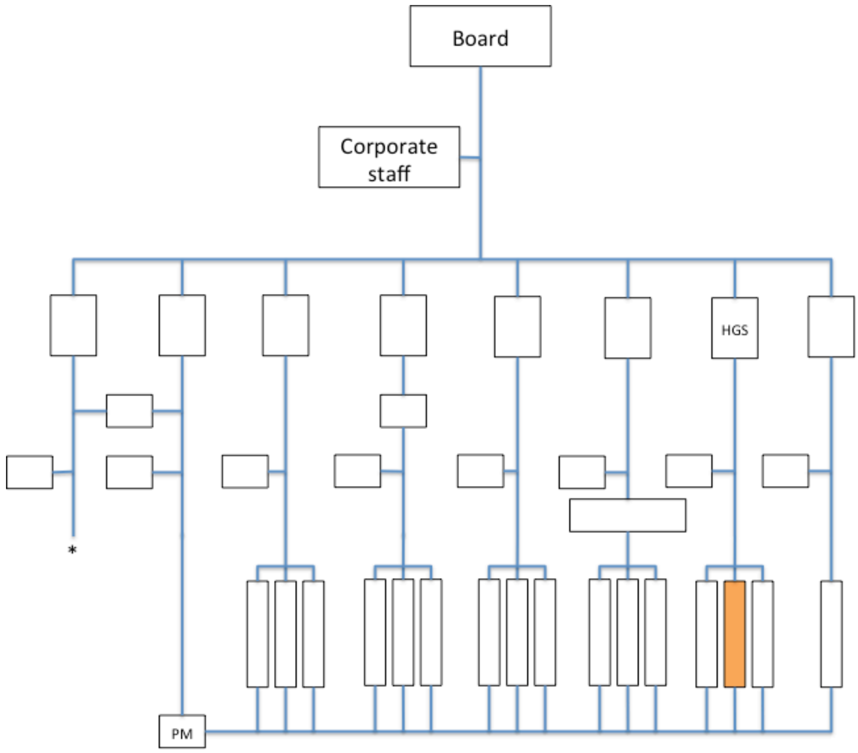

Figure 10: Organization chart of Huisman Equipment BV(Huisman Equipment BV, 2008)

4.2 post commissioning software system change management protocol

Now that Huisman as a company has been described in the previous paragraphs the focus will be transformed to the service department of Huisman Global Service. When new build equipment and systems start their operational life cycle they are directly transferred under the supervision of the service department. Management together with the team lead of the service department have designed a post-commissioning software change management process as illustrated in figure 11 below. Employees that implement the software changes to systems and equipment are required to work according this change management process. Post commissioning means that the equipment or systems have been inspected, checked and tested according to all pre-set requirements.

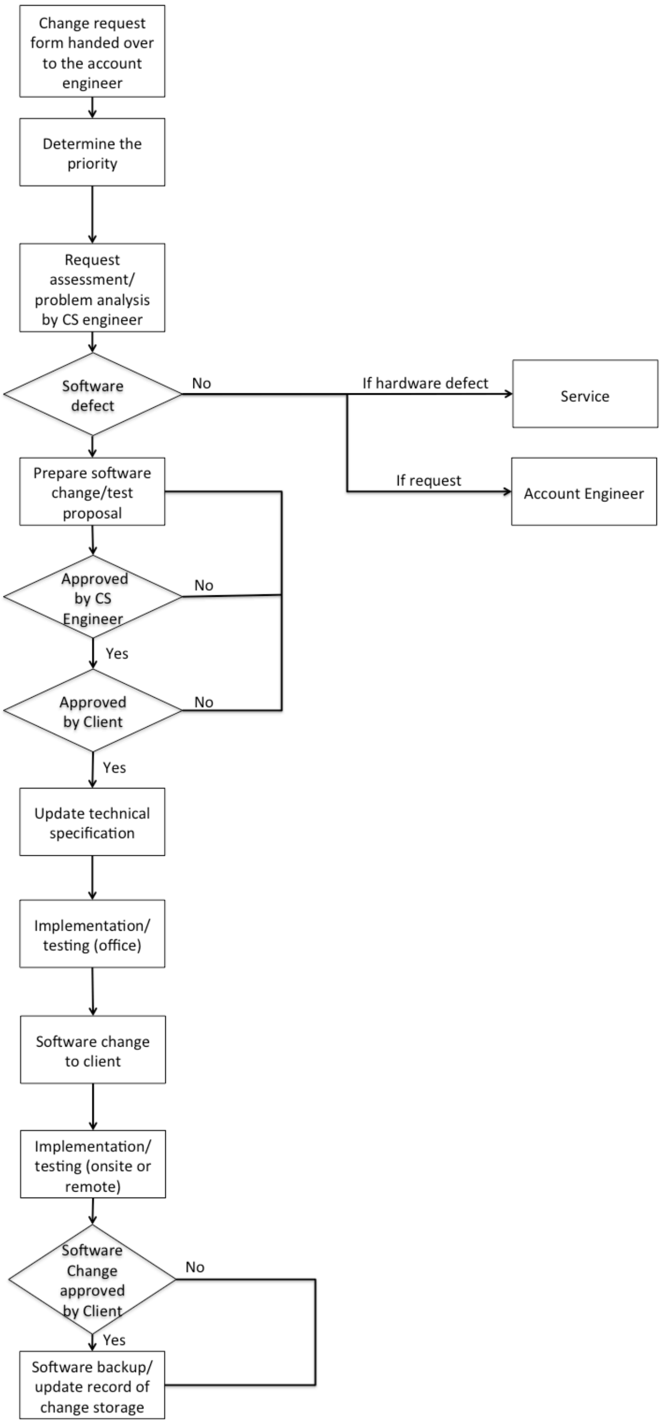

Figure 11: Post-commissioning software change management protocol(Verkerk & Ee, 2013)

The system change process as designed within Huisman will be described according to figure 11. Generally the process starts when the change request form is handed over to the account engineer. When the account engineer has the change request in his possession the priority of the change will be determined. Then the account engineer hands the change request over to the CS (Control Systems) Engineer and will perform a request assessment and a problem analysis in order to make a plan how to solve the problem/implement the change.

The process is designed for software defects, if it is not a software defect it is a hardware defect and the task will be handed over to the service department. If requests will be communicated with the account engineer and if-requests mostly contain of requests for tools or materials. Once is defined that there is a software defect the control systems engineer prepares a software change proposal and a test proposal. The proposals all need to be confirmed and approved by the control systems engineer and the client. If the proposals are not approved they need to be improved until both parties approve them. When all proposals are approved the technical specifications can be updated which means all changed and updated changes need to be archived within the database (sourcesave) where other employees can find a track of the changes. The changes will be implemented and tested in the office, once it is proven that it works at the office the software change go to the client and will be implemented and tested onsite (on board of the vessel). One of the last stages within the process is to get the software change approved by the clients. When the changes are approved a software backup can be made and an update can be made of the record of change storage. When the change is not approved it goes back to the change approval section again.

The description on the system change process that is given above is how management and the "team leads" of the Service department design it. The protocol gives a concise description on how to implement a change and should initially be used by the employees of the service department of Huisman Global Service.

In order to acquire data for this thesis, employees of several disciplines within the service department were interviewed and gave their critical reflection an opinion on the system change management process in its current existing form as referred to in figure 14. The employees were asked to give their vision on how a change is handled actually and what steps in the process are used and what steps are not used or are not in the right order/the right place in the process.

A general statement needs to be made: almost none of the employees that were interviewed were familiar with the system change management procedure and when critically evaluated not used in the same order as the procedure prescribes. Furthermore the process is not complete. The interviewees indicated that they have not used this procedure because they are not familiar with the process. There is no specific training in order to learn how to work with such a system change management process. Employees stated that when they have to apply a change this can only be done by the system change management procedure, however no one knows how this works precisely.

The generic trend is nicely illustrated by the following quote stated by a service engineer: *"when you talk to me about lines, bars and triangles that relate to each other and form a process flow, I am lost, you lost me, I have nothing to do with this managerial stuff….I know how everything works technically and that's enough".*

Interviewees, especially the interviewees who work in the field, often mention that they do not prepare their assignments in great detail because an assignment could be totally different at the sight compared to what was initially communicated by the client to Huisman. Several employees mentioned to have to deal with a different problem then communicated prior to the assignment. According to preparations that specialist engineers and service technicians do prior to their assignments illustrate their way of working (with and without the system change management protocol). This way of working illustrates the offshore business especially mentioned by interviewee five.

Interviewee #8: "Prior to an assignment I do not prepare myself at all. I don't like preparation; I just investigate what I have to do when I enter the ship. However this is not the way Huisman wants to work. My previous employer did not mind me lacking preparation but in the offshore industry this is more or less not done simply because there are more risks in shipping. When something goes wrong, it goes terribly wrong".

Interviewee #8: "Now I prepare myself by making the SCP (System Change Procedure), when I enter the vessel I will continue work. My experience tells me when I prepare myself for a certain situation it is usually different from the actual problem on the ship. Preparation was not suitable for the actual situation. Therefore I do not prepare myself anymore".

An interviewee mentioned the difficulties of implementing procedures because it should involve so many employees, company layers and disciplines. It is good to get acquainted with a certain procedure in order to deliver jobs in a proper and structured manner. However the difficulty is to make sure every involved party is aware of this procedure and how is meant to work.

Interviewee #5:"It is interesting to get familiar with a variety of methods and to show the advantages of a structured procedure. But the implementation of a structured procedure (System Change Management Procedure) is quite difficult".

An interviewee illustrates an example of difficulties specifically in the offshore business that has to do with the communication between onshore and offshore.

Interviewee #5: Typical change management in the offshore industry: there is a clear difference between works onshore and offshore. Change management has an important cultural basis as well an example is given on the first "symptoms" of change management within Huisman. "17 years ago when I started working at Huisman, nobody wore a helmet while working in the yard". Slightly the offshore industry is changing from a "cowboy mentality" towards a more professional and risk-based business.

The interviewee also mentions the mentality of the early offshore business. A few decades ago there were not that many (safety) regulations and nowadays increasingly more regulations are implemented in the offshore business in order to make the business more professional.

The results of the interviews revealed that there is not yet uniformity on which events occur iteratively. Starting from the initiation of a change the protocol does not provide clarity on what kind of change is being initiated. It can either be an unplanned change a planned change or an emergency. A change can be initiated in different ways. When a client initiates a change this can be directly communicated to the responsible account engineer or the client sends an email to the service mail. The service coordinator manages the "service email" and plans the assignments. Sometimes the client communicates directly with the service engineer. These various ways of communicating are not always clear enough. The first step in the change management protocol starts with handing over the change request form over to the account engineer. The second step determines the priority of the changes. But the respondents did not know if there are uniform criteria for determining the priority. On what basis is the priority of the implementation of a change based? The interviewees state that the order in which events are put in the flow diagram is not the order in which events should occur. Specific examples are the update of the technical specification. It is not quite clear what this means and why why this should be updated emediately after the approval of the change request by the control systems engineer and client. Employees suggest it should be the description of the change in technical specifications and the documents that are applicable to the change.

4.2.1 Comparison with ITIL and ABS

The post commissioning software change management protocol plays an important role within the service department of Huisman Global Service. According to several interviews with employees about the change management protocol is tried to create insights in how this protocol is specifically designed, accepted and used by employees. Several employees have been specifically asked questions on the post commissioning software change management protocol, which means that every step in the protocol has been discussed with the interviewees. The three employees occupy positions of Team Lead, Specialist Engineer, Engineering Specialist A and Service Coordinator. One of the overlapping comments the employees reported that the protocol does not give a complete overview of how to handle a change let alone that all the steps in the protocol are defined unambiguously. Besides the lack of clarity of the protocol in general the roles and responsibilities of employees who have to work according to this protocol is not (clearly) defined. A few employees have stated that they were not aware of the existence of the post commissioning software change management protocol at all, let alone they were aware of how to use it in what particular situation. After consulting all interview results according to the change management protocol the sequence of events within the protocol did not correspond to reality according to the interviewees. These conclusions were mainly based on the logic that employees use for executing their work. Within the interviews they were forced to evaluate the protocol and criticize the iterative position of different tasks. The most important findings are based on reality being different from the protocol that has been designed.

4.2.2 Ishikawa diagram within Huisman

While performing desk research and studying the documentation from Huisman, a document was found that contained a "Huisman vision for Engineering Information Management".

Within Huisman improvement committees are active in order to analyse and improve the organization. In order to achieve this Huisman needs to investigate its organization thoroughly en therefore has started with an improvement program. This program contains of a group of employees who study the functioning of the organization. One of the participants in this improvement program has stated the urge for improvement as follows:

"Engineering departments and disciplines within Huisman recognize business problems and the improvement opportunities within the engineering processes and has taken the initiative to improve engineering processes and enhance the quality of the data output to other disciplines. Engineering also realizes that many business issues require radical changes, out of the box thinking, a movement away from historical restrictions to breakthrough, and also the need to avoid sub-optimization and ad-hoc improvements"(Dang, 2013).

This statement is made transparent by including an Ishikawa diagram. This Ishikawa diagram shows a complete set of causes for an unsatisfactory effect. In this case the unsatisfactory project delivery will be discussed and when quickly consulting figure 12 below there can be concluded that various categories of causes lead to the unsatisfactory project delivery.

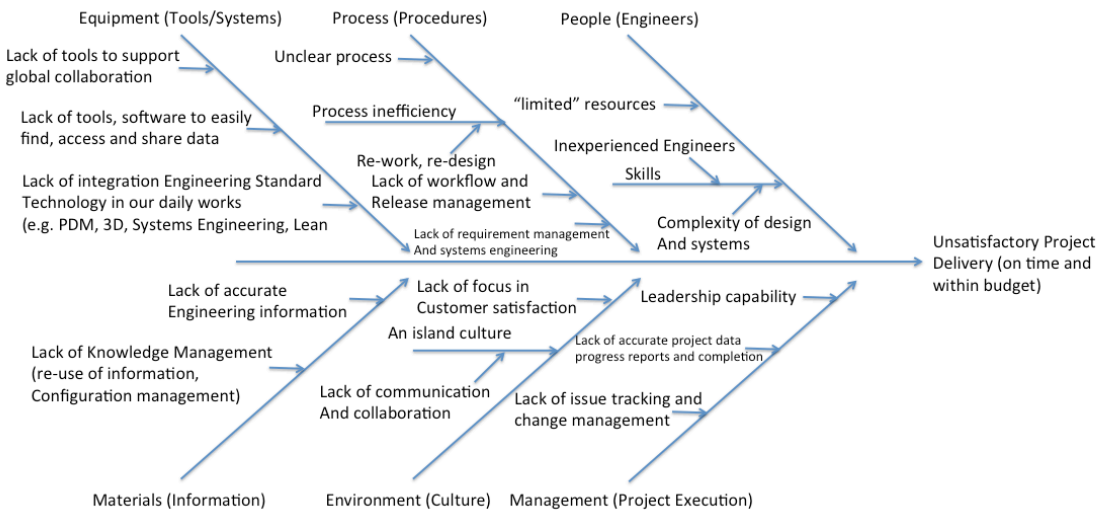

Figure 12: Ishikawa diagram(Dang, 2013)

In the diagram there are identified six different categories of factors that can contain root causes for the undesired effect. A group members of the improvement team have discussed (and consulted literature) and obtained these causes together and have stated that the following six main cause categories can be specified into primary and secondary sub-causes.

1. Equipment (Tools/Systems)
2. Process (Procedures)
3. People (Engineers)

4. Materials
5. Environment (Culture)
6. Management (Project Execution)

Equipment
What can go wrong with equipment is the question that is asked in order to find primary and secondary sub-causes in the category equipment. There could be lack of tools to support global collaboration. Systems that support easy access and sharing of data could be insufficient.

Process
The process category in the diagram contains all the causes that fall in this category and lead to the unsatisfactory project delivery.

People
The employees that are actively involved in the project can form a cause for unsatisfactory project delivery. Inexperienced employees as well as experienced employees can make mistakes due to several reasons. Human error is an important cause for unsatisfactory project delivery.

Materials
Unsatisfactory project delivery can be a result of lack of high quality materials or lack of adequate information. Causes that are found in this category should be placed in this part of the Ishikawa diagram.

Environment
Causes that are related to the environment can lead to a certain outcome of the project as well. An island culture, which consists of experts that are not communicating with eachother.

Management
Management of a company or a department is responsible for the distribution of information according to keep the project on track. The tasks of management can be a cause for unsatisfactory project delivery.

Due to the lack of focus on functional requirements and System Engineering within the organization and on specific projects within the new-built department or the service department, projects are not satisfactorily delivered. Many of the project risks that should be analysed on beforehand were not analysed, which resulted in a lack of insights in control over, project costs, project risks early in the concept and design phase. Specific areas in which risks can occur that should be investigated that are related are the manufacturability, maintainability, testability, procurement delivery, safety and regulatory aspects of the project(Dang, 2013).

As is often the case currently, disagreements with customers or between disciplines regarding design and technical specifications or issues with cost overrun are brought up during a late stadium in the project when there is no possibility for improvements. The goal is to achieve control over and insight into the actual total product cost during the bidding process and as early as possible in the engineering processes(Dang, 2013).

Within Huisman intensive collaboration is required in order to deliver the high standard equipment. Throughout the design, build and operational phase frequently requests for change are made. These changes are costly are accompanied with many impacts for the organization. The goal is to improve the quality of engineering data output to other disciplines and departments in order to do it right the first time. Getting the engineering of the equipment right the first time should reduce the number of engineering changes during the procurement and production phases. The inefficient business processes and information systems require extra steps and effort by business users to accomplish their work and this often resulted in an unpleasant working environment and frustration for many employees.

The Ishikawa diagram that is used within the improvement group of Huisman in order to investigate unsatisfactory project delivery can very well be used for the investigation of incidents as well. As been stated in the literature the fishbone diagram or the root-cause investigation techniques are based on a set of well-defined operational questions and statements to investigate the incident(Ji & Zhang, 2012). Therefore the Ishikawa diagram will be used to investigate the Seven Oceans incident and two other pipelay incidents in chapter five.

4.3 Conclusion change management protocol

This chapter has focused on the organization of Huisman Equipment BV and zoomed into Huisman Global Service's specific service department. According to Mintzberg the organizational structure has been identified as an "adhocracy" because of the complex products and systems the company designs, builds, operates and maintains. The dynamic and turbulent environment in which the company operates also fit the characteristics of an adhocracy. While performing research within the company an important document was analysed according to the improvement of project deliveries. The Huisman improvement team has made a study of an unsatisfactory project delivery by means of an Ishikawa diagram. The Ishikawa diagram is a feasible incident investigation tool, which can be used to identify the root causes for a particular incident. In the following chapter three pipe lay incidents will be investigated for their root causes according to the Ishikawa diagram.

During the operational life cycle, when the Huisman CoPS have been transferred to the service department, changes should be implemented according to the post commissioning software change management protocol as designed by several employees of the service department. This protocol will be specifically investigated on its role according to incidents in chapter 5 but first the conclusions from the general analysis of the change management protocol. The most important findings on the change management protocol are that not everyone that is supposed to use the change management protocol is aware of the existence of the protocol. The employees who are aware of the existence of the change management protocol are often not aware of what their roles and responsibilities are within the protocol. Frequently during the quarterly department meetings the change management protocol is however discussed but the content is not discussed substantively. People therefore are not aware of the content let alone that they are aware how to make use of the content. Mentioning the overall advantages of using a system change management protocol briefly creates little awareness. The goal of the following chapter will therefore be to investigate specific incidents and zoom in on the process/organizational and human root causes for incidents. The intention is that insights are generated in why the change management protocol is malfunctioning.

5.

Pipe lay Incident investigation

The main goal of chapter five is to explore the relationship between technology, process and organization, and people by means of investigating the root causes of three pipe lay incidents. The findings from the incident investigation methods will generate the answer to sub-question four.

5.1 Introduction

This chapter will give an answer to the sub question:

What are root causes of pipe-lay incidents in the offshore industry related to the implementation of changes during the operational phase of the life cycle?

The main goal of this chapter is to extract learnings about the root causes of pipe-lay incidents. These learnings are obtained by the analysis of three cases. Specifically three pipelay incidents will be analysed:

Case I: Seven Oceans 2013

Case II: Saipem 7000

Case III: Seven Oceans 2010

The analysis is done by the use of the Tripod Beta Incident Analysis and by means of an Ishikawa diagram. Prior to the TBIA should be mentioned that this analysis technique is seldomly used to investigate root causes. In general analysis techniques are seldomly used unless in some cases when the incident is “severe” enough. The technological, organizational and human root causes will be the output of this chapter. The figure below illustrates how the incident analysis methods are related to eachother, what information the analysis should provide and which methods are performed by the researcher.

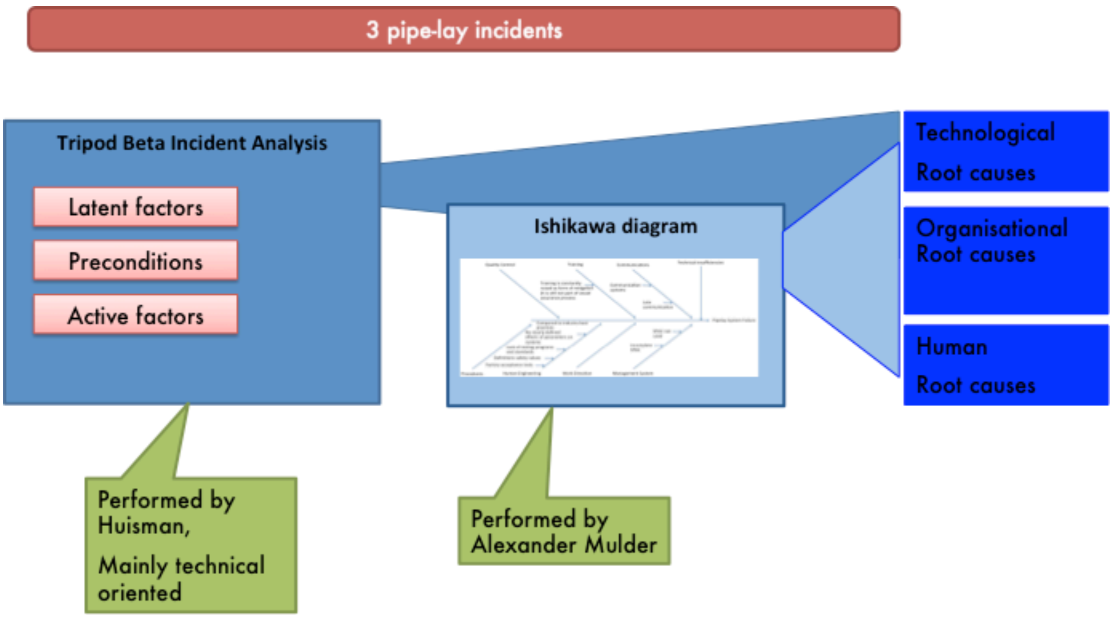

Figure 13: Incident analysis strategy

5.2 Goal of TBIA and the Ishikawa diagram

For this research two types of incident investigation methods are used (figure 13) to perform incident analyses. Employees from the service department of Huisman have executed a TBIA. The TBIA focuses on the sequence of events that occurred prior to an incident.

Secondly an Ishikawa diagram is performed on all three incidents in order to investigate technical, process/organizational and human root causes for the incidents to occur. An extended description on these two analysis techniques can be found in the literature study.

The Ishikawa diagram will be used to investigate several categories of root causes of incidents. First of all an Ishikawa diagram that is performed by Huisman employees will be discussed. This Ishikawa diagram represents a general investigation of an unsatisfactory project delivery. Secondly several Ishikawa diagrams will be designed for the Seven Oceans incidents in 2010 and 2013 and the pipe lay incident on the Saipem 7000 in 2008.

Discription of the TBIA: what can be substracted?

The goal of the analysis of this incident according to the study of the TBIA from Huisman is to order, to group and organize the events that occurred prior to the incident. The TBIA makes a destinction between latent failures, preconditions and active failures as described in chapter three and is illustrated in figure 14 as a reminder. The main goal of ordering this information is to conclude on the existence of root causes for incidents which can be distinguished in the three proposed categories from the theoretical framework from chapter three: technology, process/organization, human. The actual results from the TBIA that was executed by Huisman can be found in appendix five.

Figure 14: Latent failures, preconditions and active failures substracted by means of a TBIA

What can be substracted from an Ishikawa diagram?

In order to rank the available information on the three incidents various literature is used on root cause analysis and specifically on the Ishikawa diagram.. The results of the Ishikawa diagrams can be found in appendix 5 and will be explained in detail. The seven categories in which root causes are investigated are:

1. Quality Control
2. Training
3. Communications
4. Procedures
5. Human Engineering
6. Work Environement
7. Management System

The root cause categories will be used as a guideline to distinguish and place causes under specific categories. Within this chapter a distinction will be made in technical, process and organizational and human root causes. All the technical, process and organizational and human root causes found from the three different cases can be compared to eachother.

5.3 Case I: Seven Oceans 2013

5.3.1. Case I description

In 2013 an incident occurred on SubSea 7's deep-water rigid pipe lay vessel "the Seven Oceans"(SubSea7, 2014). The safety mode of the spooling tensioner did not work. This allowed for the tension in the pipe sections to increase and the risk occurred that the pipeline would collapse and fall on the deck of the ship. A detailed description of the incident is obtained from an incident report from Huisman(Verkerk & Ee, 2013). In the running version on board, changes were applied to the existing software in order to solve issues when installing the spooling tensioner. Software upgrades were required to meet functional requirements of the system. Simultaneously onshore also changes were implemented to the software. This resulted in two different versions of the software. The new spooling tensioner required some additional safety protocols within the software, but having two different software versions led to problems. Before the final installation of the spooling tensioner was completed on board of the vessel, the two software versions were merged together. Merging is done by comparing two versions and integrating the differences. This job is manually executed and is very time consuming and difficult. A timeline of events is presented in table 15.

Date	Event
02-01-13	Start installation spooling tensioner
10-1-2013 - 31-1-2013	Start control systems implementations
1-2-2013 -14-2-2013	Finalize control systems upgrade
12-02-13	Unexpected movement incident
13-02-13	Start investigation
13-3-2013 -27-3-2013	Technical review
06-03-13	Review SubSea 7 SM / Huisman on incident
11-03-13	Technical review SubSea 7 CS / Huisman
27-03-13	Progress meeting SubSea 7 SM / Huisman
27-3-2013 - 27-4-2013	Procedural review
28-04-13	Final incident review report

Table 15: Timeline of events prior and after incident

5.3.2. TBIA, Ishikawa observations ranked towards technological, organizational and human factors

Findings TBIA Seven Oceans 2013

The TBIA reveals latent failures, preconditions and active failures. Active failures are failures that are directly attributable to the incident. Preconditions lead to active failures but the latent failures are more structural. The latent failures are root causes that should be solved from a proactive perspective. Solving active failures is a reactive process. The latent failures that have been investigated from the Seven Oceans 2013 incident are: Records of change are structurally not kept up to date, checks are not completely followed, no sign-off procedures, lack of awareness of performing work with respect to the bigger picture and the ability to visualize the consequences of ones actions. Furthermore it is not in the nature of technical employees to investigate incidents. Sometimes (in this case the Seven Oceans 2013) an incident is investigated because a client asks for this. Usually the severity of an incident determines whether it is investigated for its root causes or not. Important root causes from the Ishikawa diagrams are: people do not know there is a change management procedure, people do not know how it works, people are not aware of their roles and responsibilities within the protocol, lack of training to use change management techniques, not skilled to investigate incidents for root causes in order to create lessons learned. In general is found that there is high time pressure imposed by client, no time for second opinions, improper communication because this takes to much time, uncomfortable working culture due to time pressure, not filling out forms, not fully executing procedures, gathering many signatures is time consuming, sometimes hard to communicate because of time difference or lack of knowledge.

Findings Ishikawa diagram Seven Oceans 2013

Resuming on the results of the Ishikawa diagram on the Seven Oceans 2013 incident the technical indicators can be described as a software issue that resulted into a failure/the lack of an emergency stop. This resulted into an issue that could have been witnessed in the physical form that the reel ran in opposite direction of the tensioner. This then resulted in an increase in pressure on the pipeline combined with the possibility to break and crash into the deck. The software issue is a technical root cause for the possibility that the pipeline could have crashed into the deck of the vessel. However by means of the Tripod Beta incident analysis and the Ishikawa diagram the process/organizational and human root causes and the roles of process/organization and people are investigated. Resuming from the Ishikawa diagram considering process and organizational indicators the awareness of the existence of a change management protocol is low. Employees have expressed their lack of awareness towards the existence of a change management protocol. Having observed this it is logical to find the “records of change documents” not being up to date. Employees are not aware of where and when to update the/a record of change. Employees have also stated that their roles and responsibilities are not clear/clearly defined. Furthermore the human root causes which are fuelled by lack of a particular training and lack of peer reviews. An important finding considering input of employees who were interviewed lay in the conviction that they had to work under extremely high pressure from superiors and imposed tight working schedules.

Technical rootcauses		
Observation (what came out of the analysis?)	**Learning (wider learning applicable for offshore industry)**	**Recommendation (what to do to solve the learning?)**
Safety interlock not in software	Safety interlock should be in the software program	Testing software thoroughly before it is used

Table 16: Seven Oceans 2013 (technical root causes)

Organisational/process rootcauses		
Observation (what came out of the analysis)	**Learning (wider learning applicable for offshore industry)**	**Recommendation (what to do to solve the learning)**
Not complying the system change management procedure	Comply to the system change management procedure (in order to create a uniform working standard)	Investigate why is not complied to the system and find a remedy for this: create awareness and provide training and compare the existing system to commonly known standards like ITIL and ABS
Not aware of the existence of SCM procedure	Employees should be aware of the existence of systems if they are required to use these systems	Create awareness of the goal of system change management (and of the existence of SCM procedures)
Responsibilities not defined	Employees are not aware of their specific responsibilities within a system change management system, this might lead to incidents	Define responsibilities to create clarity for the users of the system by using ITIL and ABS as examples
No checks/double checks and peer reviews	Employees could not be aware of their mistakes, which could inevitably lead to incidents	Make sure that key decisions are only made with a second opinion by means of defining redundancy using ITIL and ABS
Records of change are not up to date	No up to date history to check/ reason back all events	Create a "platform" where easily "key decisive" events according to the implementation of change can be updated → this is formulated in the change management protocol by using ITIL and ABS
Handover newbuild department to service department is not thoroughly executed	Awareness of two different phases in the product life cycle	Actual handover accompanied with specific processes corresponding with the new phase in the product life cycle (and clear and understandable for the involved employees in this phase of the life cycle)
No sign-off procedure	No tangible overview on the status of the implementation of the change	Introduce a clear stage-gate system in order to maintain overview on the status of the implementation of the change
No SCP/Risk assessment	No tangible system to measure the status of the	Make sure that there is always an SCP/risk

	change	assessment
No particular specific training	Employees are not familiar with specific change management systems because they are not trained for using this	Provide employees with suitable training before they start working

Table 17: Seven Oceans 2013 (process and organisational root causes)

Human rootcauses		
Observation (what came out of the analysis)	**Learning (wider learning applicable for offshore industry)**	**Recommendation (what to do to solve the learning)**
People do not know what to do with the SCM procedure	Employees work at cross of eachother because they are not aware (they have not been told/taught) of what they should do	Introduce a clearly defined and uniform change management procedure by using ITIL and ABS to design this procedure properly
Lack of awareness so the change was treated as a newbuild project	Awareness of two different phases in the product life cycle	Actual handover accompanied with specific processes corresponding with the new phase in the product life cycle (and clear and understandable for the involved employees in this phase of the life cycle)
Responsibilities were unclear	Employees did not exactly know what to do because this was not clearly defined	Introduce a clearly defined and uniform change management procedure with clear responsibilities using ITIL and ABS as universal standards
Procedures were not followed completely	Procedures were not followed completely because the employees were not aware of their existence let alone they knew how the procedure worked	Introduce a clearly defined and uniform change management procedure with clear responsibilities. Train employees on how to use the change management procedure → designed by means of ITIL and ABS
Human error	Human errors can be made without people are aware of making human error	Provide clarity in work procedures in creating awareness and explaining standardized work procedures by performing training on the basis of a designed protocol by means of ITIL and ABS

Table 18: Seven Oceans 2013 (human root causes)

Conclusions on the technical, process and organizational, and human root causes

The Seven Oceans 2013 has one technical root cause (table 16), nine process and organizational root causes (table 17) and five human root causes (table 18). Mainly process and organizational root causes have been found and it seems that the human error is a result of process and organizational root causes for the Seven Oceans 2013 incident. Noteworthy process and organizational findings are the lack of awareness of the existence of a system change management procedure let alone that employees could be aware of how to comply the system change management procedure. It is therefore quite logical that interviewees stress out that the individual responsibilities are not defined clear enough so that everyone is aware of what to do in which situation. Various employees expressed that no training about the system change management procedure has been provided.

For the human root causes can be concluded that decisions are made with lack of awareness and without knowing exactly what to do according to a system change management procedure. Employees were also not aware of modifications in the running software after the start of the project. Because there was no clear and thoroughly executed handover from newbuild towards service the change to the Seven Oceans 2013 was treated as a new build project.

5.4.Case II: Saipem 7000 "pipe lay system failure" 2008

5.4.1. Case ii description

In the international waters between Spain and Algeria on 17 September 2008 an incident occurred on the Saipem 7000 during pipe lay operations. The Saipem 7000 is a large crane vessel equipped with a J-lay pipelay tower. A system failure in the hydraulic pipe handling system of the J-lay tower caused two "quadruple joints" to suddenly drop. Each of these pipe sections were 50 meters long and weighed 24 tons(Saipem QHSE, 2008). The dropping of the pipe sections caused fatal, seriously and slightly injuries.

5.4.2. Ishikawa observations ranked towards technological, organizational and human factors

The safety bulletin of Saipem according to the pipe lay incident moreover describes five corrective actions in order to foresee accidents like these in the future(Saipem QHSE, 2008):

1. Develop and improve the safety culture of personnel working on board through the "leadership in safety" initiative.
2. Ensure that procedures are in place and represent working practices
3. Ensure that the personnel is familiar with the new technologies put in place
4. Develop training programs to ensure the development of the competency of all personnel
5. Ensure that the organization, the personnel roles and responsibilities, communication channel are familiar to all personnel

And at last the safety bulletin describes a long-term corrective action considering a full refurbishment of the Jay-lay tower in which all systems will be subject to safety review(Saipem QHSE, 2008). This actually means that all software systems that run the pipelay tower as well as all hardware elements will be checked thoroughly. These corrective actions imply that actual root causes for the incident can be found in categories like safety culture, procedures, awareness of procedures and new technologies, training programs and roles and responsibilities.

Technical rootcauses		
Observation (what came out of the analysis)	**Learning (wider learning applicable for offshore industry)**	**Recommendation (what to do to solve the learning)**
Pipe sections fell from the hydraulic pipe handling system due to a system failure	This incident should not have happened → lessons learned could help in the future	Investigate the root causes for this incidents on different levels (technical, process/organizational and human)

Table 19: Saipem 7000 (technical root causes)

Process and organisational rootcauses		
Observation (what came out of the analysis)	**Learning (wider learning applicable for offshore industry)**	**Recommendation (What to do to solve the learning)**
Training is raised as form of mitigation (but still not part of a vessel assurance process)	Employees are not familiar with specific change management systems because they are not trained for using this	Provide employees with suitable training before they start working
Compared to industry best practices; but not specifically towards detailed equipment information	No specific standards available on highly specialized equipment → create lessons learned where possible to start a database	Create lessons learned from incidents but also keep a record of change by using ITIL, ABS, TBIA and Ishikawa diagrams
No clearly defined effects of parameters on systems (technical)	No records of system behavior available on highly specific equipment characteristics	Create lessons learned but also better be safe than sorry (follow change management procedures in great detail) by using universal methods like TBIA and Ishikawa diagrams to find root causes
Lack of testing programs and standards	Availability of testing programs and standards can increase careful working	Integrate testing programs and standards into work procedures
No clear definitions of safety values	Safety should be of primary concern at all times	Build up work procedures and standards around safety

No factory acceptance tests	Work procedures should include factory acceptance tests (as check and double check)	Integrate factory acceptance tests into work procedures by defining these in the protocol by using ITIL and ABS
Failure of communication systems	Relevance of proper communication between employees, clients and departments	Formalize communication lines between employees, clients and departments by defining these communication lines in the protocol by using ITIL and ABS

Table 20: Saipem 7000 (process and organisational root causes)

Human rootcauses		
Observation (what came out of the analysis)	**Learning (wider learning applicable for offshore industry)**	**Recommendation (What to do to solve the learning)**
Late communication	Early communication can create clarity and prevent incidents from occuring	Awareness of communication lines → who to call when necessary by defining communication lines in the protocol by using ITIL and ABS
No specific experience on specific equipment	Relevance of a record of experience (knowledge) on specific equipment	Start a record of experience on specific equipment and make sure this is accessible for employees who work with this equipment by defining this in the protocol by using ITIL and ABS
Employees did not know what to do specifically to test equipment	Testing equipment is important (to be ahead of possible failures) and knowing exactly how to test equipment makes it more easy to test	Integrate test protocols into work procedures (easy to understand and uniform) by using standards like ITIL and ABS
Safety values not clearly communicated → people were in places where they should not have been	Safety is of primary concern and should be maintained at all times. Everyone should be aware of these safety standards and everybody regardless of position should respect safety decisions	Make safety the main primary concern

Table 21: Saipem 7000 (human root causes)

Conclusions on the technical, process and organizational, and human root causes

The analysis of the Saipem 7000 incident has produced one technical root cause (table 19), seven process and organizational root causes (table 20) and four human root causes (table 21). This incident has revealed more process and organizational root causes than technical and human root causes. The technical root cause for the dropped pipes was a system failure.

However mainly the process and organizational root causes show similarities with the process and organizational root causes that were found in the Seven Oceans 2013 case. Process and organizational findings indicated the absence of training in the assurance process. There were no details or lessons learned available on specific parts of equipment. This resulted in human error: late communication because employees were not aware of whom to communicate to. There was no specific experience with this specific type of equipment, which resulted in decisions and actions of which the possible consequences were unknown. Employees were not aware of how to test specific equipment. Furthermore people were in places where they should not have been. No clear safety values indicated that people were not allowed in these places let alone they were defined properly.

5.5.Case III: Seven Oceans 2010 pipe lay incident “dropped pipe”

5.5.1. Case iii description

In 2010 an incident occurred on the Seven Oceans. In this particular incident a pipe section fell into the sea just of the coast of Brazil. This incident occurred on SubSea 7’s deep-water rigid pipe lay vessel “the Seven Oceans”. The tensioners lost grip onto the pipe section so that this section eventually fel into the sea.

5.5.2. Ishikawa observations ranked towards technological, organizational and human factors

Resuming on the Ishikawa diagram for the Seven Oceans incident in 2010 a distinction again can be made in three directions of cause categories of root causes.

Technical root cause:

The most important technical root causes for this incident to occur were electrical distributions to fail that resulted in the pipe that dropped into the sea. However there are numerous other causes described in documentary that made this incident to occur. These causes are usually not immediately visible but were revealed while investigating the circumstances of the incident and placing them into the Ishikawa diagram.

Process and organizational root causes:

These causes can be summarized by the lack of insights into communication lines between involved employees and feedback communication. The communication lines and feedback sessions were not defined properly in the management system. They were either to difficult or not clear enough for employees to understand and apply to their work.

Human root causes:

As a result of the identification of human root causes there has been an inability from employees to identify and understand the circumstances of the incident. The employees have experienced a lack of communication between departments, managerial layers and among themselves. The final human root cause is related to the misjudging of specific technical data.

After a possible failure has not been created a “lessons learned” database that could be a cause for a new incident to occur. An incident could have possibly been foreseen because of an up-to-date “lessons learned” database. If the circumstances of a particular incident would have been in a “lessons learned” database because it had occurred before, there might be a chance to foresee the incident due to this information. Many causes within this Ishikawa diagram applied to the Seven Oceans 2010 incident seem to be appointed retroactively there is not many information available anymore on the actual chronological sequence of events that occurred prior to the incident. However one of the more general findings considers the complexity of the products and systems. Due to the complexity of the equipment failures like electrical failures are not specifically considered outside individual motor failures prior to the incident investigation studies.

Technical rootcauses		
Observation (what came out of the analysis)	**Learning (wider learning applicable for offshore industry)**	**Recommendation (What to do to solve the learning)**
Electrical distribution failures caused a dropped pipe	Technical malfunctions can have serious consequences which could jeopardize the overall safety	Build up work procedures with respect to safety learnings (due to technical causes for the incidents)

Table 22: Seven Oceans 2010 (technical root causes)

Process and organisational rootcauses		
Observation (what came out of the analysis)	**Learning (wider learning applicable for offshore industry)**	**Recommendation (What to do to solve the learning?)**
Factory acceptance tests consider the system only in normal operating conditions → they do not consider failure	What to do when a failure is detected? This is not particularly clear	Create a knowledge exchange platform where experience according to failure can form a lessons learned database
No lessons learned	Possibility that mistakes are made more than once because experiences are not shared and documented in order to learn from them	Create lessons learned from experiences and incidents by using universal incident analysis methods like TBIA and Ishikawa diagrams
Lack of training for possible risks	Employees are not familiar with specific change management systems because they are not trained for using this	Provide employees with suitable training before they start working
Testing is not normally carried out (is not in training)	Testing is relevant in order to prevent undesired effects from happening	Make testing part of a working standard
No sufficient employee/feedback	Employees could not be aware of their mistakes,	Make sure that key decisions are only made with a second

communication	which could inevitably lead to incidents	opinion by defining this redundancy in the protocol by using ITIL and ABS
Lack of peer reviews	Employees could not be aware of their mistakes, which could inevitably lead to incidents	Make sure that key decisions are only made with a second opinion by defining this redundancy in the protocol by using ITIL and ABS
No fault tree analysis	Methods for analyzing incidents can create insights in the causes	Perform root cause analysis by using universal standards like TBIA and Ishikawa diagrams
Feedback communication is not in management system	Employees could not be aware of their mistakes, which could inevitably lead to incidents	Make sure that key decisions are only made with a second opinion by defining this redundancy in the protocol by using ITIL and ABS
Employee communication is not in management system	Employees could not be aware of their mistakes, which could inevitably lead to incidents	Make sure that key decisions are only made with a second opinion by defining this redundancy in the protocol by using ITIL and ABS
No failure modes or consequences are defined for the pipelay systems	Specific failure modes and insights in consequences for pipelay systems create can prevent from incidents occurring again	Create knowledge on specific insights and consequences from pipelay systems

Table 23: Seven Oceans 2010 (process and organisational root causes)

Human rootcauses		
Observation (what came out of the analysis)	**Learning (wider learning applicable for offshore industry)**	**Recommendation (what to do to solve the learning)**
Inability to identify and understand the circumstances of incidents	Make sure that employees are knowleagable enough to understand the circumstances	Design and implement training and feedback sessions
Misjudging of specific technical data	Ensure that people are knowleagable enough to judge data correctly	Training sessions and peer groups and create lessons learned
Lack of communication between department, managerial layers and between employees (interfaces)	Interface management should be properly formulated and should be relevant	Define communication lines, roles and responsibilities so that everyone is aware whom to contact when necessary

Table 24: Seven Oceans 2010 (human root causes)

Conclusions on the technical, process and organizational, and human root causes

To conclude on the findings of the Seven Oceans 2010 the incident analysis revealed yet again that there are underlying causes that have eventually led to the incident to occur. There is one technical root cause (table 22), twelve process and organizational root causes (table 23) and three human root causes (table 24). Most important causes that presumably underlie the root causes of the incident are the lack of communication lines within the change management protocol, the general awareness of a change management protocol (prior to implementing a change), the awareness of the existence of training facilities, the lack of training facilities considering the roles and responsibilities according to the implementation of change (lack of peer reviews). In the Seven Oceans 2013 case the lack of peer reviews has been found as a root cause as well. Reviewing each other's work is not an action that is structurally performed. Reviewing each other's work has not yet been defined in a change management protocol.

5.6 Conclusion of the TBIA and Ishikawa analysis

From the incident investigations several root causes are obtained which will be summarized in this paragraph. The findings in this paragraph form the answer to sub-question 4. With regards to the implementation of change nog everyone is always aware of the existence of a change management procedure let alone how it works. A change management protocol is usually implemented top-down and this very often results in lack of clarity of the roles and responsibilities for the actual users of the protocol. Moreover there is very little control on the execution of a change management protocol (if a protocol is used). Little feedback is given on executed work, but most of the time no feedback at all is given on how assignments or changes are implemented.

Specifically by means of the TBIA the observations that are done can be grouped into latent failures, preconditions and active failures as described in chapter 3 and appendix 5. The Seven Oceans 2013 incident revealed that there was no sign-off procedure. The absence of a sign-off procedure is a latent failure. But the question is why is there no sign-off procedure? The answers to this question are the preconditions and the active failure.

The key findings with respect to the preconditions are: incompletely followed (or not followed at all) procedures, lack of awareness of considerable information on requested changes and the implementation of changes, and unclear responsibilities. Furthermore other findings from the TBIA considering the preconditions are: assumption differences, confusion on newbuild procedures versus service procedures, and human error. The active failures are the actual case specific failures but the latent failures are the ones that actually need to be solved in order to address the structural problem.

The Ishikawa diagrams have specifically revealed the following root causes for the incidents because they were found for all the incidents: due to high time pressure there is often no possibility for a second-opinion. Time pressure is exerted by the client (cost driven perspectives), which results in long working days for employees from the service department, which could easily lead to human error. The time-pressure exerted by the client can create a highly uncomfortable surrounding/culture to work in and this can easily lead to human error or to be obliged to focus on a hurried completion. Insufficient communication due to reasons like unclear roles and responsibilities, time difference, unsigned forms or the high complexity of products and systems could lead to incorrect decisions or human error that could lead to incidents. Due to high time pressure a conflicting situation is created between client and service employee; it is to be experienced very time consuming to fill out all forms, collect all required signatures and in general implementing change according to the protocol.

Reflection on results from incident analyses

The reflection is written while keeping two things in mind: in which root cause category did the most of the observations occur and secondly if this was expected.

When reflecting on the findings that resulted from the three incident analyses can be observed that the most findings are in the process and organizational category. It is unlikely that a pure technical root cause is the only type of cause for an incident to occur. There must be more detailed explanations for the precise circumstances of an incident. The similarities in findings in all three incidents with respect to the process and organizational root causes and the resultant effects that are seen in the human root causes explain that something structural is going on. The three analysed incidents all show that most findings are in the process and organizational category. Most practical example that can be withdrawn form the incident analyses is the lack of awareness of the existence of a system change management protocol. This is a root cause that can be assigned to the process and organizational characteristics of a company. Consequential people do not know what to do and are unaware of the possibility of making wrong decisions or making interpretive errors. This could lead to a technical effect like a pipe section that could have crashed into the deck of the ship because of the absence of a safety interlock in the operating software of the pipelay tower. One could resolve the software but this does not mean that such an incident could occur again. Once the root causes that are found in the process and organizational category are being remedied the possibility for human error can be reduced which in the end can prevent technical effect of an organizational failure.

6. Conclusions and recommendations

This chapter gives an overview of the main conclusions of this thesis, which focused on changes to complex products and systems of offshore equipment in the operational life cycle. This thesis is based on research within the service department of Huisman Global Service as part of Huisman Equipment BV. The conclusions are build up by answering the sub-questions specifically. And the combined answers to the sub-questions lead to answer to the main research question. After the conclusions a set of five recommendations to Huisman Global Services are presented. Subsequentely, the limitations of the research are discussed, which will provide input for recommendations for further research. To conclude, Huisman Global Services' feedback on this research is presented, which amongst others validates the results.

6.1 Conclusions

This research has focused on finding an answer to the following main research question:

How can companies in the offshore industry cope with changes to complex products and systems in order to avoid incidents, during the operational phase of the life cycle?

To find an answer to this research question a set of sub-questions is formulated to find answers to parts of the main research question that eventually form a combined answer to the main research question.

1. **What are CoPS and changes in the offshore industry and how are these concepts defined in literature?**
2. **What are requirements for applying change to CoPS during the operational phase of the life cycle**
3. **What are strengths and weaknesses of the current approach on how changes are treated?**
4. **What are root causes of incidents in the offshore industry related to the implementation of changes during the operational phase of the life cycle?**
5. **What insights and conclusions can be generated from the findings from this research?**

Contribution of subquestions towards the answerwering of the main research question

To find an answer to the main research question that is applicable and feasible to the industry in which this research is performed the first subquestion focuses on the characteristics of the CoPS in the offshore industry. The research specifically focuses on changes to these CoPS during the operational life cycle. Therefore in the literature study is focused on CoPS, change and the management of change. In order to generate insights in possible requirements to apply change to CoPS, two different change management standards are investigated. ITIL is chosen to generate insights from a software perspective and ABS is chosen because of its focus towards the marine and offshore industry. Subquestion two focuses on requirements from three different perspectives: technical, process and organizational (substracted from ITIL and ABS), and human factors, which are covered in the literature study as well (substracted from HOF). Subquestion three focuses on the experiences that are available in the case company according to the implementation of change by means of their system change management system. Subquestion four focuses on the main occasion primarily for this research to be executed. The investigation of three pipelay incidents (all related to the implementation of change during the operational life cycle) by means of TBIA and Ishikawa diagrams should provide the research with root causes divided into technical, process and organizational, and human factors. Finally subquestion five focuses on the learnings and insights of the findings generated by means of this research and help to answer the main research question.

Conclusions based on findings:

1. The incident analysis that have been performed so far, were mostly focused on the technical events that led to the actual incident. The statement of facts mainly shows technical events. The analysis of the Seven Oceans 2013 case shows latent failures through preconditions that lead to active failures. Causes that are difficult to interpret like awareness and human error are observed, but this does not result into clear actions. Gower Jones (1998) confirms the existence of "difficult to interpret" causes that can by distinguished by means of a TBIA and he also confirms that "hard" technical causes more easily result in resolving actions than "soft" process/organizational/human causes. An explanation for the technical approach of the incident is the mainly technical monodisciplinary background of the employees. People tend to think from the confines of their training/discipline in order to come up with solutions.
2. The results of the analysis of an incident are rarely linked back in order to create lessons learned. The scarcity of thoroughly performed incident analysis confirms there are little analysis results to feedback to employees who were actively involved in an incident. Incidents are not analysed on an on-going basis, just if the incident is severe enough and when the client requests an incident analysis, it will be analysed. The incident is then analysed by management team leads and involved employees. After this analysis it is not clear how these results will prevent incidents from occurring again in the future. There is no clear operationalized goal of what one wants to achieve with the analysis of incidents.
3. The work floor has little support for a thorough incident-analysis; people are not educated to analyse incidents, they are educated to fix problems. Fix the problem quickly and get on with the job. People are not held responsible for an incident; there is a low sense of urgency for analysing the incidents and prevent future incidents from occurring.
4. Customer requirements with respect to the ordered equipment where a change needs to be implemented are insufficiently mapped. Prior to the implementation of a change it is important to not immediately think in terms of solutions from the confined expertise of the background of most employees, but to identify the optimal solution for the particular situation. "Satisficing" powered by (corporate) culture, monodisciplinary confinements of education and background, time pressure counteracts the clarification process of client requirements.
5. People/employees are insufficiently aware of the expected use of a change management protocol; management takes little time to explain their expectations of the change management protocol to employees. The ever-growing market for complex offshore equipment can clarify this; more complex products and system become in the operational lifecycle which means that the possibility that a change is requested to one of the products or systems increases. The amount of service personnel dos not increase linearly with the number of complex products and systems, which means the workload increases. When the workload increases the possibility that incidents occur increases.
6. People/employees are insufficiently trained in order to use the change management protocol. There is a low sense of urgency to address problems around change

management and incidents that occur. Addressing problems and investigating them in order to solve them is very time consuming and is not proportionate to the amount of income from new orders placed within that time frame. The benefits from new orders outweigh the lost income from incidents.

7. There is no uniform line of contact with the client; change requests can “enter” in various ways. Client maintains contact with the account engineer, but with the service coordinator as well and specific contact is performed with service engineers as well. It is less time consuming to communicate directly with the service engineer while working “in the field” then maintaining contact with the account engineers and service coordinators at the main office.

<u>Reflection on results from incident analyses</u>

The reflection is written while keeping two things in mind: in which root cause category did the most of the observations occur and secondly if this was expected.

When reflecting on the findings that resulted from the three incident analyses (consult appendix 7) can be observed that the most findings are in the process and organizational category (table 28). Considering the highly skilled technical professionals that work in the offshore industry it is not expected on a regularly basis that incidents occur with a pure technical root cause (table 27). There must be more detailed explanations for the precise circumstances of an incident. The similarities in findings in all three incidents with respect to the process and organizational root causes and the resultant effects that are seen in the human root causes (table 29) explain that something structural is going on. The three analysed incidents all show that most findings are in the process and organizational category. Most practical example that can be withdrawn form the incident analyses is the lack of awareness of the existence of a system change management protocol. This is a root cause that can be assigned to the process and organizational characteristics of a company. Consequential people do not know what to do and are unaware of the possibility of making wrong decisions or making interpretive errors. This could lead to a technical effect like a pipe section that could have crashed into the deck of the ship because of the absence of a safety interlock in the operating software of the pipelay tower. One could resolve the software but this does not mean that such an incident could occur again. Once the root causes that are found in the process and organizational category are being remedied the possibility for human error can be reduced which in the end can prevent technical effect of an organizational failure.

6.2 Recommendations to Huisman Global Services

Equipment mostly runs on intricate software that requests constant change in order to retain its function. Specifically complex software systems increase in their complexity and according to Lehman’s laws of software evolution it can be stated that software must continually adapt to its environment otherwise it becomes progressively less usefull as stated by Xie (2009) and described in paragraph 3.2.2. Huisman works with equipment that runs on complex software that requests constant change. Besides increasing complexity on software level the complexity of the environment in which the offshore companies operate are increasing as well due to increasingly stringent safety standards. For Huisman in particular and other similar companies the sense of urgency can be translated into the need for a sufficient change management protocol that focuses on management of the interfaces between different company layers, departments and employees.

In order to formulate recommendations three incidents have been analysed in order to find root causes. The investigated root causes have been divided into technical, process and organizational, and human root causes. The three incidents have mostly resulted in process and organizational root causes. All three cases show similarities in the process and organizational root causes. The incidents seem to have occurred because of human error due to process and organizational root causes.

Referring back to the findings, learnings and recommendations in tables 25,26 and 27 many process and organizational root causes have been found. Returning to the main topic of this research, which was coping with change in a way that incidents can be avoided during the operational life cycle, recommendations on the process and organizational level appear to generate the most impact. When observing the findings from the incident analyses and keeping the ITIL and ABS change management standards in mind, these standards can remedy process and organizational root causes. It will remain important to generate input from incidents. This input can be generated by analysing incidents in a structured and universal manner (by means of TBIA and Ishikawa diagrams as described in chapter three) so that a valuable database is generated. Lessons learned can be formulated from the results of the analysed incidents. This results in the following recommendations.

The following recommendations will be made

By means of the following reccomendations the conclusions can be addressed. The reccommendations are strongly focused on the specific circumstances that have been investigated in the case company.

1. Conclusions one and two resulted from findings considering the performance and analysis of incident analyses. In short is concluded that incidents have been investigated from a technical technical point of view and that the results from the incident analyses are insufficiently used as feed back material and to create “lessons learned”. To obviate the first two conclusions is recommended to investigate all incidents using a universal method (TBIA and Ishikawa diagrams as used in this thesis) to find root causes. To focus on the origin of the cause make a disctinction between technical, process and organizational, and human root causes.
   Action: Investigate all incidents by using universal methods to find root causes.
2. Besides the tangible insights into the causes of incidents that are generated from the incident analyses, the insights as well generate valuable information that can be used to improve the change management process. This leads to the recommendation to use universal incident investigation methods like TBIA and Ishikawa diagrams to distinguish process and organizational factors. These generated process and organizational findings can be used as feedback to improve the change management protocol.

Action: Use TBIA and Ishikawa diagrams to distinguish process and organizational root causes.

3. Conclusion three, five and six all request the need of a properly designed change management protocol. In order to design a change management protocol can be recommended to use existing standards like ABS and ITIL as described in detail in this thesis. The use of standards will contribute to designing a uniform change management protocol that can be accepted throughout the organization.
   Action: Consult ABS and ITIL standards to design a change management protocol.
4. Conclusion three, five and six sequentially described the little support for thorough incident analyses, insufficient awareness of the existence of a change management protocol and the lack of training with regards to the use of the change management protocol. The actual relevance that lies behind these conclusions is to make people aware of a change management protocol, how it works including roles and responsibilities, and how a decent incident analysis can potentially lead to improvements of the change management protocol. The following recommendation is therefore made and contains the design of an interactive training session in order to get familiar with the concept of change and how changes should be implemented according to a change management protocol as designed according to ITIL and ABS. Within this training session roles and responsibilities in the system change management protocol should be discussed and be clearly defined in the protocol. Furthermore a specific training could lead to emphasizing the relevance of using a change management protocol and stressing out the need for thorough incident analysis methods.
   Action: Set up an interactive change management training session.
5. Conclusions four and seven resulted from the observation that a change can be initiated from different departments within the organization as well as the client. Subsequently the requirements and other information according to the change are not mapped in a uniform way so not all information is universally accessible let alone employees are aware of where to find the information or who to contact. The recommendation to address these findings is to set up a uniform set of contact-lines between interfaces. All relevant interfaces between departments, employees within departments and clients should be clearly be defined prior to the start of the implementation of a change. These contact-lines should be defined in the change management protocol as well.
   Action: Set up formalized contact-lines between departments, employees and clients.

6.3 Limitations of the research

To keep a research clear it has a certain scope and constraints, but due to these constraints the research has some limitations.

1. This research has focused on the investigation of three specific pipe lay incidents. To perform a more extensive research extra cases might be investigated and this will increase the validity of the research results and might provide extra insights.

2. This research has been specifically performed at the service department of Huisman Global Service as part of Huisman Equipment BV. The service department is only one specific department within Huisman. Analysis could also be performed in other departments at Huisman in order to generate a broader selection of insights on change management.
3. Besides the fact that this research has been performed at a single department the research has also been performed in a specific industry. The research could be extended towards other industries to generate a broader vision and to gather insights into other industries. These new insights might be applicable to the offshore industry as well.
4. To collect data several interviews have been held with people from the service department of Huisman Global Service. To create more insights on the sense of urgency, the perceptions on complexity and change management people from other departments and different management layers should be interviewed as well.
5. This research has made a comparison between the existing change management protocol and the ITIL and ABS change management standards. These standards describe how a change management procedure ideally looks like. However not yet is researched how a change management procedure can best be implemented.

6.4 Recommendations for future research

The recommendations that obviate the conclusions for Huisman Global Services can be considered in a wider perspective in order to meet the entire offshore industry. What will be necessary to make the recommendations applicable to the entire offshore industry? The recommendations for future research will also meet the limitations of this research as mentioned in paragraph 6.3.

1. The results of the research performed in this thesis are depending on its specific context. By means of future research can be recommended to select more and different cases and from other industries in order to make a comparison regardless of the context in which the cases were selected.
2. Selecting more and different cases and creating a more complete perspective from different departments within a company can generate a database containing of situations that can be compared on general findings. By means of a large and more complete data set a fit-for-purpose solution can be provided for the entire offshore industry.
3. A step further could be the investigation of a platform for the exchange of the details of incident analyses. At this platform information can actively be shared and used as input for the prevention of incidents in the future.
4. Performing comparative studies with respect to change management standards that are suitable for the specific context of the offshore industry. Select the best standard that leads to a fit-for-purpose design of a change management protocol.
5. Research plan-do-check-act cycles (PDCA) because planning and doing are abundantly performed because of the rising demand of complex equipment,

however checking and acting seem to be less represented. PDCA might be of use for the entire offshore industry.

6.5 Expert validation of the research

To conclude, Huisman Global Services' feedback on this research is presented, which amongst others validates the results. In order to generate an impression of the usability of the results of this research three questions were asked. The questions were presented to the daily supervisor of this research from the case company.

Questions have been asked to validate the results of the research

1. Are the results from the research expected?
2. Are the recommendations feasible?
3. To what extent have the recommendations already been used within Huisman (how far is the organization now according to change management)?

The answers to the first and the second question lead to the conclusion that the results of the research are as expected. According to the supervisor from the research company "the results are not new". However the question now rises how the results (and the related recommendations) of the research can transformed in an actual plan of action to implement in the organization. The supervisor indicates that changes can only be implemented in a very gradual manner.

The answer to the third question gives an overview of what the organization is currently working on.

1. The change management protocol at the service department has been revised and supplemented with the allocation of specific roles and responsibilities by means of a RASCI system. RASCI stands for: Responsible, Accountable, Supports, Consulted, Informed. The new proposed protocol is currently on the desk of the manager of the service department for approval.
2. Employees of the service department have designed a "policy document" according to change management. This document describes the function of change management in the organization. This document also consists of the intended benefits that the change management protocol entails. This document is currently on the desk of the manager of the service department for approval.
3. Training regarding change management has been started. The purpose of this training is to create awareness of the existence of a change management protocol and the working of. By means of this training is attempted to create insights in the overall benefits of using change management within the organization and the specific benefits for the users that use change management in a specific context. However the training is still in an early phase and should be further improved to be "fit-for-purpose" in the specific department.

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Appendix 1: Process Flow Change Management according to ITIL

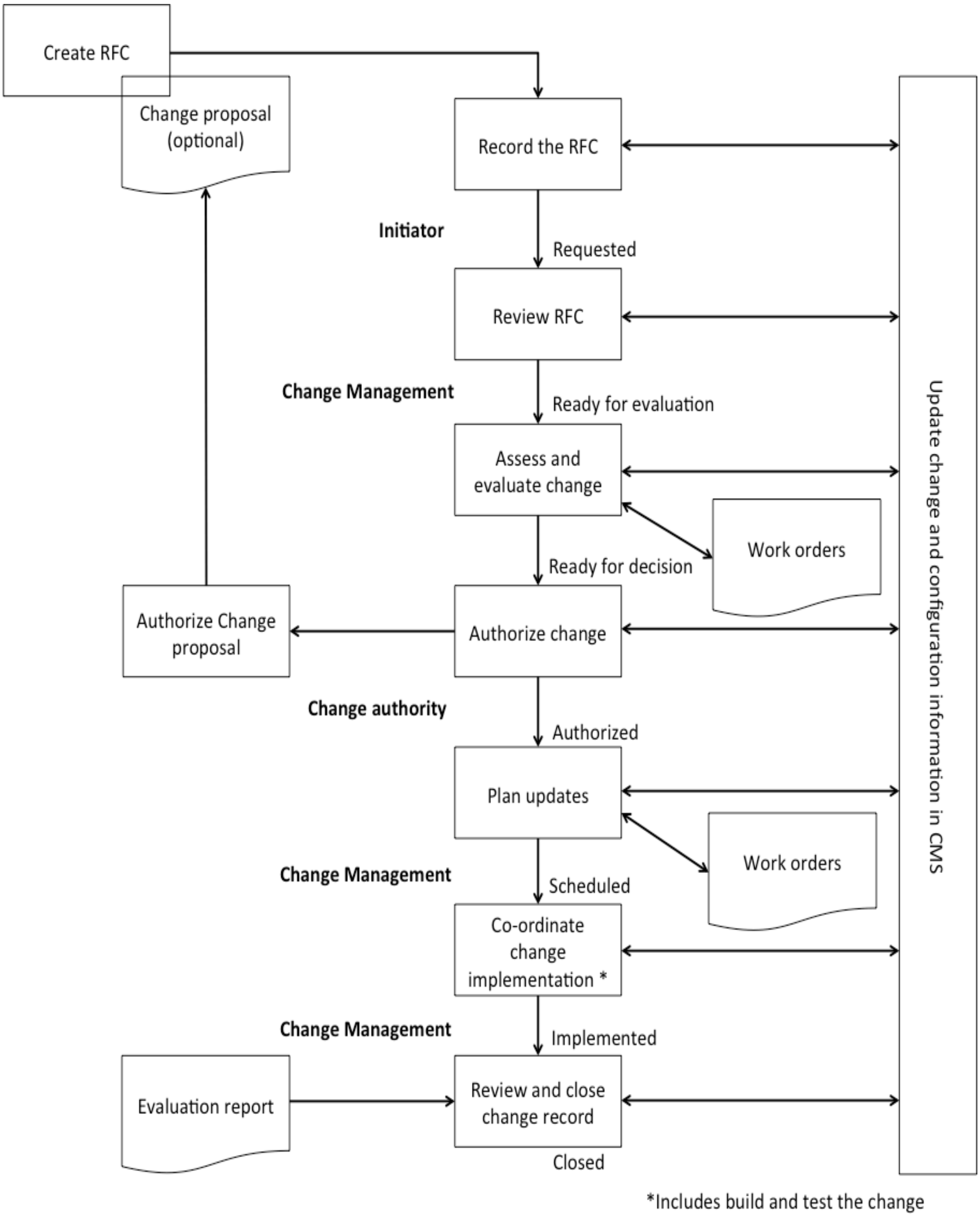

Figure 15: Process flow for normal change according to ITIL(Lacy & MacFarlane, 2007)

APPENDIX 2: SYSTEM CHANGE MANGEMENT PROCESS HUISMAN GLOBAL SERVICES (POST-COMMISSIONING SOFTWARE)

Some offshore organisations have a specific definition for change management: they call it "system change management". System change management is a type of change management, which specifically focuses on changes to their products and systems. This type of change management does not primarily focus on the organisation but considers the technical functionality of the CoPS(Dang, 2013).

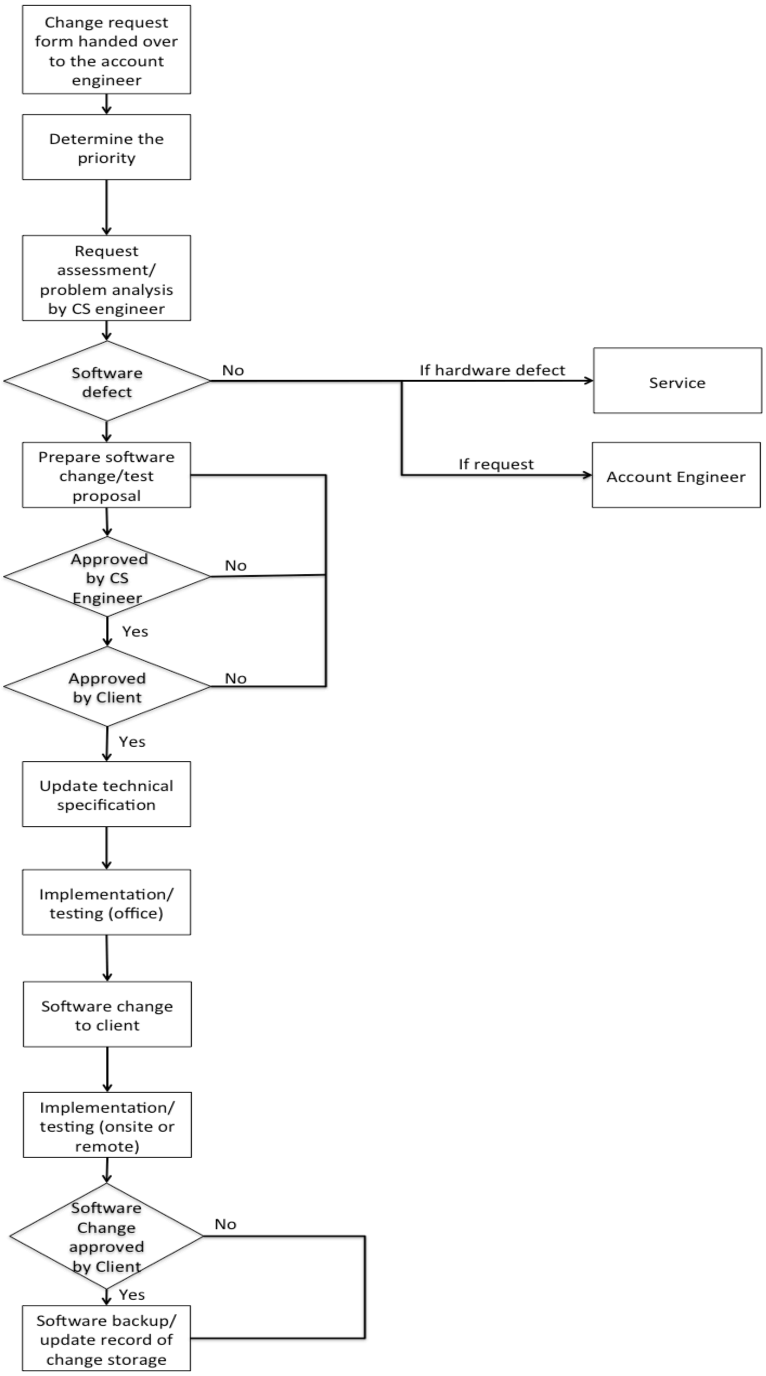

Figure 16: System change management protocol(Verkerk & Ee, 2013)

Appendix 3: Characteristics of CoPS

Characteristics CoPS vs. mass production	CoPS project organisation	Mass production organisation
Product characteristics	- Complex component interfaces - Multi-functional - High unit cost - Product cycles last decades - Many skill/knowledge inputs - (Many) tailored components - Upstream, capital goods - Hierarchical/systemic	- Simple interfaces - Single function - Low unit cost - Short product life cycles - Fewer skills/ knowledge inputs - Standardized components - Downstream consumption goods
Production characteristics	- Project/small batch - Scale-intensive, mass production not relevant	- High volume, large batch
Innovation processes	- User – producer driven - Highly flexible, craft based - People-embodied knowledge	- Supplier driven - Formalised, codified - Machinery embodied knowhow
Competitive strategies and innovation coordination	- Focus on product design and development - Systems integrated competencies - Management of multi-firm alliances in temporary projects	- Focus on economies of scale/cost minimisation - Volume production competencies - Focus on single firm
Industrial coordination and evolution	- Project-based multi-firm alliances	- Large firm/ supply chain structure - Single firm as mass producer - Alliances usually for R&D or asset exchange
Market characteristics	- Duopolistic structure - Few large transactions - Business to business - Negotiated prices - Partially contested	- Many buyers and sellers - Large number of transactions - Business to consumer - Market prices - Highly competitive

Table 25: Characteristics CoPS vs. Mass production industries obtained from Hobday(Hobday, 1997)

Complexity described within Huisman

An interesting quote to start with is a quote of an engineering specialist who illustrates the actual complexity of the equipment in the offshore business. Complexity is expressed by the given fact that numerous components of the equipment are all interrelated to each other and when a modification is applied to a specific component, this has a certain effect on the other components and the overall functioning of the equipment(Hobday, 1997).

Interviewee #5: "Usually incidents are the result of an ingenious thought of an employee in order to solve a first order problem. But a change that solves the first order problems can result in second and third (etc.) as well. The second and third order problems can arise from other functionalities of the equipment that is not the particular discipline of the employee who is solving the first order problem".

According to Hobday(Hobday, 1997) the complexity within Huisman is described on the basis of several categories starting with product characteristics. The products and systems form Huisman are characterised by complex component interfaces because of the software, mechanical, electrical and hydraulic characteristics of for instance cranes and pipelay towers. The products and systems are very often multi-functional, have very high unit costs and the product cycle lasts for approximately twenty years(Huisman Equipment BV, 2008). In order to design, operate, build and maintain such complex products a lot of different and specialized knowledge and skills are required. Components of which the products contain of are all tailor-made and require a lot of specific specialized labour. The production characteristics of an organisation like Huisman allows being illustrated the best as the focus on specific projects and small batches like a batch of pipelay towers in the coming two years. The innovation processes within an offshore company like Huisman can be characterized by a user-producer driven process. There is clear communication between the producer and the client in order to agree upon requirements for new or improved products and systems. The innovation requires a lot of people embodied knowledge because of the complexity of the products and systems in the offshore business. An important focus of a company that works with such complex products and systems is the constant focus on product design and development. Furthermore the commissioning of the equipment consists of the management of multi-firm alliances in temporary projects. At last the market in which offshore organisations like Huisman operate is characterized by its duopolistic structure, it mostly contains of few large transactions, the industry is business to business oriented, prices are negotiated because the equipment is tailor made and the industry is partially contested.

Appendix 4: ITIL and ABS explained

Added value of change management

An organization strives for continuity of business and a maximum profit without many disruptions(Bessant & Tidd, 2007). The goals of change management can contribute to the goals of a business in various ways and therefore create added value to the CoPS and to the business in general. Several forms of added value of change management according to the ITIL standard, are described by Lacy and MacFarlane(Lacy & MacFarlane, 2007):

- Implementing changes that meet the agreed (service) requirements that will improve the equipment or maintain operation ability
- Uniformity of implementing change in order to meet requirements of equipment
- The reduction of failed changes that might lead to service disruption, other new defects and risk of starting all over again
- Adequate and immediate implementation of change in order to meet time requirements
- Monitor the functioning including the interfering of systems and of equipment during the service lifecycle; when changes are required they can be implemented in an early stage
- Quality, time and costs of a change can be estimated and met more precisely
- Insights in detailed risk assessment with respect to the change which needs to be implemented
- Improvement of the mean time in order to restore operations due to service

Change mangement process according to ITIL

In order to execute change management in a proper manner several topics need to be covered within a protocol that form a guideline for the implementation of change. For the implementation of change a process flow diagram is used. Appendix 1 provides a change management flow diagram in order to implement a change according to the ITIL standard(Lacy & MacFarlane, 2007). The first steps in the flow diagram consist of a proper design and assessing phase of the change. First of all a request for change should be created, recorded, reviewed, assessed and authorized. All the previous steps all contribute to an organized an orderly change management process. All activities are carefully updated in the change management system (CMS). When the first steps have been completed, an actual plan can be made in order to implement the change. The change can now be implemented and that includes building and testing of the change. This should all be co-ordinated precisely and updated in the CMS. When the change has been implemented the change record can be closed and the change can be reviewed according to the evaluation report that has been written based on the change process that has been followed.

According to Lacy and MacFarlane there are nine activities that are mandatory for overall change management activities with respect to the ITIL standard(Lacy & MacFarlane, 2007):

1. Planning and controlling changes
2. Change and release scheduling
3. Communications
4. Change decision making and change authorization
5. Ensuring there are remediation plans
6. Measurement and control
7. Management reporting
8. Understanding the impact of change
9. Continual improvement

The first step in the change management protocol according to ITIL is to organize various changes(Whittleston, 2012). Changes can be requested or can be initiated at all time internally or externally and should therefore be planned and controlled to maintain overview and distinction between various changes(Ahmed & Kanike, 2007). At the same time the priority of a change will be determined because some changes have effect to more vital functionalities of equipment then others. When a change is planned and scheduled it can be made sure that all changes are implemented in a controlled way(Lacy & MacFarlane, 2007). Changes can have effect on multiple functionalities, systems or departments and therefore communication is evident to create awareness of the status of the implementation of the change at every department(Eckert et al., 2004). Communication starts before implementing change, at first is determined who is authorized, to whom the change will be assigned to and who is responsible for the change. Implementing changes safely is not a guarantee but a change management plan, which contains an investigation of risks and provides remediation plans, will help create a safe and organized way of working(Gran et al., 2012). All phases that are undertaken in the change management process should be controlled in order to provide a consistent way of working(Lacy & MacFarlane, 2007). Whenever incidents occur the causes can be identified throughout the controlled way of working. Overall responsibility of the change, the progress of the change and the functionality requirements of CoPS are defined and reported to a manager or a specific department(Sudin & Ahmed, 2009). An advantage of a central responsibility is the ability to clearly communicate to all other involved parties and give frequent updates to everyone who is involved, on the implementation process of the change. When ITIL is used as a standard the nine mentioned activities should always be part of a change management protocol(Lacy & MacFarlane, 2007). The ITIL standard could to be placed over the specific processes within a company and can function as a framework to build up a customized process for a specific client or a company wide customized process(Lacy & MacFarlane, 2007).

The previous paragraphs have described the complexity of the environment in which the offshore industry operates, the complexity of the products and systems the offshore industry designs, builds, operates and maintains. The frequent application of changes during the operational phase of the life cycle and the management of these changes in combination with complexity characteristics might lead to incidents. Several incidents have been investigated according to specific incident analysis methods that will be explained in the following paragraphs.

ABS

The first step consists of the question how the change should be covered and if the change should be implemented according to the change management program. A first impact assessment is made and an implementation plan is designed. The change owner is considered to be responsible for the initial review. The second step consists of the senior review step once the impacts of the change are assessed. The initial review is repeated but with extra focus on concerns that have been raised by the approver of the change. Outcomes of this extensive second review could be that the change is rejected or the risk assessment is requested in a more detailed form. This directly leads to the third step of the change management process that consists of the detailed risk assessment. If the outcome of the preliminary impact assessment shows a reasonable possibility for major consequences this particular phase consists of a more thorough and extensive risk assessment. The number of people involved is different from the preliminary impact assessment because a team of experts from different disciplines will carry out the detailed risk assessment. This phase is also initiated in order to provide insights in several possible scenarios and insights into potential hazards. The outcome of this step is a set of requirements and an implementation plan(American Bureau of Shipping, 2013). The change can be executed if the implementation plan in either step one or three has been approved. The fourth step is the approval step that consists of the approval of the implementation plans by the people who are responsible for the change and who have sufficient knowledge on the change in order to judge if the potential impacts have been analysed thoroughly enough. The second to last step in the change management process consists of the implementation phase. The established implementation plans will be executed in this phase as well as this phase is used for the updating of documentary to reflect changes, communication of the change and training of personnel considering the implementation and the use of the changes product or system. ABS acknowledges the importance of proper documentation, communication and training of personnel and states an extensive increase of the possibility that incidents occur. Therefore the focus in this step is effective documentation of everything that has to do with the change which means up to date drawings, procedures, checklists, permits, emergency response plans, training manuals, software codes and safety instructions(American Bureau of Shipping, 2013). Before the change will be implemented it is of great importance to communicate all relevant developments according to the change towards the involved/affected personnel. ABS describes and assigns roles and responsibilities to personnel who work with the management of change process. On beforehand all involved personnel should be properly trained for the usage of the management of change process. The last step in the change management protocol is the verification and close out step. When the implementation has come to an end the change should be verified according to if it meets the intended functions and does the implementation plan meet the intended functions? If new changes are required the management of change process can be started again.

When discussing all the steps in performing change management in order to implement a change it seems a quite complicated matter that will not always proceed as planned. When a change is not implemented according to the process, people communicate along each other or something else of unforeseen nature happens an incident may occur. One of the goals and sub-questions of this thesis is to investigate root causes for incidents due to the implementation of change in the operational life cycle. Therefore techniques will be described in the next paragraphs to investigate root causes for incidents.

Appendix 5: Pipelay incidents explained

TBIA applied to Seven Oceans 2013 case

The TBIA is applied to the Seven Oceans incident, but this technique is not usually used because normally incidents are not investigated in a thorough manner like this. SubSea 7 (the client) had particularly requested for an incident investigation analysis.

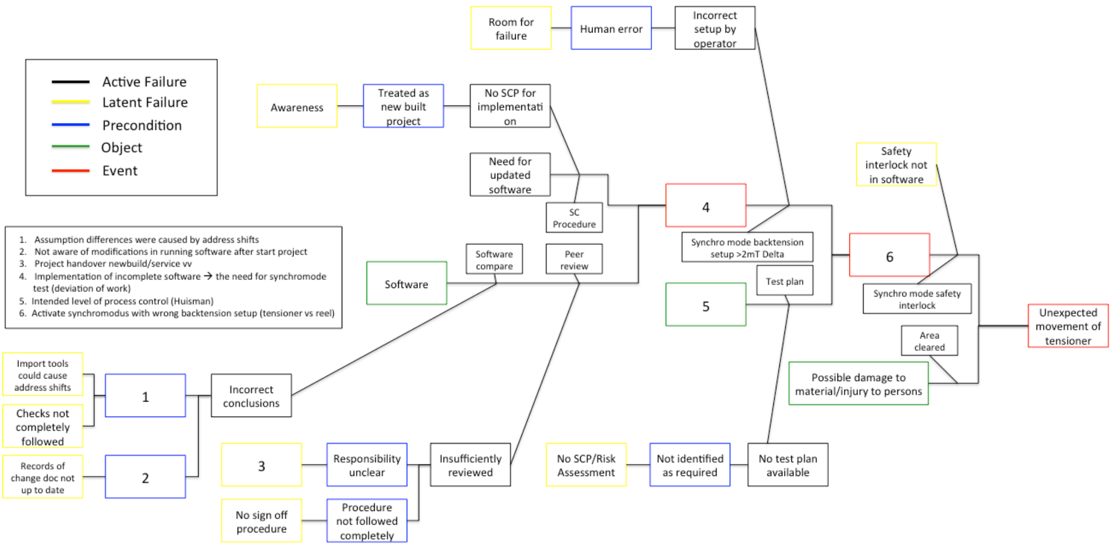

Figure 17: TBIA(Verkerk & Ee, 2013)

Figure 17 shows an illustration of the TBIA diagram that has been performed by employees of Huisman on the Seven Oceans incident. The most important findings lay in the causal constellations between the identified latent failures, preconditions and active failures. However the results of this analysis do not go beyond observations of several relevant latent factors. The latent factors are not yet revealed into what actually results into these latent factors from a technical, process/organisational and human perspective.

Latent failures, preconditions and active failures by means of TBIA

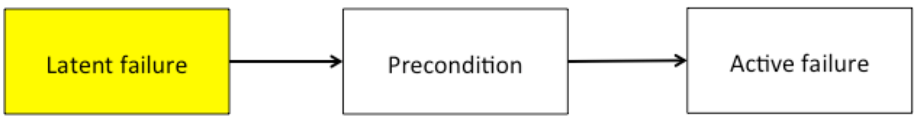

Figure 18: Latent failure (yellow)

The employees that have investigated the Seven Oceans incident identified nine latent failures (figure 18). They are called latent because they may have been present for a long time before a specific type of human error has occurred that could be related to specific factors that are underlying:

1. Use of import tools could cause address shifts
2. CS standard checks not completely followed

3. Records of change document not up to date
4. Project handover newbuild/ service vv
5. No sign off procedure
6. Awareness
7. Room for failure
8. No SCP/Risk assessment
9. Safety interlock not in software

The latent factors that have been identified need a brief explanation: the import tools are tools considered not to be designed by Huisman internally and could cause address shifts in the software if it is not totally clear how the specific tool works. The control systems (CS) department has standard checks for implementing software changes but if these checks are not performed thoroughly because the consequences are not directly noticeable it is not immediately clear that the checks have not been followed. Once an incident occurs and the records of change are consulted in order to identify happenings chronologically and it appears to be incomplete or not up to date, it is actually too late. A lot of latent failures are based on not performing tasks/activities in a structural way and appear into sight when a serious incident investigation needs to be performed in order to investigate root causes. Internal communications between handing over the newbuild project to the service department did not take place adequately. There appeared to be no sign off procedure in order to move from one phase to another phase during the implementation of the change. Employees were not aware of any procedure considering the implementation of change and therefore treated this change as it would be treated as if it were a change in a newbuild project. There was also too much room for failure because employees were not peer reviewed and could prepare an incorrect setup without peer reviews. There were no system change procedures (SCP's) and risk assessments that eventually resulted in the safety interlock not being in the software. This resulted in the absence of an emergency stop function that did not occur as such and eventually resulted in the unexpected movement of the tensioner. The latent factors can lead to specific precondition that eventually lead to active failures. The preconditions that are distinguished for the Seven Oceans incident are the following:

Figure 19: Precondition (blue)

1. Assumption differences were caused by address shifts
2. Not aware of modifications in running software after start project
3. Treated as new built project
4. Responsibility unclear
5. Procedure not followed completely
6. Human error

From the above seven preconditions (figure 19) can be concluded that the combination of several latent failures can lead to preconditions that will be explained briefly below. Because of the use of import tools and not completely following CS standard checks resulted in possibility that differences in assumptions could be made and could lead to address shifts. And because of the records of change that appeared not to be up to date, the employees were not aware of modifications in the running software after the start of the project.

Because employees were not aware of any other procedures during the operational life cycle changes were treated as if it were a new built project. Furthermore it was not perfectly clear who is responsible for which task or part of the change implementation phase. The procedures that were available from the newbuild projects were not followed completely. Because there were no system change procedures and risk assessments it was not clearly identified as required. Because of all previously mentioned discrepancies there is a likely possibility for human errors to occur and eventually lead to the unexpected movement of the tensioner. The sets of preconditions lead to active failures, which are identified as the following (figure 20):

Figure 20: Active failure (red)

1. Incorrect conclusions
2. Insufficiently reviewed actions
3. No SCP for implementation
4. Incorrect setup by operator
5. No test plan available

The active failures resulting from the causally related latent failures and preconditions are summarized as incorrect conclusions that are made while implementing changes as illustrated in figure 20. The steps and phases that are executed are insufficiently reviewed because there is no actual awareness of the system change procedure of the implementation phase. Due to these active failures, the absence of an actual test plan the operator has provided an incorrect setup of the synchromodus. Therefore eventually the tensioner started to move unexpectedly.

Employees' reaction on system change management procedure

According to the management of the service department of Huisman Global Service any change to a product or system should be implemented according to a system change management procedure that is designed by the particular manager and the team lead of the service department. One of the reasons for the incident that occurred on the Seven Oceans to happen was a malfunctioning or not complying of the system change management procedure. Interviewees reflected on these statements in several ways:

Interviewee #5:"A change management procedure does not function as it should (in the opinion of several Huisman employees) main cause that is given is a cultural cause. But the mal-functioning has also to do with how it is implemented. A change management procedure is implemented top-down, people do not really know what they should do with it and how they are supposed to use it".

This response of this interviewee implies that not everyone is aware of the existence of a certain (system change management) procedure let alone that people know what they should do with it, so what its main purposes and goals are. It is not at all clear what kind of responsibilities are situated within this procedure, but this will be confirmed by the interviewees that are service engineers and technicians who work in "the field".

Interviewee #8: "Maybe this check and double check can be built in the process; the attention slackens here because incidents like the Seven Oceans illustrate the relevance of backups again. There is no control on this process whatsoever, when I return to the office in Holland nobody double checks if everything has been performed correctly or checks the system if everything is in there".

People are not aware of their responsibilities because some employees in the first place are not aware of the existence of a procedure. An interviewee that is a specialist engineer stresses that backups in software systems/during software changes were not made. As a result eventually the incident on the Seven Oceans occurred. However there is no control on this particular process, nobody double-checks if there are made any backups of checks "the system" if everything has been performed as should be and if there are any abnormalities. This is not in the routine system of people. In order to explain how a certain process works within an organization the type of organization is carefully researched and its characteristics are identified. An interviewee stated the following about change management in an organization: *Interviewee #5: In order to identify change management in an organization, the organization needs to be identified first. What kind of organization is this? Huisman is a company that designs, manufactures and maintains its equipment.*

Ishikawa diagram applied to Seven Oceans 2013

By interviewing employees who were actually involved in the Seven Oceans 2013 incident many characteristics of real life situations during projects were revealed. The following interviewee spoke about the relevance of a second opinion and about the high-pressurized circumstances in which is worked offshore. *Interviewee #5: Situation: A senior has been sent to the "Seven Oceans" vessel, but the fact that a senior has been sent to the vessel does not necessarily mean that the problem can be solved immediately. It rather implies that it is a good idea to request a second opinion or at least to reconsider (think) before acting. Given the time pressure that is usually a characteristic of a service job it is not always easy to request for a second opinion. The client quite often imposes time pressure. Once the service engineer does not trust a situation due to this imposed time pressure there is no time to wait for a second opinion.* This quote confirms the relevance of several human factors in the triangle of effectiveness. There are no clear defined roles and responsibilities, which the employee may rely on and which can be used in times of heavy time pressure. The factor of management participation considers the establishment of offshore working schedules according to a 24-hour rhythm and duty lengths. The workplace design factor considers communication as very relevant, which the lack of the possibility of a second opinion is an example of improper communication. This quote also shows the factor "interpersonal relationships" because of the (un) comfortable culture in which is worked in.

"Easiness to read and understand company policies" and "team responsibility instead of caste order control" as part of the human factor "management participation" are illustrated by a specialist engineer by giving the following quote: *Interviewee #8: Partly because of Huisman and partly because clients ask to work with a process. Not every client requires a process but SubSea 7 does. To give you an example of the time consuming process: SCP has been written, SS7 headquarters did not approve, and changes could not be implemented. SCP's are made at the Huisman office in Schiedam then they have to be transferred to the SS7 office in Aberdeen. The people over there need to sign the forms and have a software background so they understand what the SPC is about.* This quote focuses on the enormous amount of authorizations and signatures are requested from clients. This makes it impossible to implement a change in a short period of time. The same specialist engineer describes the lack of own responsibility as a problem for doing his job properly by the following quote: *Interviewee #8: My main problem is that I cannot do my job properly due to the fact that everything needs to be signed. But the people who need to sign the forms do not (always) have time to sign the forms.* Everyone is very busy and when a signature is required immediately the lead engineer for instance is not available at that very moment.

"Comfortable culture" as part of the interpersonal relationships defined in the human factors. The offshore business is a very costly business as the price of possible down time illustrates. This creates pressure on the employees who have to work in this environment. *Interviewee #8: Downtime is approximately 700.000 US dollar per 24 hours…testing is not appreciated if it is not necessary. Just because of this reason it is important to involve the client in the change process. It is important to have a line of communication from the top of the organization onshore towards the ship (from the client) just as this line of communication is in the organization of Huisman as well."*

Several service and specialist engineers have been asked about their working experiences during assignments and within the service department. The following quotes illustrate some interesting findings: *Interviewee #8: head technical department is your main point of contact and the other employees who have their shift at the moment.* This quote illustrates the points of contact while working offshore. There is a possibility to contact colleagues at the head office in Schiedam but this is limited to the working hours in Holland. According to the introduction of protocols in the offshore industry a specialist engineer mentioned: *Interviewee #8: The red-tape culture is more an offshore thing, my experience from visits to dredging ships were less bureaucratic. Dredging is shipping business and that is different from the offshore industry where risks are higher and it costs more money.* Not every employee is aware of the existence of a protocol, but some are and they were also asked how they use it. *Interviewee #8: I try to use it a little bit. I still just start a job usually the most important thing I should do is to save data on a structural basis. On the Seven Pacific vessel it appeared that parameters had not been saved for the last two years. It is not in people's routine to do this and it is not in the routines of the client either. There is not explicitly stated in the procedure that it is required to save parameters intermediate. Important notice is that the work that needs to be done is done in a rush because of extreme urgency. It should be within the routine that people save their work and make backups frequently while working. Frequent communication with each other (vessel and office back home) should promote mutual control so that making backups will not be forgotten).* This particular specialist engineer used the protocol as a backup document, but not as guidance for his job.

The findings of the documentary and the interviews according to the Seven Oceans 2013 incidents have been placed into the Ishikawa diagram of which the result is illustrated in figure 21. The focus is to investigate the root causes and together with employees who where involved in this incident and try to find out what for instance "an incorrect assumption" really means in a particular case and weather this is similar/comparable to findings within other incidents.

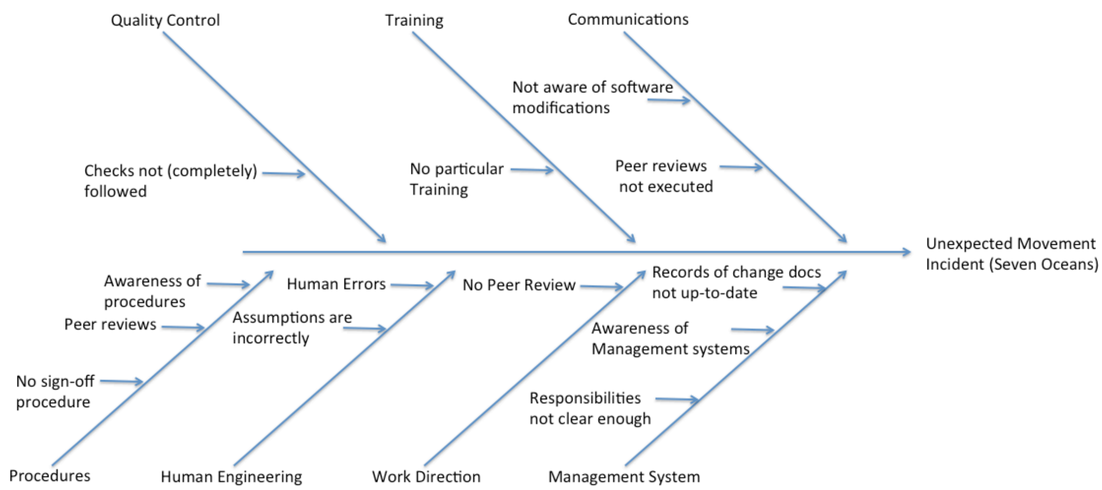

Figure 21: Ishikawa diagram Seven Oceans 2013

Considering the quality control during the implementation of a change the checks are not completely followed. Practical examples of the checks that are not followed were the facts that "employees were unaware of modifications in running software after the start of the project". The procedures, which ideally should be followed is available, but employees are not aware of the availability of the procedures. Employees are not interactively trained to cope with the available procedures. There is no clear sign-off protocol of which employees are aware and there are very few peer reviews on the work that is executed. The category of human engineering contains all human errors that are made and which resulted in the unexpected movement of the tensioner. Examples of human errors that were made can be dedicated to the clarity of responsibilities of involved employees, departments and clients. Incorrect assumptions are made and essential tasks considering software modifications are not executed because incorrectly is assumed that another employee has already checked the software modifications. It is not in peoples systems that it is necessary to check and double check it in the first place. These checks and double checks are not structurally communicated because it is not clear how and to who should be communicated. This might be standardized in a protocol, but if the involved employees are not aware of the existence of this protocol it does not have the effect as intended. The intended effect of proper communication and the compliance with a protocol should prevent incidents as the unexpected movement of the tensioner from occurring. The main conclusions that could be drawn from this Ishikawa diagram and the documentary from Huisman that were made available prior to the graduation research is the lack of awareness of the existence of (change) management systems. Various employees have confirmed during interviews according to the Seven Oceans incident that they were not aware of the existence of particular change management systems let alone the responsibilities within this protocol of the technicians and engineers who are actually supposed to work with this protocol. Consequently records of change documents appeared to be not up to date and due to the lack of peer reviews employees were not aware of modifications (integrated changes) made to the software.

Ishikawa diagram applied to Saipem 7000

For the application of the Ishikawa diagram to the Saipem 7000 pipe lay incident the safety bulletin from the QHSE (Quality Health Safety and Environment) department is consulted. This documentary resulted in the Ishikawa diagram in figure 21. Primarily several technical insufficiencies were indicated as root causes for the incident tot occur, referred to as technical insufficiencies in the Ishikawa diagram. Several explanations for events that preceded the actual incident can be grouped under the communication cause category. The communication systems were not feasible in other words it was not clear when should be communicated to whom. This resulted in the fact that if there was any communication at all it was usually late. Training is also constantly raised as a form of risk mitigation in order to make employees familiar with different scenarios, however this appeared to still not yet being part of a vessel assurance process. The lack of completeness and the effectiveness of processes seem to be a root cause for human error, which might lead to an incident eventually.

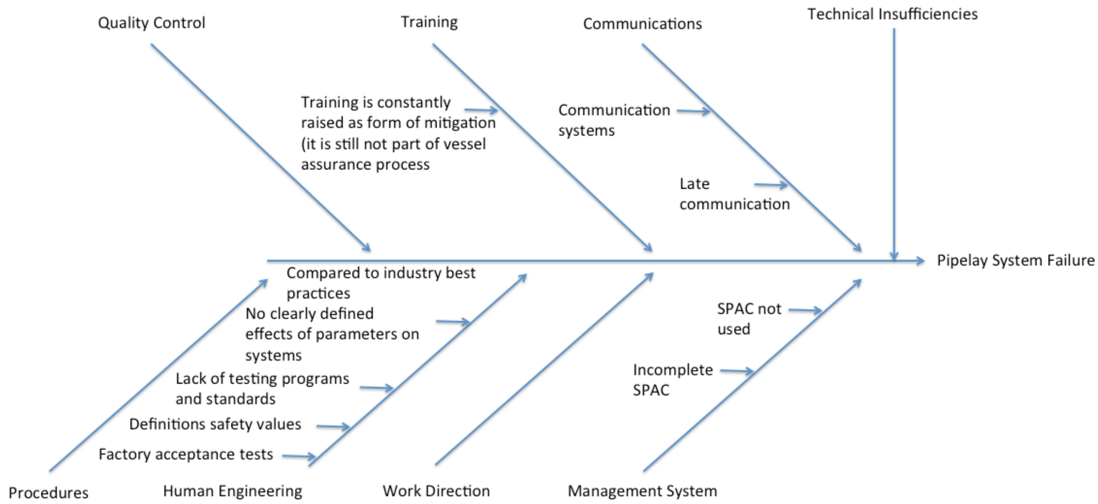

Figure 22: Ishikawa diagram Saipem 7000

Multiple sections of pipe fell into the deck of the vessel due to a system failure in the hydraulic pipe handling system of the J-lay tower. From the information that has been retrieved and is made available an Ishikawa diagram is constructed. Documentation on this incident is combined with literature on accident investigation and root cause analysis methods. In figure 22 the results can be seen and will be described. Again the same indicators of root cause analysis are used in order to rank the information within the provided documentary. Compared to another accident that occurred on the Seven Oceans in 2010 prior to the accident in 2013 the Saipem 7000 incident shows similarities once ranking findings in the Ishikawa diagram. The documentary on the Saipem 7000 incident according to the safety bulletin provides two primary technical causes for this incident to occur(Saipem QHSE, 2008):

1. A failure in the conceptual design of the control system software.
2. The uncontrolled access of working personnel on the access platform that was destroyed by the falling pipe has exposed the injured people to suspended load hazard and to this catastrophic event.

But are these causes the real (root) causes for this incident to occur? The documentary from BP shipping (the Marine & Offshore Assurance Team)(Cranch & Delaney, 2010) provide an analysis of the Saipem 7000 pipe lay incident as well as the pipe lay incident on the Seven Oceans in 2010 (not to be confused with the incident on the Seven Oceans in 2013). An Ishikawa diagram is made from the Saipem 7000 incident as well as the Seven Oceans incident in 2010. The root causes were again ranked according to the root cause investigation indicators and the technical causes as mentioned in the safety bulletin are grouped under the cause "technical insufficiencies". Employees are not always aware of the standards, policies or administrative controls (SPAC)(Ji & Zhang, 2012). Either the standards and policies are not used or they are incomplete or the employees are not aware of the existence. A J-lay tower is an example of a complex product that runs on complex systems and it appears to be an issue that employees are not always aware of the effect of the change of parameters on the J-lay systems. Testing programs and standard appeared to be not available in the first place and were not clear at all. Safety values for the functioning of the system are not always clearly defined and employees are not aware of these safety values. Considering the communication can be concluded that there was no clear communication towards employees who were on the "access platform" while they were not supposed to be there according to safety regulations. Employees were individually not communicating as effective and efficient as they should according to the complexity of the system and the awareness of employees when they apply a change that they should communicate this with other involved employees and superiors. A root cause for the pipe lay incident on the Saipem 7000 is found in the lack of proper training as well. Highly trained and skilled employees have been identified not to be part of a vessel assurance process. This means that employees are not properly trained in order to deal with emergency situations and makes it more likely that human errors can occur or are a root cause for incidents like the particular Saipem 7000 pipe lay incident.

Ishikawa diagram applied to Seven Oceans 2010

In figure 23 below the information available has been ranked according to seven categories apart from technical insufficiencies in the Ishikawa diagram.

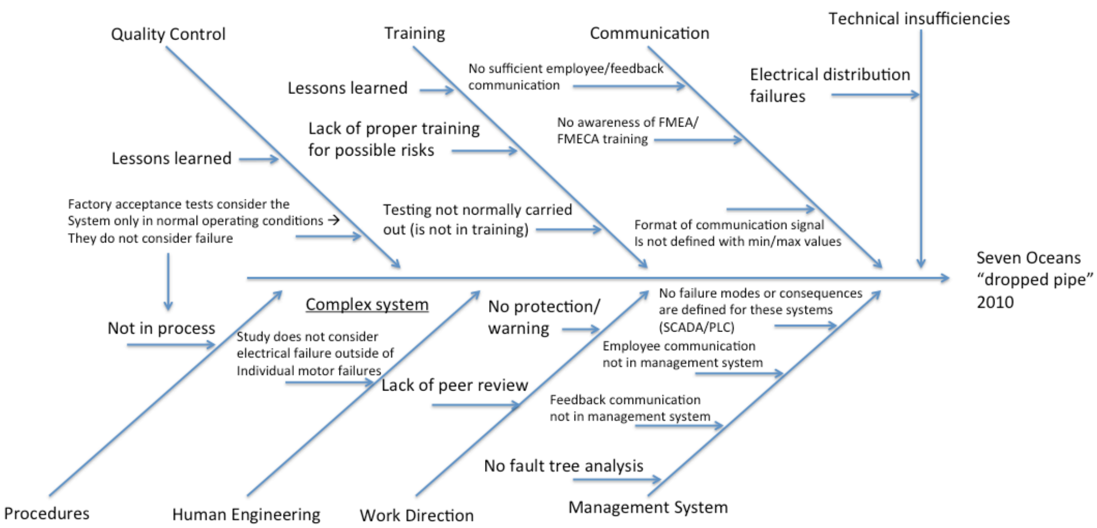

Figure 23: Ishikawa diagram Seven Oceans 2010

Starting with communication issues as root cause for the incident there appeared to be no awareness on incident investigation methods training like FMEA and FMECA (Failure Mode Effects Analysis and Failure Mode Effects and Criticality Analysis). Employees were not aware of specific training programs in order to identify and understand the circumstances of incidents let alone creating a "lessons learned" environment in order to foresee incidents like this in the future. Data communications form a root cause for the incident because minimum and maximum values are not assigned to the signal. This must be clear for all involved employees who need to judge the value of the signal and perform action on the height of the signal. When this has not been defined (such as in the Seven Oceans 2010 case) employees are not aware of the minimal/maximal value of the signal and do not no when to interfere. Employees are not trained properly in order to observe, identify risks and find underlying root causes for incidents, which means they are not able to create evident lessons learned to put in practice “the next time” a dangerous situation/an incident occurs. Proper testing of equipment and testing of modified (integrated with changes) software is not always carried out and is not in the training prescriptions. Considering the root causes in the quality control again the lessons learned component emerges from the documentary: there were no factory acceptance tests considering the systems beyond the normal operation conditions. Failure was not considered let alone personnel that had proper training to deal with malfunctions. According to the “procedure” root cause category can be analysed that several items were not in the procedures as previously mentioned the factory acceptance tests considered beyond normal operating conditions. Due to the high complexity of pipe-lay towers and the systems that operate this equipment there was no sufficient insight in specific electrical failures outside of stand-alone engine failures. The management systems do not contain failure modes or consequence defined specifically for SCADA/PLC systems that are essential for the operation of pipe-lay systems. Repeatedly has been observed that communication between employees and communication that ensures feedback is underexposed. Employees are not aware of the relevance of proper communication and feedback between different departments, managerial layers and among employees themselves. Furthermore after the incident had occurred no fault tree analysis had been performed.

Appendix 6: (Confidential) Transcripted interviews

Appendix 7: Combined findings from three incident analyses

<u>Findings from three incident analyses divided into technical, process and organizational, and human root causes</u>

Technical rootcauses		
Observation (what came out of the analysis)	**Learning (wider learning applicable for offshore industry)**	**Recommendation (What to do to solve the learning)**
Safety interlock not in software	Safety interlock should be in the software program	Testing software thoroughly before it is used
Pipe sections fell from the hydraulic pipe handling system due to a system failure	This incident should not have happened → lessons learned could help in the future	Investigate the root causes for this incidents on different levels (technical, process/organizational and human)
Electrical distribution failures caused a dropped pipe	Technical malfunctions can have serious consequences which could jeopardize the overall safety	Build up work procedures with respect to safety learnings (due to technical causes for the incidents)

Table 25: Technical root causes from analysed incidents

Process and organisational rootcauses		
Observation (what came out of the analysis)	**Learning (wider learning applicable for offshore industry)**	**Recommendation (What to do to solve the learning?)**
Factory acceptance tests consider the system only in normal operating conditions → they do not consider failure	What to do when a failure is detected? This is not particularly clear	Create a knowledge exchange platform where experience according to failure can form a lessons learned database
No lessons learned	Possibility that mistakes are made more than once because experiences are not shared and documented in order to learn from them	Create lessons learned from experiences and incidents by means of using universal incident analysis techniques like TBIA and Ishikawa diagrams
Lack of training for possible risks	Employees are not familiar with specific change management systems because they are not trained for using this	Provide employees with suitable training before they start working
Not aware of the existence of system change management procedure	Employees should be aware of the existence of systems if they are required to use these systems	Create awareness of the goal of system change management (and of the existence of SCM procedures designed by means of ITIL and ABS)
No system change protocol/risk assessment used	Comply to the system change management procedure (in order to	Investigate why is not complied to the system and find a remedy for this →

	create a uniform working standard)	design a change management protocol using ITIL and ABS, create awareness and provide training
Lack of training for the use of a system change management protocol	Employees are not familiar with specific change management systems because they are not trained for using this	Provide employees with suitable training before they start working
No clear handover from newbuild to service → operational life cycle	Awareness of two different phases in the product life cycle	Actual handover accompanied with specific processes corresponding with the new phase in the product life cycle (and clear and understandable for the involved employees in this phase of the life cycle)
Records of change not up to date (lessons learned)	No up to date history to check/ reason back all events	Create a "platform" where easily "key decisive" events according to the implementation of change can be updated
No roles and responsibilities defined	Employees are not aware of their specific responsibilities within a system change management system, this might lead to incidents	Define responsibilities to create clarity for the users of the system → by using universal standards like ITIL and ABS as an example
No sign-off procedure (clear stage gate)	No tangible overview on the status of the implementation of the change	Introduce a clear stage-gate system in order to maintain overview on the status of the implementation of the change by defining this in a protocol using ITIL and ABS as an example
Testing is not normally carried out (is not in training)	Testing is relevant in order to prevent undesired effects from happening	Make testing part of a working standard
No sufficient employee/feedback communication	Employees could not be aware of their mistakes, which could inevitably lead to incidents	Make sure that key decisions are only made with a second opinion by defining this redundancy in a protocol using ITIL and ABS as an example
Lack of peer reviews	Employees could not be aware of their mistakes, which could inevitably lead to incidents	Make sure that key decisions are only made with a second opinion by defining this redundancy in a protocol using ITIL and ABS as example

No fault tree analysis	Methods for analyzing incidents can create insights in the causes	Perform root cause analysis by using universal methods like TBIA and Ishikawa diagrams
Feedback communication is not in management system	Employees could not be aware of their mistakes, which could inevitably lead to incidents	Make sure that key decisions are only made with a second opinion
Employee communication is not in management system	Employees could not be aware of their mistakes, which could inevitably lead to incidents	Make sure that key decisions are only made with a second opinion
No failure modes or consequences are defined for the pipelay systems	Specific failure modes and insights in consequences for pipelay systems create can prevent from incidents occurring again	Create knowledge on specific insights and consequences from pipelay systems

Table 26: Process and organizational root causes from analysed incidents

Human rootcauses		
Observation (what came out of the analysis)	**Learning (wider learning applicable for offshore industry)**	**Recommendation (What to do to solve the learning)**
Inability to identify and understand the circumstances of incidents	Make sure that employees are knowleagable enough to understand the circumstances	Design and implement training and feedback sessions
Misjudging of specific technical data	Ensure that people are knowleagable enough to judge data correctly	Training sessions and peer groups and create lessons learned
Lack of communication between department, managerial layers and between employees (interfaces)	Interface management should be properly formulated and should be relevant	Define communication lines, roles and responsibilities so that everyone is aware whom to contact when necessary

Table 27: Human root causes from analysed incidents